Status of water quality and level of trophic in Juanda Reservoir of Purwakarta Regency, West Java, Indonesia

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Abstract. Juanda reservoir is one of the reservoirs located in Purwakarta Regency, West Java Province, Indonesia, whose primary function is hydropower, water resources for irrigation, industrial and drinking water, and secondary function for fisheries and tourism activities. Currently, an increase in activities around the existing reservoir has affected its water quality. In order to determine the water quality and trophic level status of the Juanda reservoir, research has been conducted within five stations during the period of August-December 2020. The water quality status includes physical, chemical, and biological parameters that compared with Store standards on Class II and III. Meanwhile, the trophic status was determined by Trophic Level Index (TLI) based on the parameters of transparency, chlorophyll-a, total nitrogen, and total phosphorus. The results show that the water quality status of Juanda reservoir has been contaminated Class III and heavily polluted Class II. The parameters that exceed include ammonia, nitrate, and BOD_5. The Juanda reservoir's tropic status was in the eutrophic category, with TLI values ranging from 4.6 to 5.2.

1 Introduction

Fisheries activities in Juanda reservoir have grown since the reservoir began to operate and have become a source of livelihood for residents around the reservoir. Human activities near the reservoir include aquaculture fisheries, fish rearing on floating net cages (*Keramba Jaring apung/*FNC), and fish catches. Fisheries activities developed in Juanda reservoir are expected to be a value-added function for society. Numerous fisheries activities have also triggered negative impacts, such as feed waste from the FNC, which causes silting. It threatens the sustainability of fisheries and the function of the reservoir as a water source. An increase in the number of fish cultivation in FNC that exceeds the carrying capacity of the reservoir has impacted the aquaculture productivity, by a frequent number of fish biomass mortality, especially for native species [1]

Degradation of water quality in Juanda reservoir caused by silting has triggered the corrosion rate of turbines as water controllers. This made water availability for hydropower and agricultural need decrease. Pollution is also in charge of hypereutrophic water [2]. Its characterized by decreased brightness increased concentration of phosphorus, nitrogen, and phytoplankton blooms.

Two external and internal factors mainly cause environmental degradation in the Juanda reservoir. The source of external contamination that enters the Juanda reservoir is from the Saguling Reservoir and surrounding rivers. The source of internal contamination comes from activities within the reservoir itself, such as aquaculture on the FNC). The development of FNC in Juanda reservoir is getting out of control, growing to 48.989 units that exceeded the carrying capacity of 2.364 units [3]. The increasing number of FNC has caused various problems, eutrophication of reservoirs due to waste and fish manure.

Meanwhile, eutrophication also causes turbine corrosion to occur rapidly. This condition makes the management cost higher for turbine maintenance and economic losses due to fishing mortality. Various ecological and economic losses and maintaining economic elements have encouraged implementing a multi-function reservoir aquatic resource management system through a sustainable fisheries development approach.

This research aims to determine the water quality and fertility status of the Juanda reservoir after two years of implementing the *Citarum Harum* program. This program is aimed at the mass movement to improve the Citarum watershed from the upstream and control/reduction the floating net cages in the reservoir [1].

2 Materials and methods

The research was conducted in Juanda reservoir (Jatiluhur Reservoir) on Purwakarta Regency, West Java Province. The period of research was from August to December of 2020. The location of the study is presented in Fig. 1, while Water quality observations were conducted at five stations, as seen in Table 1.

Fig. 1. Location and research station.

Table 1. Locations and their coordination of the research station in Juanda reservoir, West Java.

Station	Location and Area	Latitude Position	Depth (m)
St. I	A reservoir outlet is a hydropower area (DAM)	S 06'31,543 and E 107'23,098	102
St. II	Aki Island is an FNC-free area	S 06'31,103 and E 107'22,264	108
St. III	Near Cilalawi River/Municipal waterwork area, close to the settlement	S 06'33,496 and E 107'23,610	108
St. IV	Pasir Canar (FNC area)	S 06'32,946 and E 107'23,341	107
St. V	Astab (close area to reservoir inlets)	S 06'32,135 and E 107'20,132	108

The research sampling was conducted at three depths. Observed stations for water quality and plankton sampling are in a predetermined area. Plankton samples were taken using a Kemmerer Water Sampler of 5 liters, then filtered using net plaque No. 25 (mesh size 60 μm). The filtered water is then put in a sample bottle measuring 25mL Filtrated plankton samples are then preserved with a 1% Lugol solution. Observations were made on 20 fields of view using a binocular microscope at a magnification of 100x. References used for phytoplankton identification are from [4],[5],[6]. Furthermore, water samples were analyzed in the laboratory of water chemistry and plankton, Research Institute for Fisheries Enhancement (RIFE), Ministry of Marine Affairs and Fisheries in Jatiluhur, Purwakarta.

