Asian Journal of Fisheries and Aquatic Research

14(3): 1-9, 2021; Article no.AJFAR.72867
ISSN: 2582-3760

Primary Productivity of Jatigede Reservoir Based on Light and Dark Bottle Method

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJFAR/2021/v14i330295
Editor(s):
(1) Dr. Luis Enrique Ibarra Morales, State University of Sonora, Mexico.
Reviewers:
(1) Adib Saad, Tishreen University, Syria.
(2) Achide Samson Achide, Nigeria.
(3) Rakesh Gothwal, Madhav University, India.
Complete Peer review History: https://www.sdiarticle4.com/review-history/72867

Original Research Article

Received 22 June 2021
Accepted 28 August 2021
Published 02 September 2021

ABSTRACT

This research aims to determine the value of primary productivity by using light-dark bottles at different depths in Jatigede Reservoir, Sumedang, West Java. This research was conducted from October 2020 until March 2021 using survey method research. Determination of the research location was done by using the purposive sampling method. Sampling was carried out at five stations and three depths: surface, 0.5 compensation depth, and compensation depth. The results showed that the primary productivity in Jatigede Reservoir ranged from 300.29-1013.47 mgC/m^3/day. The results of supporting water quality parameters are light transparency ranging from 38-150 cm, temperature ranging from 26.6-29.7 ^{o}C, pH ranging from 6.69-8.7, carbon dioxide (CO_2) ranging from 4.4-22.0 mg/ l, dissolved oxygen (DO) ranged from 3.00–6.6 mg/l, Biochemical Oxygen Demand (BOD) ranged from 1.62-16.22 mg/l, ammonia ranged from 0.0004-0.0055 mg/l, nitrate ranged from 0.017-0.044 mg/l and phosphate ranged from 0.06-0.14 mg/l. Based on the value of primary productivity, the waters of the Jatigede Reservoir are categorized as mesotrophic waters.

Keywords: Primary productivity; dark light bottle; jatigede reservoir.

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1. INTRODUCTION

Primary productivity is the rate of organic carbon production per unit time, which captures solar energy by green plants to be converted into chemical energy through photosynthesis [1]. Primary productivity can be used as a determinant of the fertility of water. Waters rich in nutrients and autotrophic biota (phytoplankton) will have high primary productivity. This will directly affect fish in the waters seeing that phytoplankton are producers in the waters. According to [2], decreased productivity can lead to reduced catches and disrupt the life of biota in the waters and disrupt the ecological system.

Jatigede Reservoir is a dam that submerges 26 villages or five districts. Judging from its function, the Jatigede Reservoir is used as a source of irrigation water and flood management in the north coast area, namely Cirebon and Indramayu, which can also be used for intensive fishing activities for communities affected by the inundation of the Jatigede Reservoir. Primary productivity in the form of plankton is considered one of the essential elements in one of the water chains, the plankton in the waters will be very useful in supporting fish resources, especially from the primary consumer group [3].

Primary productivity can be measured several ways, including the isotope of charcoal (C14) method, the chlorophyll method, and the oxygen method [4]. According to [3], the oxygen method with light and dark bottles is more accurate because the observations were made by measuring changes in DO concentration resulting from the photosynthesis process. This study aimed to determine the value of primary productivity using the dark and light bottle method at different depths in the Jatigede Reservoir.

2. MATERIALS AND METHODS

2.1 Description of the Sampling Sites

The research was conducted from October 2020 to March 2021. The research was conducted using a survey method and the determination of research stations was carried out using the Purposive Sampling method. Five observation stations can be seen in Fig. 1. The sampling location was chosen because it represents each watering zone, water input source, anthropogenic activity and BOD value during the preliminary test.

Station 1: This station is the primary inlet of Jatigede Reservoir, originating from the Cimanuk River, Cialing River, and Cibuntu River. This station is a riverine zone with coordinates 60°55’52,6”S, 108°05’46,9”E.

Station 2: Is the station with the lowest BOD value of 4.9 mg/l. Irrigation comes from two tributaries, namely the Cimuja River and the Cijajaway River. The coordinates of station 2 are 60°55’19,6”S, 108°05’45,7”E.

