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Implementation of Floating Net Cages (FNC) cultivation and risks to sustainable fisheries in the Gajah Mungkur Reservoir, Wonogiri, Central Java, Indonesia

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Abstract. *Kurniasih S, Sunarto, Setyono P. 2024. Implementation of Floating Net Cages (FNC) cultivation and risks to sustainable fisheries in the Gajah Mungkur Reservoir, Wonogiri, Central Java, Indonesia. Nusantara Bioscience 16: 228-236.* Floating Net Cages (FNC) is an effort to intensify fish production in the Gajah Mungkur Reservoir, Wonogiri, Central Java, Indonesia. The increase in the number of FNC is directly proportional to the production of FNC fish, so it can decrease water quality. The study aims to look into how FNC affects the water quality in the FNC area of the Gajah Mungkur Reservoir and how the threat of FNC water conditions affects the long-term viability of FNC aquaculture in the Gajah Mungkur Reservoir. The data collection technique was purposive sampling, which was analyzed using quality standard evaluation and plankton community structure analysis. The research results show that the water quality parameters measured are based on standards for fisheries activities, except for the COD and BOD parameters. Most plankton found are from the Bacillariophyceae class. The FNC area in the Gajah Mungkur Reservoir includes eutrophic waters with a low diversity and moderate pollution. The evenness exceeds 6 and the C value is less than 0.5. The saprobic indexes for the pollution level in the FNC area's waters is classified as very low to low, with few organic and inorganic compounds in the Oligo/β-Mesosaprobik to β-mesosaprobik phase. Six families of fish have been found in the Gajah Mungkur Reservoir, namely Cyprinidae, Pangasiidae, Eleotrididae, Cichlidae, Channidae, and Bagridae. Social conflict, mass fish deaths, and increasing water pollution are risks to floating net cages cultivation. Commitment, implementation, and supervision are crucial in executing FNC management through an ecosystem approach, ensuring the sustainability of FNC aquaculture and preserving food security.

Keywords: Floating net cages, FNC, Gajah Mungkur Reservoir, risks, sustainable fisheries, water quality

INTRODUCTION

Reservoirs are created by blocking rivers or streams. They serve various purposes such as flood control, hydropower generation, providing drinking water, and irrigation. Additionally, they significantly contribute to inland fish production (Sarkar et al. 2017). Reservoir ecosystems are sensitive to disturbances caused by human activities and climate change (Yang et al. 2017; Znachor et al. 2018). Climate change, eutrophication, and human impact lead to issues in lake and reservoir waters (Ismest'eva et al. 2015). Reservoirs and lakes are commonly used for fisheries and aquaculture. Floating Net Cages (FNC) are widely used for aquaculture in reservoirs as they are easy to monitor and harvest (Astuti et al. 2020, 2023).

FNC cultivation, an intensive aquaculture production system in net cages, has gained significant attention in recent years. The increase in fish production in net cages worldwide is helping to meet the growing demand for animal protein due to population growth (Sajina et al. 2021). There is encouragement to continue developing FNCs due to their economic benefits (Simangunsong and Hidayat 2017). In Sumatra and Java, Indonesia, several lakes and reservoirs have FNCs and fish production numbers that exceed their carrying capacity (Figure 1). If this situation is left unchecked, it is predicted that the frequency of mass fish deaths will increase (Sulaiman et al. 2020).

The Gajah Mungkur Reservoir, Wonogiri, Central Java, Indonesia, has great potential for fisheries. According to Wonogiri District Regional Regulation Number 2 of 2020, the FNC area in the Gajah Mungkur Reservoir covers approximately 25 hectares on the reservoir's edge. The FNC cultivation area is located in Wuryantoro and Wonogiri Sub-districts. Based on the marine, fisheries, and livestock services of Wonogiri District in 2023, the trend of increasing FNC numbers is accompanied by an increase in FNC production (Dislapernak Wonogiri 2023), as shown in Figure 1. In Wonogiri District, FNC fish production in the Gajah Mungkur Reservoir accounts for 90% of the aquaculture output. Cultivation of FNC can increase fish production (Astuti et al. 2023).