Van Dorn Water Sampler took water samples. The observed parameters were transparency using Secchi disk, pH that measured by pH indicator with litmus paper scales of 0 to -14, temperature by the thermometer, and titration equipment for dissolved oxygen measurement. The watercolor and number of garbage are seen visually in the reservoir. Water samples for the parameters such as BOD5, turbidity, the concentration of nitrate, nitrite, total N, and total P were stored in cooling boxes (4 °C) and analyzed in RIFE Laboratory. The water quality analysis refers to [7]. Determination of the water quality status using the Storet method [8], by comparing the data result with water quality standard of Class II and III (Government Regulation [9]. Method to determine the water quality status was using the US-EPA (United States Environmental Protection Agency). The quality status was classified into four classes, i.e., Class A "Well" that scored 0 or meet quality standards; Class B "Good" that scored -1 to -10 or Lightly polluted; Class C "Moderate" that score -11 to -30 or Moderately polluted, and Class D "Bad" scored ≤-31 or Highly polluted (when the measurement result of each water quality parameter does not meet the water quality standard) Then, given a score of 0. Oppositely, results do not meet the water quality standard then rated as -1 to -9. The trophic status of the reservoir was calculated by the Trophic Level Index (TLI) method, according to [10].

3 Results

Results from the water quality measurement on Juanda Reservoir are presented in Table 2. Based on measurement during this research, the maximum observed depth across stations ranged from 17.5 m – 49.1 m. On this water column, the temperature ranged from 28.9 °C –

31.40 °C in August and 27.9 °C - 31.60 °C in December. The highest temperature value in August was found at station IV and lowest at station V. This temperature value on station V was lowest during December. In contrast, the highest was laid on station III. Transparency value during the research ranged from 90 cm – 175 cm in August and shifted during December to 110 cm – 170 cm. Meanwhile, the turbidity value ranged from 2.3 NTU – 45.5 NTU in August, then ranged at 1.77 NTU – 6.04 NTU in December. The watercolor varied from green to dark green, with some samples smelling of sulfur.

Tabel 2. Result of water quality measurement at five stations from August to December 2020.

Parameters	Station I (Hydropower)	Station II (Aki Island)	Station III (Cilalawi)	Station IV (Pasir Canar)	Station V (Astab)
Physics					
a. Water Temperature (^{0}C)					
August December	28.98 - 28.97 29.70 28.00	29.36 - 29.44 30.00 - 28.6	30.21 - 29.13 31.60 - 28.6	31.40 - 29.14 31.00 - 28.20	30.46 – 28.9 30.10 - 27.90
b. Transparency (cm)					
August December	120 170	100 110	90 140	175 130	120 145
c. Turbidity (NTU)					
August December	6.53 - 45.50 5.77 - 1.86	9.97 - 6.07 6.04 - 4.73	14.6 -2.30 3.34 -4.33	3.87 – 6.34 3.51 - 1.77	5.89 - 16.8 4.61 - 2.77
d. Depth max (m)					
December	46.90	22.30	17.50	41.50	49.10
e. Watercolor/smell					
December	Green – smell	Clear green - the smell of sulfur	Dark green – the smell of sulfur	Green – smell	Dark green – smell
Chemical					
a. pH					
August December	8.01 - 7.10 8.25 - 7,01	8.88 - 7.42 8.44 - 7.25	8.79 -7.87 7.48 -7.06	7.88 - 6.76 7.49 - 6.92	7.89 - 6.84 8.00 - 6.92
b. DO (mg/L)					
December	4.18 - 0.78	3.69 - 0,77	2.40 - 0.43	3.06 - 0.76	3.06 - 0.77
c. N-NO_3 (mg/L)					
December	0.783 - 0.839	0.775 - 0.819	1.670-0.8170	1.547 - 1.158	0.852 - 0.842
d. N-NO_2 (mg/L)					
December	0.001 - 0.003	< LOD-0.001	0.009 -0.001	0.008 - 0.001	0.005 -0.004
e. P-PO_4 (mg/L)					
December	0.006 - 0.199	0.007 - 0.074	0.006 -0.079	0.004 - 0.250	0.007 - 0.245
f. Total P (Total P-PO_4) (mg/L)					
August	0.038 - 0.350	0.030 - 0.038	0.060 -0.035	0.022 - 0.009	0.146 - 0.049
g. BOD 5 day (mg/L)					
December	1.90 - 5.06	3.48 - 2.85	1.90 - 2.22	1.90 - 2.22	5.38 – 4.43
h. Organic materials (mg/L)					

