Environmental and Socio-economic Impact of Floating Net Cages Aquaculture in Cengklik Reservoir

Fatimah Nurul Mahdiyah Jayatri[1], Adhy Kurniawan[2(✉)], and Susilo Budi Priyono[3]

[1] Master of Technology for Sustainable Development, Postgraduate School, Universitas Gadjah Mada, Yogyakarta, Indonesia
[2] Department of Civil Engineering, Vocational School, Universitas Gadjah Mada, Yogyakarta, Indonesia
adhy_kurniawan@ugm.ac.id
[3] Department of Fisheries, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia

Abstract. The existence of Cengklik Reservoir is used by the surrounding community for aquaculture using a floating net cage system. The floating net cage system is often in demand because it reduces the loss of fish when the reservoir volume changes so that it is easier to culture, but this system also has an impact on water quality. The purpose of this study was to analyze the environmental impact of aquaculture using a floating net cage in Cengklik Reservoir on water quality and the communities economy. This study uses secondary data of fish production for the last 5 years and data on floating net cage farmers, as well as primary data on water quality analysis and trophic status to evaluate water quality which is a challenge to environmental quality. Based on analysis of satellite imagery in 2022, there are approximately 1,355 floating net cage units with total cage area of 5.92 ha. The number of cage has exceeded the Boyolali Regent Regulation No. 79 of 2020, the number of cages allowed is 400 units. Fishery production in the Cengklik Reservoir has fluctuated from 2017–2022, but the huge potential of tilapia around >2,000,000 kg/year has increased the economic potential of fish cage farmers. However, this increased opportunity also results in a decrease in water quality because fish feed settles to the bottom of the waters. This feed contains nutrients of high phosphate levels and has the potential to cause eutrophication. The results of the water quality analysis of the Cengklik Reservoir showed that the BOD and Total-P levels had exceeded the water quality standard and the trophic status (based on the Trophic State Index) is mesotrophic. This water quality condition is a challenge that needs to be resolved to make the potential of the Cengklik Reservoir sustainable.

Keywords: Aquaculture · Cengklik Reservoir · Eutrophication · Floating Net Cage · Water Pollutant

J. Sumantyo et al. (Eds.): ICoSIA 2022, ABSR 29, pp. 242–249, 2023.
https://doi.org/10.2991/978-94-6463-122-7_21

1 Introduction

Cengklik Reservoir is a freshwater dam that surrounds three villages in Ngemplak District, Boyolali Regency including Ngargorejo Village, Sobokerto Village and Senting Village. The existence of this reservoir provides benefits for the surrounding community because it can be used for irrigation water, aquaculture and tourism. The utilization of this reservoir can be seen by the number of floating net cages used for freshwater aquaculture, this is explained by [1]. The fish cultured are red tilapia, carp, catfish, sepat, koi, and wader.

Aquaculture using a floating net cage system is in great demand because of the ease of maintenance, namely the presence of fish in cage makes it easier for farmers to select fish according to size and age so that it is easier to harvest and feed. In addition, the economic value of this floating net cage system can be directly calculated by farmers. But on the other hand, fish culture using floating net cages also provides input for waste containing nutrients such as nitrogen and phosphorus. This is explained by research [2] that the increase in fish culture activities using floating net cages in Jatiluhur Reservoir causes a decrease in water quality. This waste input comes from fish feces and uneaten feed. Based on research conducted [3], there is 70% of the feed eaten by fish, and the rest is released into water bodies which then settle in aquatic sediments. The load of organic waste that contains nutrients that are too high and settles in the waters can cause a decrease in water quality and eutrophication (algae blooming). Based on these problems, this study aims to analyze the environmental impact of aquaculture using a floating net cage in Cengklik Reservoir on water quality and the communities economy.