Station 3: Is the station with the highest BOD value of 16.2 mg/l. This station is a transition zone with irrigation from the Cihonje River, Cimuja River and Cacaban River. At this station, there are captured fisheries and aquaculture activities using floating net cages. Station 3 is located at the coordinates of 60°55’11,8”S, 108°05’42,1”E.

Station 4: Station 4 is the estuary of the Cacaban River and is still a transition zone. There are capture fisheries activities using gillnet fishing gear and aquaculture using floating net cages. 60°55’16,1”S, 108°06’50,7”E.

Station 5: This is the station that represents the lacustrine zone. There is no anthropogenic activity around station 5 due to strong winds and the station is close to the Jatigede Reservoir outlet. Station 5 coordinates are located at 60°53’31,1”S, 108°06’13,5”E.

2.2 Sampling and Water Quality Measurement

Sampling was carried out every 30 days, and six repeats for each station. Samples were taken at three different depths based on the amount of light input: surface, 0.5 compensation depth, and compensation depth. Water samples for depth are taken using a water sampler. Primary productivity measurements were carried out using a 150 ml bottle. The sample water was put into a dark bottle and a light bottle carefully so as not to bubble. The initial DO was measured as the initial bottle (IB) then the dark bottle and light bottle were incubated in water for four hours. After incubation for four hours, sample bottles were taken and measured DO on dark bottles denoted as DB and DO on light bottles denoted as LB.

2.3 Primary Productivity Measurement

The value of primary productivity is obtained by calculating respiration, gross primary productivity

(GPP) and net primary productivity (NPP) [5], the relationship between the three can be stated as follows:

- Respiration rate = IB-DB (mg/l)
- GPP = LB-DB (mg/l)
- NPP = (LB-DB)-(IB-DB) (mg/l)

Information:

IB (initial bottle): Dissolved oxygen concentration before incubation (mg/l)
DB (dark bottle): Dissolved oxygen concentration of dark bottle after incubation (mg/l)
LB (light bottle): Dissolved oxygen concentration of bright bottle after incubation (mg/l)

The value of mg/l oxygen is converted to mgC/m^3 by multiplying the value of oxygen by a factor of 375.36. Thus the unit becomes mgC/m^3 for the measurement period. To get the value of productivity in one day, the hourly value is multiplied by 12, considering that sunlight is only obtained for 12 hours per day [6].

3. RESULTS AND DICUSSION

3.1 Water Quality Parameters

The parameters observed during the study were transparency, temperature, acidity, CO_2, DO, BOD, ammonia, nitrate, and phosphate. The average graph of measurement results can be seen in Fig. 2 and Fig. 3.

3.1.1 Transparency

The value of transparency is influenced by the intensity of sunlight on the water surface, turbidity, and plankton density in the waters [7]. The results showed that the value of transparency in the Jatigede Reservoir ranged from 38-150 cm. The highest average transparency concentration was 100.83±24.46 cm at station 5, and the lowest average transparency value was 70.5±19.35 cm at station 2.