The main commodity for FNC cultivation in the Gajah Mungkur Reservoir is tilapia (*Oreochromis niloticus*). Tilapia is an aquaculture Species that can adapt, has high tolerance, fast growth, reproductive efficiency, high fillet yields, and is widely accepted by consumers (Brande et al.

2023). FNC cultivation also produces fish waste, feed waste, and metabolic products. The remaining waste from FNC cultivation will affect water quality through changes in macrobenthos structure, phytoplankton blooms, and fluctuations in physical parameter values (Nabirye et al. 2016).

According to the Direktorat Jenderal Perikanan Budidaya (2017), measuring water quality parameters for FNC cultivation includes water temperature, brightness, pH, dissolved oxygen, ammonia, and phytoplankton abundance. Plankton is a good bioindicator of aquatic change due to its sensitivity to fluctuating environmental conditions (Hemraj et al. 2017), including physico-chemical changes and anthropogenic pollution (Dembowska et al. 2015). Phytoplankton can be a bioindicator to assess the quality of aquatic ecosystems (Haroon and Hussian 2017). Bacillariophyceae (diatoms) communities react directly to environmental physical and chemical changes. They also the most found of algal communities in many freshwater systems (Heramza et al. 2021). On the other hand, the mass growth of Cyanobacteria not only worsens the aquatic environment but also harms the economy, health and human life because of its potential toxins (Chatterjee and More 2023).

This research aims to analyze the influence of FNC on water quality in the FNC area of the Gajah Mungkur Reservoir, and the risk of FNC waters conditions on the sustainability of FNC aquaculture in the Gajah Mungkur Reservoir Wonogiri. The overall analysis includes all environmental components (abiotic, biotic, and sociocultural). The research output is data that can be used as a consideration for managing sustainable FNC cultivation activities.

MATERIALS AND METHODS

Study area

The research was carried out in September 2023. The sampling location consisted of 5 points determined based on the aquaculture area in Gajah Mungkur Reservoir, Wonogiri, Central Java, Indonesia (Figure 2). The station I is at the reservoir inlet in Wuryantoro Sub-district (110° 53' 42.84" E and 07° 52' 56.66" S), station II in the FNC area in Wuryantoro Sub-district (110°53'53.12" E and 07°52'33.32" S), station III in the FNC area in Wonogiri Sub-district (110°54'31.84" E and 07°51'59.57" S), station IV at the reservoir inlet in Wonogiri Sub-district (110°54'33.34" E and 07°51'37.29" S), and station V in the reservoir outlet area (110°54'58.42" E and 07°51'23.27" S).

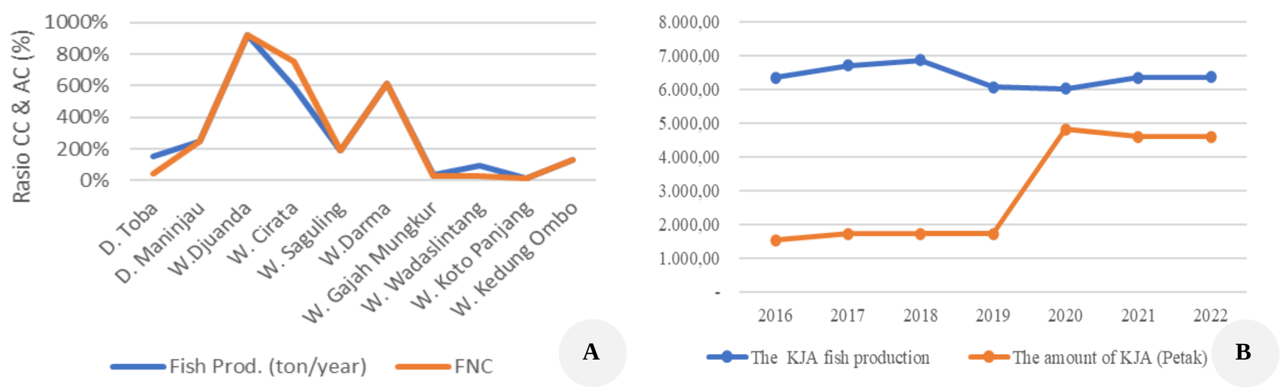

Figure 1. A. The trend of FNCs and fish production numbers that exceed their carrying capacity (Sulaiman et al. 2020) and B. Trend of FNC's fish production and amount of FNC in Gajah Mungkur Reservoir, Wonogiri, Indonesia (Dislapernak Wonogiri 2023) in left to right