2 Methods

This study analyzes waters as a result of aquaculture activities in Cengklik Reservoir using primary data of water quality compared to the quality standard of Government Regulation No. 22 of 2021 and analysis of trophic status. In addition, an analysis was also carried out on secondary data of fish production for the last 5 years and data on floating net cage farmers to overview of the potential utilization in the Cengklik Reservoir. Water samples were taken using the purposive sampling method at 9 observation points which included the inflow point (T9), the middle point, and fish cage points (T2, T3, T4, T5, T6, T7, and T8) and the outflow point of the Cenglik Reservoir (T1) is shown in Fig. 1. Water quality analysis was carried out at the Jasa Tirta 1 Environmental Laboratory using the parameters presented in Table 1.

The determination of the trophic status of the Cengklik Reservoir waters in this study used the Trophic Level Index (TLI) method using the following equation:

$$TLI_{chl} = 2{,}22 + 2{,}54 \log_{10}(chl)$$
$$TLI_{s} = 5{,}10 + 2{,}60 \log_{10}(S)$$
$$TLI_{TP} = 0{,}28 + 2{,}92 \log_{10}(TP)$$
$$TLI_{TN} = -3{,}61 + 3{,}01 \log_{10}(TN)$$
$$TLI = \frac{TLI_{chl} + TLI_{s} + TLI_{TP} + TLI_{TN}}{4}$$

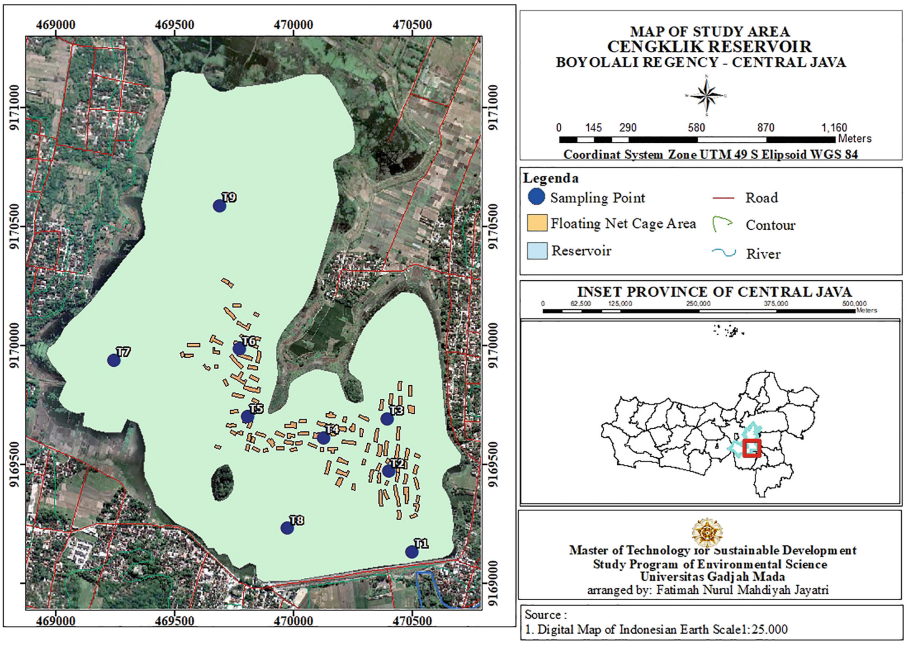

Fig. 1. Cengklik Reservoir Water Sampling Point

Table 1. Cengklik reservoir water quality test method

Parameters	Methods
Total Suspended Solid (TSS)	APHA 2540 D-2017
Dissolved Oxygen (DO)	Winkler Methods
Biological Oxygen Demand (BOD)	APHA 5210 B-2017
Chemical Oxygen Demand (COD)	SNI 6989.2:2019
Total-N	QI/LKA/65, APHA 4500-NO_2 B-2017, APHA 4500-NH_3 F-2017
Total-P	SNI 6989-31:2021
Chlorophyll-a	APHA 10200 H-2017

where the TLI value is, 0–1: ultra-microtrophic, 1–2: microtrophic, 2–3: oligotrophic, 3–4: mesotrophic, 4–5: eutrophic, 5–6: supertrophic dan 6–7: hypertrophic.