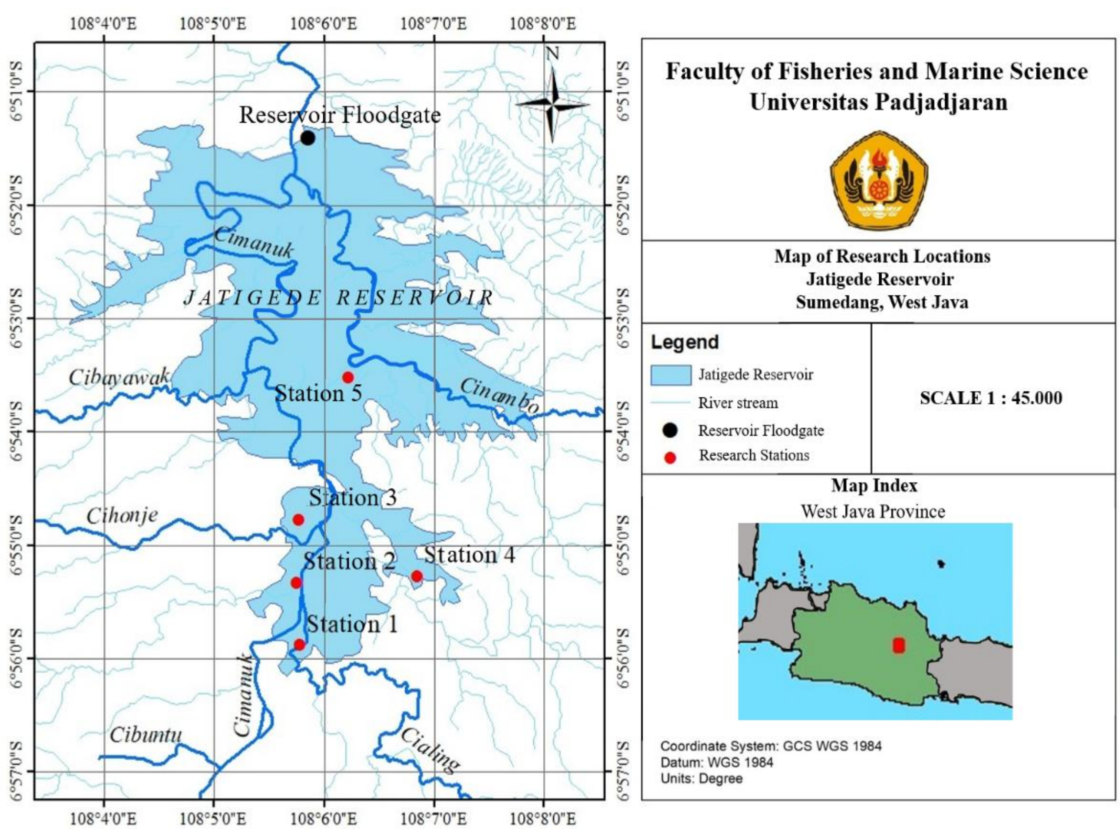

Fig. 1. The location of study station at Jatigede reservoir

Station 2 has low transparency because this station accommodates domestic and agricultural waste along the Cimuja and Cijajaway rivers. In addition, this station is the location with the shallowest depth after station 1, which is 11±2.78 meters. Meanwhile, station 5 has the most profound depth compared to other stations, which is 26.5±10.63 meters and there is no anthropogenic activity around the station. According to [8], the depth of water will affect the entry of sunlight into the waters, the deeper the waters, the higher the value of the transparency of the waters. Based on the water quality standards stated in Government Regulation No. 22 of 2021 Transparency of the Jatigede Reservoir is classified as a Class III water quality standard with a value below 2.5 meters.

3.1.2 Temperature

The water temperature of Jatigede Reservoir ranges from 26.6-29.7 ^{o}C. The highest average temperature value is 29.02±0.38 ^{o}C at station 3 surface and the lowest temperature is 27.88±0.69 ^{o}C at station 5 compensation. The water temperature of the Jatigede Reservoir is still optimum for life phytoplankton. According to [9] the optimum temperature range for phytoplankton life is 20–30 ^{o}C.

The temperature in the Jatigede Reservoir decreases with increasing depth. This is because the intensity of sunlight is getting less and less absorbed by water bodies as the depth increases. [10] supported this statement, who stated that as the depth of sunlight decreases, the intensity of sunlight decreases.

3.1.3 Acidity (pH)

The pH value of Jatigede Reservoir waters ranged from 6.69-8.7. The highest pH was found at station 2 surface with a value of 7.45±0.57 and the lowest pH was at station 4 compensation of 6.96±0.12. The amount of pH concentration in waters can be caused by the input of water that carries organic matter from industrial waste, agricultural waste or domestic waste. According to [11] The decomposition process of organic matter can produce acid. The pH concentration in the Jatigede Reservoir is still considered optimal for phytoplankton life. According to [9] the ideal pH for phytoplankton life ranges from 6.5–8.0. Based on the water quality standards stated in Government Regulation No. 22 of 2021, the pH value of the Jatigede Reservoir is still within the limits of class II and III quality standards with a value of 6-9.