August December	6.32 - 7.58 8.81 - 6.38	7.27 - 7.58 12.15 - 10.33	9.80 - 6.32 8.51 - 6.38	5.06 - 8.53 10.18 - 7.60	13.27 - 9.48 8.20 - 7.90
Biological					
a. Chlorophyll-a (mg/m^3)					
August December	24.81 - 8.06 32.50 -19.55	16.23 - 9.36 7.39 - 25.72	44.37-23.84 11.13 - 14.72	25.06 - 48.62 13.98 - 14.53	18.74 - 11.13 10.78 - 7.52

Water temperature from each station within the depth in December is described in Fig. 2. The chemical parameters that consist of pH show the neutral and alkaline value at 6.92 – 8.44. The lowest pH during August was found at station IV, in contrast to station II. Meanwhile, the highest pH value in December was found at station II, and the lowest at station V. The dissolved oxygen concentration in the Juanda reservoir shows variation from 0.43 mg/L to 4.18 mg/L. Within stations, the average value of dissolved oxygen at station I was high, while the lowest average DO find at station V (Fig. 2)

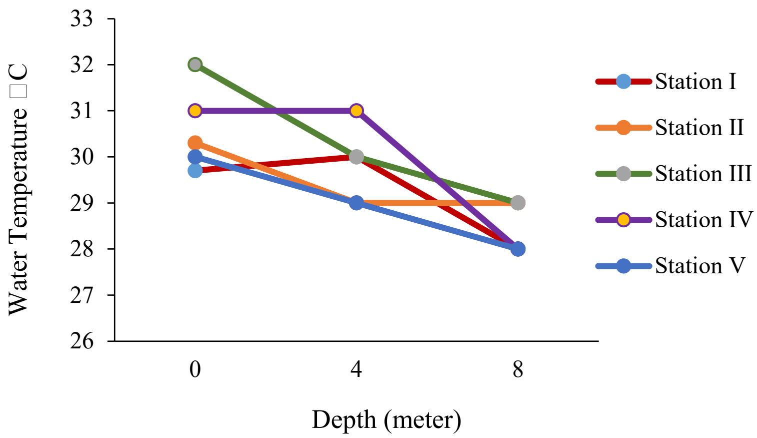

Fig. 3. Water temperature graph from each station on the surface. Depth 0 m, 4 m, and 8 m.

The detailed result for nitrogen concentration shows in Fig. 4. The highest nitrate concentration value was found at Station III and the lowest at Station I in the depth of 4 m. The value of nitrite concentration decreases from the surface layer to the bottom depth. According to [11], nitrogen and phosphates tend to increase in sediment. This tren is related to the decrease of dissolved oxygen concentration of depth >4 m in the Juanda reservoir. For nitrogen compounds, concentration of nitrate ranged from 0.783 mg/L to 1.670 mg/L, and nitrite concentrations are lower than 0.001 mg/L to 0.009 mg/L. For phosphorus compounds, phosphate concentration in between 0.006 mg/L – 0.250 mg/L and total phosphorus ranged from 0,022 mg/L – 0.350 mg/L. For the BOD5 concentration, measurements were taken in December only ranged from 1.90 mg/L to 5.38 mg/L. Meanwhile, for organic materials, concentration ranged from 5.06 mg/L – 13.27 mg/L during August and 6.38 mg/L – 12.15 mg/L in December.