3 Water Quality

In this study, water sampling was carried out on August 12, 2022, at 11.30–14.00 WIB with sunny weather conditions. The results of measuring the water quality of the Cengklik

Table 2. Cengklik Reservoir Water Quality

Point	Depth (m)	Temperature (^oC)	pH	Transparency (m)	DO (mg/L)	BOD (mg/L)	COD (mg/L)	TSS (mg/L)	Total-N (mg/L)	Total-P (mg/L)	Chloro phyll-a (mg/m^3)
T1	5,70	31,4	7,71	0,65	6,4	4,46*	20,76	7,5	0.6755	0,0390*	0,1803
T2	6,33	30,6	7,57	0,815	4,8	3,99*	19,37	6,0	0.6922	0,0427*	0,1031
T3	6,04	31,9	7,6	0,625	5,4	3,65*	19,58	7,5	0.7673	0,0429*	0,1506
T4	6,40	30,5	7,6	0,575	6,1	3,83*	19,69	5,5	0.7193	0,0325*	0,1520
T5	5,10	31,0	7,41	0,56	6,1	4,51*	20,89	8,0	0.6759	0,0380*	0,1468
T6	4,20	32,3	7,46	0,625	6,5	4,67*	21,22	6,0	0.6482	0,0304*	0,1546
T7	6,40	31,2	7,75	0,665	7	3,95*	19,90	10,5	0.6847	0,0252	0,1656
T8	1,88	31,3	8,07	0,865	6,4	4,07*	20,95	7	0.6923	0,0281	0,1694
T9	4,22	31,8	7,76	0,585	7,4	4,76*	21,28	10,0	0.6828	0,0294	0,1753
Water Quality Standard		Deviation 3	6–9	4	≥4	3	25	50	0.75	0.03	50

Reservoir are presented in Table 2 using the class II quality standard parameters based on Government Regulation No.22 of 2021 according to their designation, namely to irrigate crops, fish cultivation, and water tourism. The results in Table 1 show that the concentration of BOD at all observation points exceeds the water quality standard. This high BOD content indicates the amount of oxygen used by microorganisms, especially bacteria, to decompose organic matter in water. A large number of floating net cages in the waters of the Cengklik Reservoir is able to increase the decomposition of organic matter so that the concentration of BOD will be high. [4] also explained that there is a correlation between BOD and DO, where the higher the BOD concentration, the lower the DO concentration. However, in this study, the BOD concentration was high while the DO value was also good. This can occur due to the influence of water sampling time during the day when aquatic plants and phytoplankton carry out photosynthesis. The results of photosynthesis in the form of glucose and oxygen cause DO increase at that time.

Table 2 also shows that the Total-P at points T1–T6 exceeds the water quality standard. The point T1 is the water exit point and the T2–T6 point are the point of the cage area. The high levels of phosphate in the waters of the Cengklik Reservoir are caused by fish feed and feces. [5] explained that red tilapia requires feed containing 0.8–1.0% phosphorus, but the phosphorus content in feed which is generally marketed reaches 1.27–1.66%, so that some will be exreted by the fish. In general, fish feed contains carbohydrates, protein, and fat with a composition of 24–26% nitrogen and 0.96% phosphate. The high total P content in the waters is an indication of the eutrophication.

Based on the water quality analysis, the trophic status was determined to estimate trophic level of the Cengklik Reservoir waters. The analysis of the trophic status of the Cengklik Reservoir are presented in Table 3. Based on Table 3, the TLI values for all observation points ranged from 3.70–3.95, which indicates that the trophic status of the Cengklik Reservoir is mesotrophic. Mesotrophic status indicates that the waters of the