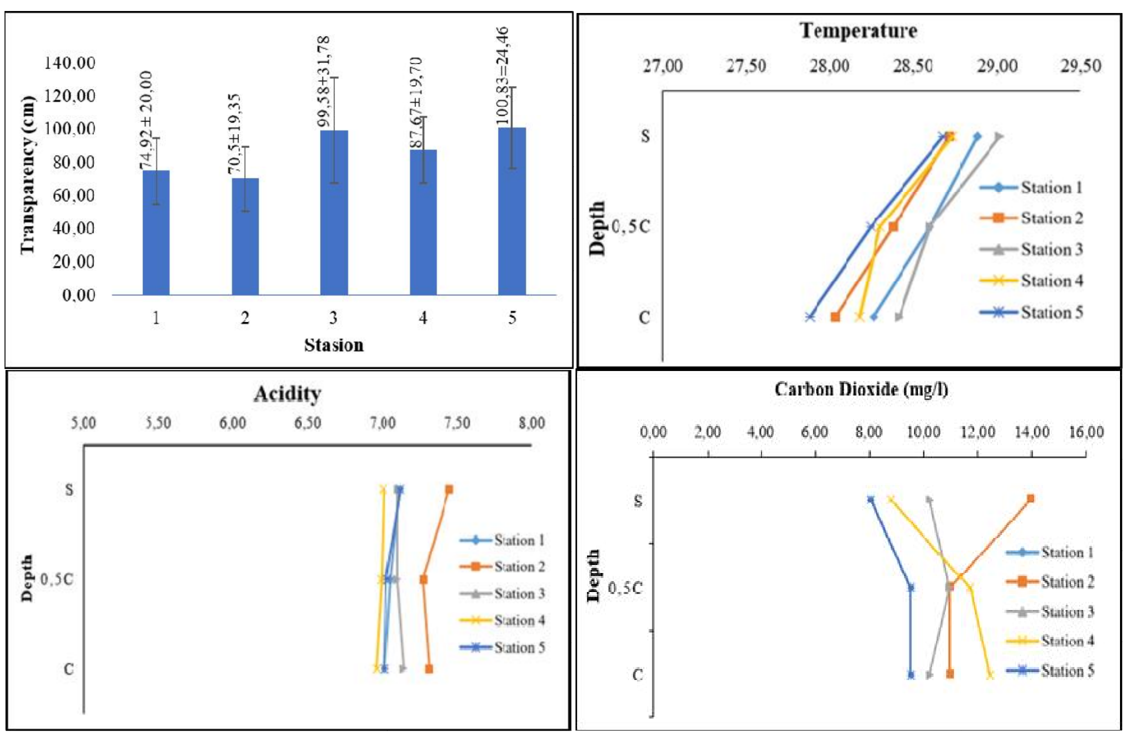

Fig. 2. Average graph of transparency, temperature, pH, and CO_2

3.1.4 Carbon dioxide (CO_2)

The concentration of carbon dioxide in the waters of the Jatigede Reservoir ranges from 4.4 to 22.0 mg/l. The highest average carbon dioxide was found at station 2 surface with a value of 13.93±3.31 mg/l and the lowest average carbon dioxide was at station 5 surface at 8.07±3.31 mg/l. Overall, the carbon dioxide in the waters of the Jatigede Reservoir is still optimum for phytoplankton life. According to [12] the optimum dissolved carbon dioxide concentration for plankton life is less than 12 mg/L. However, free carbon dioxide concentrations of less than 15 mg/l can still be tolerated by aquatic organisms but must be accompanied by sufficient dissolved oxygen concentrations [13].

Carbon dioxide is needed by phytoplankton to carry out the photosynthesis process. CO2 concentrations that are too high can damage the shape of phytoplankton cells. This is because the increase in CO2 concentration causes the pH to drop and the media becomes acidic, so the availability of calcium carbonate (CaCO3) decreases. CaCO3 is needed as a calcium supply to survive phytoplankton [12].

3.1.4 Dissolved Oxygen (DO)

Dissolved oxygen in the waters comes from the diffusion of oxygen in the atmosphere, currents or water flow through rainwater, as well as photosynthetic activity by aquatic plants and phytoplankton [14]. The value of dissolved oxygen in the waters of the Jatigede Reservoir during the study ranged from 3.00–6.6 mg/l. The highest average dissolved oxygen value was found on the surface of station 5, which was 5.77±0.95 mg/l and the lowest was at a depth of compensation at station 3, which was 3.98±0.69 mg/l. Dissolved oxygen in water can be decreased by aerobic decomposition of organic matter by nitrifying bacteria. According to [15] the ammonia oxidation process requires large amounts of oxygen, this can cause the dissolved oxygen concentration in the water to be low and conditions like this are hazardous for aquatic organisms.