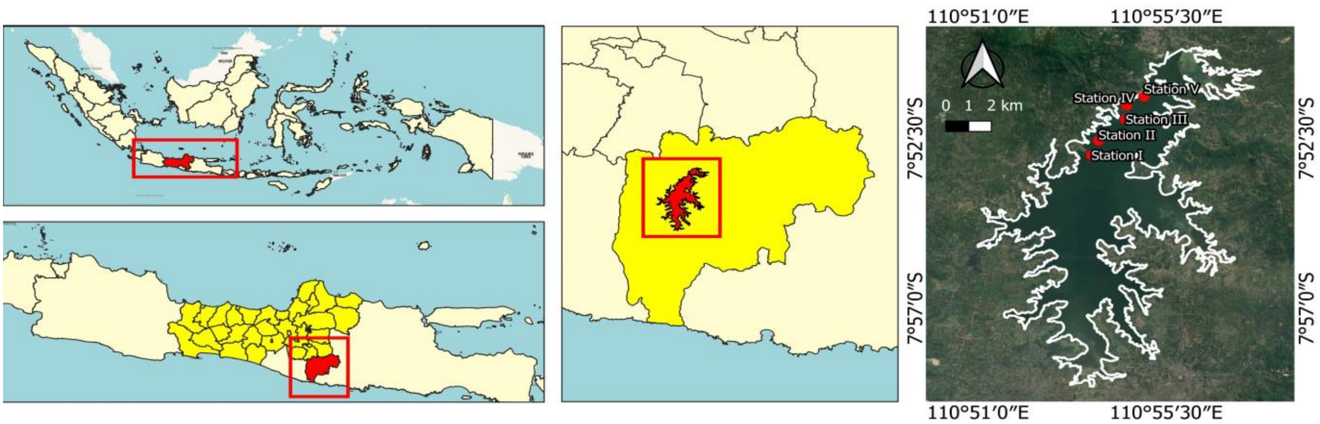

Figure 2. Maps of the research location in Gajah Mungkur Reservoir, Wonogiri, Indonesia

Procedures

Materials

Physical and chemical parameters were observed in the waters of the FNC cultivation area in the Gajah Mungkur Reservoir, Wonogiri, Indonesia (Table 1).

Data collection

Purposive sampling, with specific reasons and considerations, served as the data collection technique, yielding a representative sample that provided a comprehensive view of the research area. Water samples from the Gajah Mungkur Reservoir FNC cultivation fishery area, along with depth composites, served as the research material.

Data analysis

The data was analyzed both qualitatively and quantitatively. The objective parameters of the water quality that were studied were described, and these were then compared with the water quality standards for fishing activities set by Government Regulation Number 22 of 2021 on the Implementation of Environmental Protection and Management. The plankton data obtained is then analyzed to determine the abundance of plankton and phytoplankton, the Diversity Index (H’), Evenness Index (e), Dominance Index (C), and Saprobic Index (SI).