Table 3. Analysis of the Trophic Status of the Cengklik Reservoir

Titik	TLIchl	TSIs	TLItp	TLIn	TLI	Indicator
T1	0.330	5.568	4.864	4.907	3.92	Mesotrofik
T2	−0.286	5.308	4.979	4.939	3.73	Mesotrofik
T3	0.132	5.613	4.985	5.074	3.95	Mesotrofik
T4	0.142	5.709	4.633	4.989	3.87	Mesotrofik
T5	0.103	5.739	4.831	4.908	3.90	Mesotrofik
T6	0.161	5.613	4.548	4.853	3.79	Mesotrofik
T7	0.236	5.542	4.310	4.925	3.75	Mesotrofik
T8	0.261	5.239	4.448	4.939	3.72	Mesotrofik
T9	0.299	5.689	4.506	4.921	3.85	Mesotrofik

a

b

Fig. 2. (a) Appearance of Water Hyacinth in Fish Cage Area, (b) Appearance of Water Hyacinth on Dam (photo taken on September 9, 2022)

Cengklik Reservoir have moderate levels of nutrients, meaning that there is nitrogen and phosphate content in the waters but are still within tolerance limits. Although it is still within the tolerance limit, the growth of water hyacinth (Eichhornia crassipes) in the Cengklik Reservoir is already too much, this is shown in Fig. 2. The water hyacinth growing in the Cengklik Reservoir is blocking the way for fish farmers to go to the cages

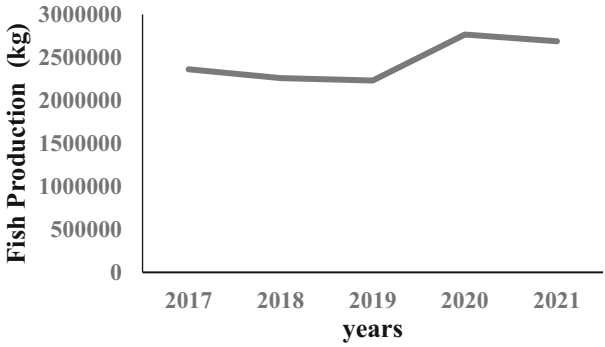

Fig. 3. Cengklik Reservoir Fish Production Results in 2017–2021

and the outflow of water near the dam. In addition, if the water hyacinth is not cleaned it can obstruct the penetration of light in the disturbing waters which can cause a decrease in the oxygen levels of the waters.

4 Socio-economic Condition of Fishing

The floating net cages in the Cengklik Reservoir are mostly traditional cages made of bamboo with sizes 6 m × 6 m and 7 m × 7 m. Farmers choose bamboo because it has cheaper cage material prices, which is around Rp. 10,000,000 for 8 cages. The average area per unit of floating net cages in the Cengklik Reservoir is 36–49 m^2 with a cage depth of 2.5–3 m. The most widelycultured fish are red tilapia and catfish. Based on data from the Department of Animal Husbandry and Fisheries of Boyolali Regency, the fish production in the Cengklik Reservoir are presented in Fig. 3 which shows that it fluctuates every year. However, this potential is very large because the number of fish produced from aquaculture activities reaches up to more than 2 million kg per year.

The local community also explained that aquaculture using floating net cages in Cengklik Reservoir was started in 2005 by the Mina Prosperous fish farmer group consisting of 7 people and is growing every year. Based on satellite imagery analysis, the number of floating net cages in the Cengklik Reservoir in 2022 is approximately 1,355 cages. This amount has exceeded the capacity allowed by the government based on Boyolali Regent Regulation No. 79 of 2020 concerning Control of Spatial Utilization in the Cengklik Reservoir and Surrounding Areas in Boyolali Regency. This regulation states that aquaculture using floating net cages is limited to a maximum of 400 cages.