Dissolved oxygen in Jatigede Reservoir decreases with increasing depth. This is because the light input of the heart decreases with increasing depth. According to [16] dissolved oxygen concentration is influenced by depth, the concentration decreases with increasing depth. The surface dissolved oxygen concentration will be higher due to the diffusion process between water and oxygen in the atmosphere and photosynthesis. As the depth increases, the dissolved oxygen concentration decreases because the photosynthesis process decreases and the remaining oxygen level is used for respiration and oxidation of organic and inorganic materials. Based on the water quality standard in PP No.22 of 2021, dissolved oxygen in the Jatigede Reservoir waters is still classified as class III and II water quality standards with a minimum limit of 3 mg/l and 4 mg/l.

3.1.4 Biochemical oxygen demand (BOD)

Based on the research results, the BOD value in the Jatigede Reservoir ranged from 1.62 to 16.22 mg/l. There was a decrease in the BOD value as the depth decreased at station 3, station 4 and station 5. While at station 1 and station 2 the highest BOD value was found in the compensation depth. The highest average BOD value of 12.16±3.8 mg/l was found at station 3 surface which is the station with the densest KJA activities while the lowest average BOD value with a value of 6.76±1.59 mg/l was found at station 5 half-depth compensation and station 5 depth compensation. The BOD value is related to the presence of organic matter that decomposes under aerobic conditions. Organisms will use the decomposed organic matter as food and the energy is obtained from the oxidation process [17]. Based on the water quality standards in PP No.22 of 2021 BOD Jatigede Reservoir waters are classified into class III and IV water quality standards.

3.15 Ammonia

Ammonia (NH_3) is inorganic nitrogen that is soluble in water. According to [18], Ammonia in waters comes from microbiological oxidation of organic substances and industrial, agricultural and community activities (domestic). The value of ammonia in the waters of the Jatigede Reservoir during the study ranged from 0.0004 to 0.0055 mg/l. The highest average ammonia was found at station 2 surface with a value of 0.0027 ± 0.0004 mg/l and the lowest average ammonia was found at station 5 surface with a value of 0.00186 ± 0.00096 mg/l.

The high level of ammonia in station 2 is because this station is the estuary of the Cimuja River and Cijajaway River. Domestic and agricultural waste along the river body then accumulates at station 2 surface. In addition, the high value of ammonia is reinforced by the highest primary productivity value at station 2 surface. According to [19], the increasing concentration of ammonia and light intensity also shows an increase in chlorophyll-a, a photosynthetic pigment in phytoplankton. While the lowest ammonia concentration at station 5 is because this station 5 is far from river input and there is no human activity so that the organic matter at station 5 is low. In addition, the low level of ammonia at the surface 5 station can be caused by the high dissolved oxygen at this station which causes the oxidation of ammonia to take place optimally. This is in accordance with [20] statement that the effectiveness of the oxidation of ammonia to nitrite with the help of nitrosomonas bacteria is more significant at high oxygen concentrations. Based on the water quality standard in PP No.22 of 2021, ammonia in the Jatigede Reservoir waters is classified as a class I water quality standard with an ammonia value below 0.1 mg/l.

3.1.6 Nitrate

Based on the research results, the nitrate value in Jatigede Reservoir ranges from 0.017-0.044 mg/l. The highest average nitrate concentration of 0.0281±0.0083 mg/l was found at station 2 surface and the lowest nitrate average of 0.0188±0.0068 mg/l was at station 4 compensation. The high nitrate concentration at station 2 is because this station is the estuary of two tributaries, namely the Cimuja River and the Cijajaway River, which carry domestic and agricultural wastes. According to [21], the high concentration of nitrate in the waters is caused by the high input of organic matter from land activities which can be in the form of land erosion, the input of household waste, agricultural waste and others that are carried directly into the waters through rivers.

Overall, the nitrate concentration in the waters of the Jatigede Reservoir has met the water quality standards according to Government Regulation No. 22 of 2021, class II which is not more than 10 mg/L and class III is not more than 20 mg/l. However, the observed nitrate concentration is not optimal for phytoplankton life. According to [22], optimal phytoplankton growth requires nitrate concentrations in the range of 0.9–3.5 mg/l.