Plankton abundance

To calculate the number of phytoplankton per liter, use the APHA formula (1989), namely:

$$N = n \times (A/B) \times (C/D) \times (1/E)$$

Where:
N: Total number of plankton (ind/L)
n: Average number of individuals per field of view
A: Area of the cover glass (mm^2)
B: Area of one field of view (mm^2)
C: Volume of concentrated water (mL)
D: Volume of one drop (mL) under the cover glass
E: Volume of filtered water (L)

Diversity index

The diversity index is used to assess the level of Species diversity in a community (Odum and Barrett 2009):

$$H' = -\sum_{i=0}^{i} pi \ln pi$$

Where:
H’ : Species diversity index
Pi : A probability function for each part as a whole (ni/N)
Ni : Number of individuals of type i
N : Total number of individuals

Evenness index

The evenness index is used to assess the amount of similarity in the distribution of several individuals from each clan at the community level. Evenness index based on equality (Odum and Barrett 2009):

$$e = H' / \ln S$$

Where:
e : Evenness index
H' : Species diversity index
S : Number of types

Dominance index

The dominance index is calculated using the Simpson index (Odum and Barrett 2009):

$$c = -\sum_{i=0}^{i} sn\ (ni/N)^2$$

Where:
C : Simpson's dominance index
ni : Number of individuals of type i
N : Total number of individuals

Saprobic index

The saprobic index is used to assess the level of organic pollution in waters using existing organisms.

Plankton Saprobic Index (X) (Dresscher and van der Mark 1976):

$$SI = (C + 3D + B - 3A) / (A + B + C + D)$$

Where:
A : the Ciliata group shows polysaprobity
B : Euglenophyta group, shows α mesosaprobity
C : Chlorococcales + Diatomae group, shows β mesosaprobity
D : Peridinae/Chrysophyceae/Conjugatae group, shows oligosaprobity

Table 1. Measurement of water quality parameters

Parameter	Units	Methods/tools
Water temperature	°C	SNI 06-6989.23-2005/ Thermometer
Total Suspended Solids (TSS)	mg/L	SNI 6989.3-2019/ Water tested
Brightness	m	Secchi disc
Current speed	cm/s	current meter
Depth	m	Scale Benchmark
pH	-	SNI 6989.11-2004/ pH meter
Free ammonia (NH_3-N)	mg/L	SNI 06-6989.30-2005/Water tested
PO4-P/phosphate	mg/L	APHA/AWWA/WEF 2017:4500-P D/Water tested
DO	mg/L	SNI 06-6989.14-2004/Water tested
COD	mg/L	SNI 6989.2-2019/Water tested
BOD	mg/L	SNI 6989.72.2009/ Water tested
Plankton	Ind/L	SNI 06-3963-1995/ Water tested

RESULTS AND DISCUSSION

The composition of bioindicators and the diversity index

Table 2 presents plankton as a bioindicator for water samples. The most commonly found phytoplankton are *Synedra* sp. from the Bacillariophyceae class and *Chroococcus* sp. from the Cyanophyceae class. *Cyclops* sp., a zooplankton belonging to the Monogononta class, is also present. Table 3 displays the Shanon-Weiner diversity index for each station. Figure 3 displays the number of individual plankton in relation to the class and composition of fish caught in the Gajah Mungkur Reservoir FNC area. Table 4 displays the fish composition based on the Dinas Kepemudaan dan Olahraga dan Pariwisata Kabupaten Wonogiri (2021) data from Wonogiri District.

Analyses of evaluation the results physicochemical parameters

The results of measuring physical-chemical (abiotic) parameters in Table 5 are evaluated using water quality standards stated in Government Regulation Number 22, 2022 to determine the suitability of water for fishing activities. Physico-chemical variables are evaluated based on Government Regulation Number 22, 2022, except turbidity and depth because there are no standards for these two parameters.

Analyses the risk of FNC's water conditions to the sustainability of the FNC aquaculture

Kartamihardja and Krismono (2016), and Sulaiman et al. (2020) found that the Gajah Mungkur Reservoir can hold a certain number of fish and FNC. This number was then compared to the most recent data from the Wonogiri District Maritime, Fisheries, and Livestock Service, which can be seen in Table 6. Figure 4 shows the trend of mass fish deaths, which is one of FNC activities' risks.