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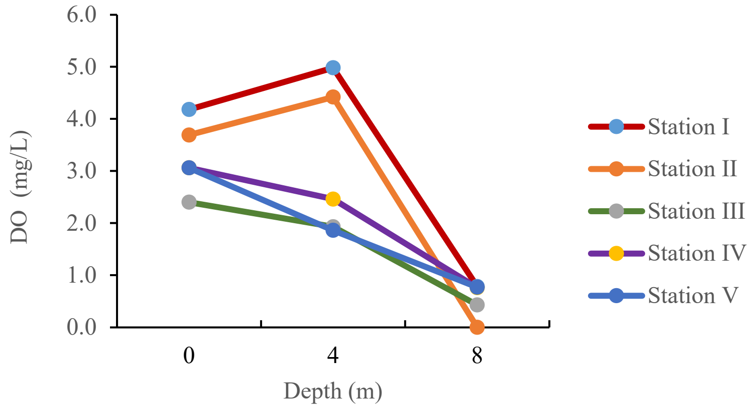

Fig. 3. Graph of dissolved oxygen from each station on the surface. Depth 0 m, 4 m, and 8m.

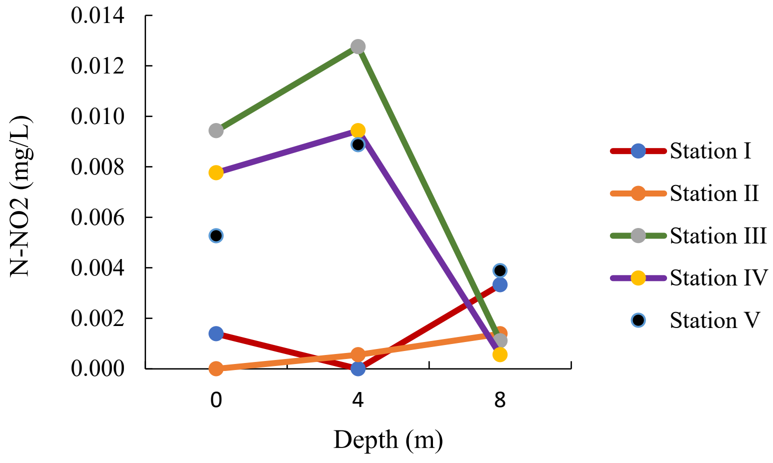

Fig. 4. Graph of nitrite concentration from each station on the surface. Depth 0 m, 4 m, and 8 m.

The high nitrate concentration is thought to be due to the high organic matter in the waters (Fig. 5), while the dissolved oxygen content tends to be below. Nitrite is usually found in very small amounts in the water because it is unstable to oxygen. For nitrate concentrations during the research, the highest value found on stations IV ranged from 1.547 mg/L - 1.158 mg/L, and the lowest found at station II of 0.775 mg/L - 0.819 mg/L [12] waters with a nitrate content of >0,2 mg/L are classified as eutrophic, causes eutrophication. It is characterized by the appearance of water plants/water hyacinth, phytoplankton of the green algae species in the water.

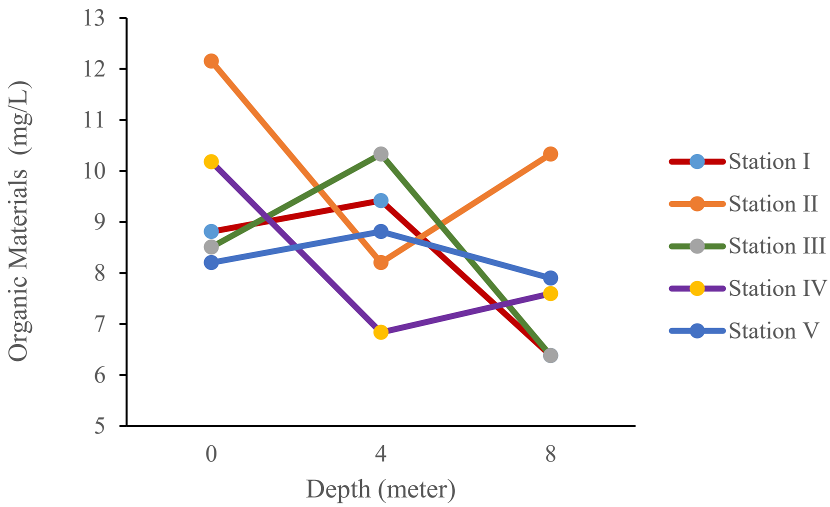

Fig. 5. The graph of solubility of organic materials from each station on the surface. Depth 0 m, 4 m, and 8 m.

There are five classes as phytoplankton found in the waters of reservoirs, i.e., the Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, and Euglenophyceae. The abundance of plankton is shown in Table 4.