3.1.7 Phosphate

Phosphate is an essential nutrient in determining water productivity. Bacteria, phytoplankton and macrophytes absorb the presence of phosphate. The concentration of phosphate in the waters of the Jatigede Reservoir ranges from 0.06-0.14 mg/l. The highest average phosphate was found at station 2 half-compensated depth with a value of 0.1065±0.0208 mg/l and the lowest was at station 4 surface with a value of 0.0897±0.0225 mg/l.

The high concentration of phosphate at the half-compensated depth of station 2 is caused by direct water input from the Cimuja River and Cijajaway River and waste from domestic and agricultural activities along the river. According to [23] the concentration of phosphate is influenced by nutrients or deposits from river and land inputs when it rains, the moving process at the bottom of the waters and the circulation process from the surface the results of other human activities. The lowest phosphate concentration at station 4 surface is due to phytoplankton utilizing phosphate well on surface waters. The value of primary productivity reinforces this on the surface of station 4, which is higher than the compensation depth. Based on the water quality standard in PP No.22 of 2021, the phosphate in the Jatigede Reservoir has met the water quality standard requirements for class II with a value of 0.03 mg/l and class III with a value of 0.1 mg/l.

3.2 Primary Productivity in Jatigede

The calculation of primary productivity consists of GPP (gross primary productivity) which is the rate of increase in autotrophic biomass by including the energy used for the respiratory process, and NPP (net primary productivity) which is the rate of increase in autotrophic biomass that does not include respiration needs by phytoplankton, macrophytes and periphyton [24]. Measurement of primary productivity in the Jatigede Reservoir using the dark bottle and light bottle methods obtained values ranging from 112.6 to 2191.3 mgC/m3/day. The average primary productivity at each station can be seen in Table 1. The highest average primary productivity of 1013,472±348.9 mgC/m3/day was found at surface station 2 and the lowest was 300,288±232.6 mgC/m3/day at station 5 compensation depth.

The high value of primary productivity at station 2 surface can be caused by the high concentration of organic matter from domestic waste and agricultural waste along the Cimuja River and Cijajaway River which empties into Jatigede Reservoir 2 station. This is reinforced by the highest average concentration of ammonia nitrate and phosphate at station 2. In accordance with [11] *statement, the more organic matter in a water, the higher the primary productivity of the waters. While the low primary productivity value at station 5 depth compensation is due to the compensation depth of the incoming sunlight, the photosynthesis process is not optimal at the compensation depth. In addition, the absence of human activities and the distance of station 5 from the river input caused the low organic matter which is a source of energy and food for phytoplankton at this station.*