Table 2. Composition of plankton in the waters of the Gajah Mungkur Reservoir FNC area, Wonogiri District, Central Java, Indonesia

Genus	Class
Nitzschia sp.	Bacillariophyceae
Amphora sp.	Bacillariophyceae
Navicula sp.	Bacillariophyceae
Synedra sp.	Bacillariophyceae
Scenedesmus sp.	Chlorophyceae
Anabaena sp.	Cyanophyceae
Chroococcus sp.	Cyanophyceae
Microcystis sp.	Cyanophyceae
Phacus sp.	Euglenoidea
Trachelomonas sp.	Euglenoidea
Ulotrix sp.	Ulvophyceae
Closterium sp.	Zygnematophyceae
Mougeotia sp.	Zygnematophyceae
Spirogyra sp.	Zygnematophyceae
Staurastrum sp.	Charophyceae
Peridinium sp.	Dinophyceae
Difflugia sp.	Tubulinea
Cyclops sp.	Copepoda
Keratella sp.	Monogononta
Trichocerca sp.	Monogononta

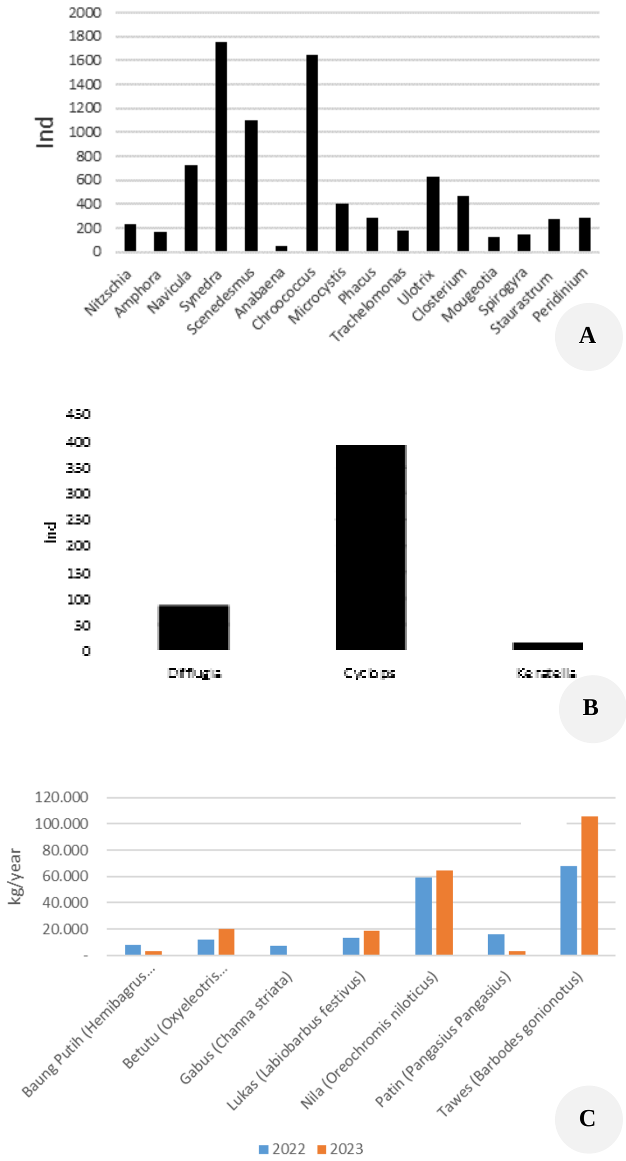

Figure 3. A. The number of in the group of phytoplankton, B. Zooplankton, and C. Composition of caught fish in the FNC's area of Gajah Mungkur Reservoir, Wonogiri District, Central Java, Indonesia

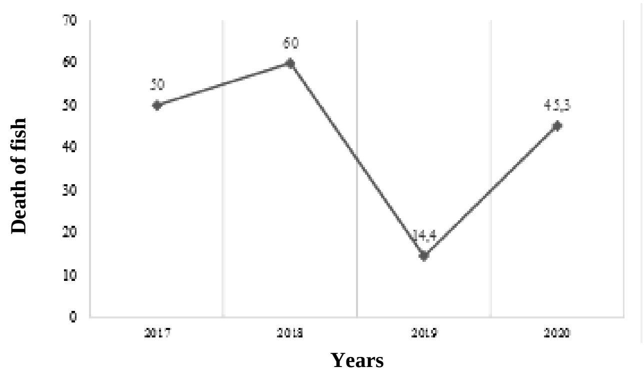

Figure 4. The trend of the mass death of fish in Gajah Mungkur Reservoir, Wonogiri District, Central Java, Indonesia