Table 4. The abundance of plankton (Ind./ml) in each station of the Juanda reservoir

No.	Class and Genus	St. I	St. II	St. III	St. IV	St V
	PHYTOPLANKTON					
A.	**BACILLARIOPHYCEAE**					
1.	*Navicula* sp	6	-	-	2	2
2.	*Nitzschia* sp	1	4	-	1	37
3.	*Synedra* sp	135	139	102	62	50
B.	**CHLOROPHYCEAE**					
1.	*Actinastrum* sp	2	1	2	-	2
2.	*Ankistrodesmus* sp	7	-	19	22	41
3.	*Chlorella* sp	29	52	42	31	21
4.	*Closterium* sp	1	-	1	8	0
5.	*Coelastrum* sp	9	57	25	29	10
6.	*Cosmarium* sp.	83	28	7	58	45
7.	*Crucigenia* sp	110	37	57	51	2
8.	*Dictyosphaerium* sp	-	3	-	-	-
9.	*Eudorina* sp.	-	1	-	-	-
10.	*Euastrum* sp.	3	1	2	-	-
11.	*Ooscystis* sp.	9	1	3	-	1
12.	*Pediastrum* sp.	8	25	34	5	1
13.	Radiococcus sp.	-	-	16	1	-
14.	*Scenedesmus* sp.	100	91	52	58	35
15.	*Staurastrum sp.*	70	30	29	12	61
16.	*Treubaria* sp.	-	10	6	17	26
17.	Tribonema sp.	8	-	50	3	-
C	**CYANOPHYCEAE**					
1.	*Acanthocerus* sp.	-	-	16	8	4
2.	*Anabaena* sp.	71	69	33	73	30
3.	*Lynbya* sp.	194	147	74	86	99
4.	*Merismopedia* sp.	50	46	86	50	46

5.	*Microcystis* sp.	10	38	1	10	-
6.	*Oscilatoria* sp.	1.751	1.489	417	412	655
D	**DINOPHYCEAE**					
1.	*Ceratium* sp	48	95	52	35	37
2.	*Peridinium* sp.	72	75	74	118	50
E	**EUGLENOPHYCEAE**					
1.	*Phacus* sp.	-	-	1	-	-
2.	*Trachelomonas* sp	1	17	-	-	16
	ZOOPLANKTON					
A	**COPEPODA**					
1.	*Cyclops* sp.	2	15	1	9	3
B	**CLADOCERA**					
1.	*Bosmina* sp	2	16	8	2	-
2.	*Moina* sp	1	-	2	-	1
3.	*Nauplius* sp	10	10	2	4	22
C	**ROTIFERA**					
1.	*Anuraeopsis* sp.	-	2	-	-	-
2.	*Asplancha* sp.	-	-	-	4	-
3.	*Branchionus* sp.	-	3	2	3	-
4.	*Chydorus* sp.	5	8	-	-	-
5.	*Hexarthra* sp	-	4	-	1	-
6.	*Keratella* sp.	1	4	-	2	-
7.	*Polyarthra* sp.	1	4	17	13	1
8.	*Tricocerca* sp.	7	13	1	5	-
D	**PROTOZOA**					
1.	*Acanthocystis* sp.	-	1	5	-	-
2.	*Cryptomonas* sp.	33	33	-	-	1
	Difflugia sp.	13	-	-	-	-

4 Discussion

4.1 Water quality status of Juanda Reservoir

The Juanda reservoir has a maximum depth of 125 m. The water supply mostly came from the Citarum river of West Java Province [13]. In contrast with measurement on this research, the maximum observed depth only reaches 49.1 m in station V. This condition might be due to the mud sedimentation or other waste products for a long period resulting from activities along the watershed and surrounding areas Juanda reservoir.

The average water temperature decreases within depth. A decrease in sunlight intensity could cause this. The temperature value during this research is in normal temperatures, which can be tolerated by aquatic organisms [14]. According to [15], fish in the tropic waters will grow optimally at a temperature of 25 °C to 32 °C.

Turbidity and transparency patterns across stations show variation. The highest concentration of turbidity was in station II, and the lowest was found in Station IV. The high turbidity level in station II is due to high materials suspended from the upstream and input materials from the land. The highest transparency value was at station I and the lowest at station II. The low transparency value at station II is caused by the murky brown color of the water and the smell due to mud particles carried from the land, also caused by the rain during the sampling. Transparency is very important because it is closely related to photosynthesis in the waters [16]. According to [17], the transparency value could be varied by the weather conditions, time of measurement, watercolor, turbidity, and suspended solids in the water.