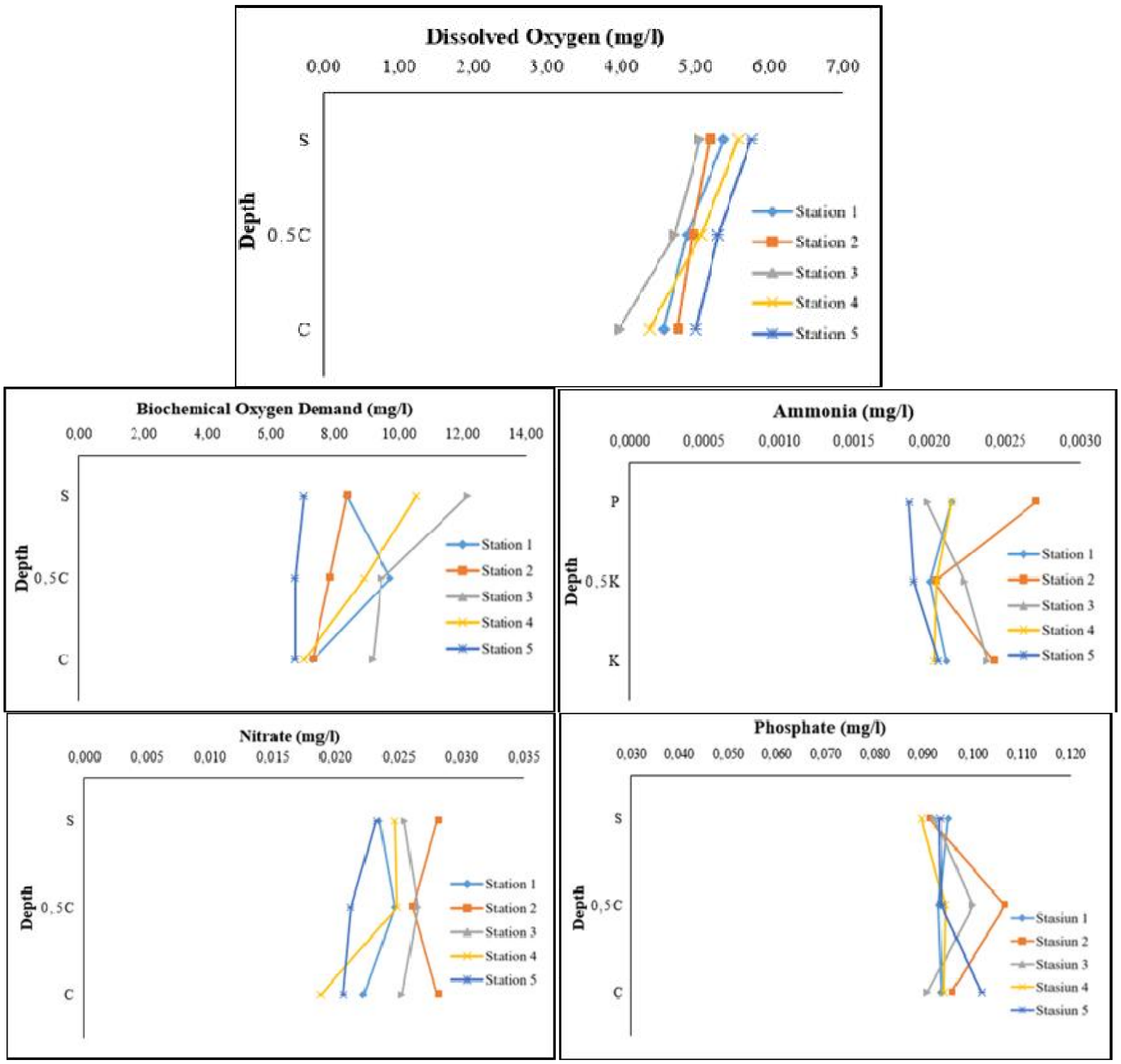

Fig. 3. Average graph of DO, BOD, ammonia, nitrate, and phosphate

Table 1. Primary productivity in jatigede reservoir

Station	Depth		
	Surface	0,5 Compensation	Compensation
1	919,63±270,42	713,18±331,51	431,66±270,42
2	1013,47±348,9	675,65±123,36	544,27±193,96
3	863,33±381,32	750,72±253,47	600,58±299,35
4	600,58±263,29	600,58±116,3	356,59±229,86
5	506,74±210,67	600,58±169,54	300,29±232,6

The average concentration of primary productivity decreases productivity value with increasing depth except at station 5. The increase in productivity at half-compensated depth at station 5 can be caused because this station is the station with the highest light transparency, so that the surface temperature is higher and the photosynthesis process is optimal at half-compensated depth. This follows the statement of [25] which states that maximum photosynthesis does not occur on the surface of the waters because very high light intensity can inhibit photosynthesis (photoinhibition) while too low intensity can slow down the rate of photosynthetic reactions. Based on the average value of primary productivity, the waters of the Jatigede Reservoir are classified as mesotrophic with moderate fertility. According to [26] in [1], waters with a primary productivity value of 0-200 mgC/m^3/day are classified as oligotrophic waters with low fertility levels. Waters with a primary productivity value of 200-750 mgC/m^3/day are classified as mesotrophic waters with moderate fertility. Waters with primary productivity values above 750 mgC/m^3/day are classified as eutrophic waters with high fertility levels.

4. CONCLUSION

Primary productivity values in Jatigede Reservoir ranged from 112.6 to 2191.3 mgC/m^3/day and were classified as mesotrophic waters. Based on the water quality standards stated in Government Regulation No. 22 of 2021, the Jatigede Reservoir is still included in class II and III water quality standards, which means that the waters of the Jatigede Reservoir can be used for fishery activities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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