5 Economic Opportunity for Floating Net Cage Aquaculture

The utilization of aquaculture using floating net cages is an economic opportunity for the surrounding community. This statement is supported by [2], aquaculture using floating net cages can be used as an alternative to increase people's income and standard of living, expand employment opportunities, and meet consumption of fish protein sources. Based on data from the Department of Animal Husbandry and Fisheries of Boyolali Regency,

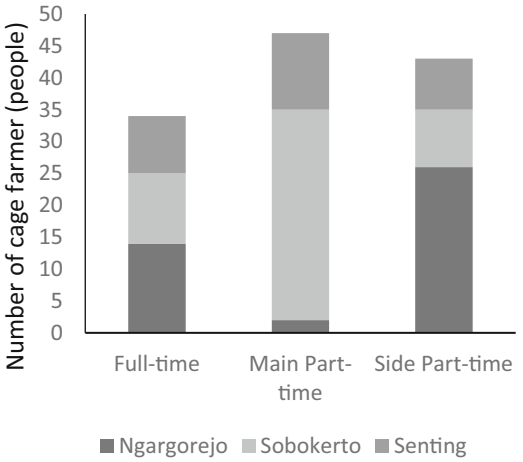

Fig. 4. Number of cage farmers in Cengklik Reservoir

there are 124 fish farmers from 3 villages, namely Ngargorejo, Sobokerto, and Senting. The number of fish farmers in the Cengklik Reservoir is shown in Fig. 4. There are several farmers who make this activity as a full-time job, main part-time, and side part-time. The existence of farmers who make this activity as a side activity also opens up opportunities for new workers for the community who provide cage aquaculture management services. In addition, the potential of floating net cages is also utilized by services for making floating net cages, middlemen or fish traders, and water tourism service providers. Floating net cages are an attractive sector for tourists who come to Cengklik Reservoir, so visitors who want to surround the reservoir can take a boat and pay Rp. 50,000 per trip.

6 Conclusion

Aquaculture using floating net cage systems in Cengklik Reservoir is currently experiencing development for the communities economic sector, namely by opening up new job opportunities as cage farmers, cage constructors, cage aquaculture management services, middlemen or fish traders, and water tourism service providers. Currently there are 124 fish farmers who are residents around the Cengklik Reservoir. However, the existence of aquaculture has an impact on water quality. This is indicated by the BOD and Total-P in the waters which have exceeded the water quality standards according to Government Regulation No. 22 of 2021. In addition, the analysis of the trophic status of the Cengklik Reservoir waters indicate mesotrophic status and there has been significant growth of water hyacinth which interfere the flow of water in the dam. These problems are challenges that need to be resolved by managers and the community in order to realize a sustainable Cengklik Reservoir. The number of floating net cages in the Cengklik Reservoir has also exceeded the capacity limit according to Boyolali Regent Regulation No. 79 of 2020, so a review of the environmental carrying capacity of the Cengklik Reservoir is needed.

Acknowledgments. This research was partially supported by Universitas Gadjah Mada, with joint funding for research, under a UGM Final Project Reconstruction (RTA) grant number 5722/UN1.P.III/Dit-Lit/PT.01.05/2022.

References

1. Kurniawan, A., Jayatri, F.N.M. dan Khasanah, K. 2022. Assessment of Water Quality Status of Cengklik Reservoir due to Eutrophication. IOP Conference: Earth and Environmental Science
2. N. F. Simangunsong and A. Hidayat, "Carrying Capacity and Institutional Analysis of Floating Net Cages in Jatiluhur Reservoir", J. of Environment and Sustainability 1(1), 2017, pp. 37–37
3. Windarti, E. Eddiwan, R. M. Putra and J. S. Tumanggor, "Feeding Habit of Fish Living Around Floating Net Cages in The Koto Panjang Dam, Riau, IOP Conference Series: Earth and Environmental Science 430, 2020.
4. Hasim, K. Yuniarti and F. Kasim, Suitable Location Map of Floating Net Cage for Environemntally Friendly Fish Farming Development With Geographic Information Systems Applications in Lake Limboto, Gorontalo, Indonesia. AACL Bioflux 10(2), 2017
5. L. P. Astuti, Y. Sugianti, A. Warsa and A. A. Sentosa, Water Quality and Eutrophication in Jatiluhur Reservoir, West Java, Indonesia, Pol. J. Environ. Stud 31(2), 2022, pp. 1493–1503