Measurement in this research indicates an excellent pH value, tending to be neutral. The pH value of the water is closely related to the water depth, that when the water recedes, then the pH value tends to fall. Also, during the dry season, waters begin to sour, and pH falls due to the decay of the leaves of plants, grass, and others. The pH value is associated with the concentration of carbon dioxide (CO_2) in the water. [12] were said that pH is closely related to carbon dioxide too-the higher the pH, the lower the carbon dioxide content, similar to the result from [18]. The highest concentration of CO_2 in the waters of Juanda Reservoir was found at stations with FNC activity of 11.6 mg/L, while the lowest part area is in the Citarum river inlet of 5.3 mg/L. However, the range of pH values on the Juanda reservoir can still support the life of fish and other organisms.

The concentration of BOD5 shows the amount of dissolved oxygen needed for the biological degradation of the organic compound at the given time. In this research, Stations III and IV indicate low BOD5 concentration. At the same time, the concentration of organic material was also low at station III during the same time. Detailed DO concentration in Fig. 3 supports the indication of decomposition within depth. The decrease in oxygen concentration occurs due to the presence of organic waste that requires high oxygen for its decomposition process.

4.2 Trophic level status of Juanda Reservoir

Chlorophyll-a is one indicator of aquatic fertility. According to [19] the fertility rate of waters can be assessed from biological and chemical characteristics, especially from the availability of essential nutrients. Chlorophyll-a is a pigment for photosynthesis that is found in phytoplankton and all autotropic organisms. According to [20], the biological factor that affects aquatic fertility rates is chlorophyll-a. Meanwhile for chlorophyll-a content in water samples describe the number of phytoplankton in water. The high and low chlorophyll-a content is caused by hydrological factors, including temperature, salinity, pH, DO, current, nitrates, and phosphates [21].

Based on water sample measurements in the Juanda Reservoir, chlorophyll-a concentrations show varied ranges. By these values, the fertility rate of the waters is determined [22], and the result is shown as eutrophic. Compared to [23] chlorophyll-a content has also reached eutrophic, i.e. 18.29 mg/m^3 - 23.21 mg/m^3 in the reservoir outlet location. These chlorophyll-a concentrations in the Juanda reservoir are relatively high that the waters have a high fertility rate, and are quite productive. Nitrogen and phosphate decomposition can be the cause of this eutrophication and will trigger phytoplankton productivity [24]

The trophic status is also derived from the rapid input of nutrients. The increased nitrogen and phosphate are due to the input of organic materials derived from feed waste, dead aquatic plants, especially water hyacinth, and urea secreted by fish. With a total of 48.989 FNC units in this recent time, the number of organic material input will be bigger than its capacity [3].

The presence of chlorophyll-a is closely related to the presence of phytoplankton. There are five classes as phytoplankton found in the waters of reservoirs, i.e., the Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, and Euglenophyceae. Phytoplankton is a primer production in the food chain, and its existence can describe the status of its water. The abundance of class Chlorophyceae was the highest among genera and was found in 17 genera at Station I. This condition can be explained due to high oxygen content compared to the others station. Meanwhile, class Bacillariophyceae was found in 3 genera: *Navicula* sp, *Nitzschia* sp, and *Synedra* sp. Bacillariophyceae class has a high growth rate, high tolerance, and can adapt to environmental changes.

Chlorophyll-a is the only biological parameter that was measured in this research. The chlorophyll-a concentration during August in between 9.36 mg/m^3 – 44.37 mg/m^3, and 7.52 mg/m^3 – 37.39 mg/m^3 during December. The range of chlorophyll-a concentration has low at station V during both measurements. Meanwhile, the high chlorophyll-a concentration was found at station IV in August and station I in December.

By comparing water quality values with standards, the Juanda Reservoir can be categorized as moderately polluted on Class III and heavily polluted on Class II. In detail, the value of chlorophyll-a concentration is then compared with the TLI index. The result shows the fertility status of reservoir waters in the eutrophic category with an average TLI value of 4.6 to 5.2.

Management of Aquaculture can be carried out for sustainable aquaculture development, among others, by reducing nutrient inputs derived from FNC activities and reducing the number of FNC. It can also be done by implementing FNC with a water management system using recirculation and plantation (SMART FNC), an ecological friendly FNC with recirculating water, and where the waste is collected in the certain tank and used as a liquid fertilizer for aquaponics [25]. Besides, law enforcement and licensing are needed to be applied. The management also needs to reduce sedimentation derived from hyacinth plants, which covers most areas of water mechanically. Mechanical cleaning can be done regularly through a clean reservoir program.

5 Conclusion

The water quality status in Juanda reservoir shows a declination. However, their status can still support the survival of organisms, especially fish, both cultivated fish, and natural fish. The water quality status of Juanda Reservoir can be categorized as moderately polluted to Class III quality standards and heavily polluted to Class II quality standards. The fertility status of reservoir waters in the eutrophic category with an average TLI value of 4.6 to 5.2, which mead the fertility level is high and quite productive.

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References

1. J. Haryadi, Adriani S.N., Krismono, *Innovation of Sustainable Fisheries Technology Supporting Citarum Harum Program* (in Bahasa Indonesia) (Research Institute for Fisheries Resources Enhancement, Jakarta, 2018)
2. M.S. Hamzah, Maarif, Marimin, E. Riani, J. Sumber Daya Air **12,** 1 (2017)
3. L. P. Astuti, A. N. Nurfiarini, Y. Sugiyanti, A. Warsa, A. Rahman, A. L. S. Hendrawan, *Sustainable fisheries management in Jatiluhur Reservoir* (in Bahasa Indonesia) (Deepublish, Yogyakarta, 2016)
4. W.T. Edmonsons, *Freshwater biology* (John Wiley & Sons, New York, 1963)
5. M. Sachlan, *Planktology* (in Bahasa Indonesia) (Faculty of Animal Husbandry and Fisheries UNDIP, Semarang, 1982)
6. J.G. Needham, P.R. Needham, *A guide to the study of freshwater biology* (Comstock Pub, New York, 1963)

7. APHA, *Standard methods for the examination of water and wastewater. 19th Edition,* (American Public Health Association Inc., New York, 1995)
8. Decree of the Minister of State for the Environment 115/2003, *Guidelines for determining water quality status* (The ministry of environmental of Indonesia, Jakarta, 2003)
9. Regulation of Indonesia's Government, *Water quality management and water pollution control* (2001)
10. N. Burns, J. McIntosh, P. Scholes, Lake Reserv. Manag. **21**, 1 (2005)
11. D. Gál, B. Kucska, E Kerepeczki, G. Gyalog, AACL Bioflux **4,** 5 (2011)
12. H. Effendi, *Study of water quality for water resources and environment managers* (in Bahasa Indonesia) (Kanisius, Yogyakarta, 2003)
13. Krismono, P.A. Lismining, Prosiding Seminar Nasional Ikan, **4** (2006)
14. C.T. Boyd, *Water quality in ponds for aquaculture* (Agriculture Experiment Station, Auburn University, 1990)
15. Sucipto, Prihartono, *Enlargement of bangkok black tilapia in floating net karamba, fast water pool, calm water pool and karamba* (in Bahasa Indonesia) (Penebar Swadaya, Jakarta, 2007)
16. J.H. Basmi, *Planktonologi: plankton sebagai indikator kualitas perairan. Fakultas perikanan dan Ilmu Kelautan IPB* (IPB, Bogor, 2000)
17. N. Zulfia, Aisyah, Bawal **5**, 3 (2013)
18. E. Sumarsih, PhD Thesis, Bandung (ID): Padjadjaran University (2014)
19. H. S. Sanusi, J. Ilmu-ilmu Perairan dan Perikanan Indonesia **11,** 2 (2004)
20. J.W. Nybakken, *Marine biology:an ecological approach* (Gramedia Pustaka, Jakarta 1992)
21. R.F. Sihombing, R. Aryawati, Hartoni, Maspari J. Marine Sci. Res. **5,** 1 (2013)
22. Heriyanto, Undergraduate Thesis, Riau (ID): Riau University (2009)
23. Hatta, Postgraduate Thesis, Riau (ID): Riau University (2007)
24. A. do N. Moura, E.C. Nascimento, E.W. Dantas, Rev. Biol. Trop. **60**, 2 (2012)
25. L.P. Astuti, L.S.H. Andika, Krismono, J. Kebijakan Perikanan Indonesia **10**, 2 (2018)