Table 3. Abundance of zooplankton, phytoplankton, Diversity Index (H'), Evenness Index (e), Dominance Index (C), and Saprobic index (X)

Location point	Zooplankton abundance (ind/L)	Phytoplankton abundance (ind/L)	H'	e	C	X
I	65,500	421,500	2.24	0.74	0.12	0.7
II	17,250	487,000	2.19	0.72	0.14	1.8
III	22,250	315,000	2.07	0.68	0.15	1
IV	23,000	543,250	2.25	0.74	0.12	1.6
V	74,250	350,000	2.04	0.67	0.16	1.3

Table 4. The fish composition in Gajah Mungkur Reservoir, Wonogiri District, Central Java, Indonesia

Scientific name	Local name	Family
Oreochromis niloticus (Linnaeus, 1758)	*Nila/ Nile tilapia*	Cichlidae
Pangasianodon hypophthalmus (Sauvage, 1878)	*Jambal siam/Patin*	Pangasiidae
Barbonymus gonionotus (Bleeker, 1849)	*Tawes*	Cyprinidae
Hemibagrus nemurus (Valenciennes, 1840)	*Saga*	Bagridae
Labiobarbus leptocheilus (Valenciennes, 1842)	*Lukas*	Cyprinidae
Barbodes balleroides (Valenciennes, 1842)	*Iro soka*	Cyprinidae
Hampala macrolepidota Kuhl & Van Hasselt, 1823	*Palung*	Cyprinidae
Osteochilus vittatus (Valenciennes, 1842)	*Salem*	Cyprinidae
Rasbora argyrotaenia (Bleeker, 1849)	*Lunjar/Wader pari*	Cyprinidae
Parachela oxygastroides (Bleeker, 1852)	*Lalang*	Cyprinidae
Oxyeleotris marmorata (Bleeker, 1852)	*Betutu*	Eleotridae
Channa striata (Bloch, 1793)	*Kutuk*	Channidae
Mystus singaringan (Bleeker, 1846)	*Nggaringan*	Bagridae

Source: Dinas Kepemudaan dan Olahraga dan Pariwisata Kabupaten Wonogiri (2021)

Table 5. Physicochemical parameters and comparison with a quality standard for the water utilization classification in FNC's area of Gajah Mungkur Reservoir, Wonogiri, Central Java, Indonesia

Parameter	Analysis results per location point					Quality standards (PP 22/2021)	
	I	II	III	IV	V	Class of II	Class of III
Water Temperature (°C)	27	28	28	28	28		Dev. 3
Total Suspended Solids (TSS) (mg/L)	45	52	50	48	39	50	100
Brightness (m)	0.36	0.38	0.39	0.35	0.4	4	2.5
Current speed (cm/s)	20	39	18	7	22	-	-
Depth (m)	11	5.5	9.5	3.5	12	-	-
pH	8.89	8.95	8.78	8.89	8.97	6-9	6-9
Ammonia Free (NH3-N) (mg/L)	0.139	0.198	0.18	0.159	0.154	0.2	0.5
PO_4-P/Phosphate (mg/L)	0.164	0.199	0.194	0.175	0.142	0.2	1
DO (mg/L)	4.9	3.51	3.4	2.58	4.74	4	3
COD (mg/L)	29.79	42.15	43.03	46.56	32	25	40
BOD (mg/L)	10.31	13.9	14.65	15.68	10.31	3	6

Note: Determination of the class of utilization was based on the standard quality of Government Regulation No. 22 the year 2021

Table 6. Carrying capacity and actual conditions of FNC in Gajah Mungkur Reservoir, Wonogiri District, Central Java, Indonesia

Gajah Mungkur Reservoir	Fish production (tons/year)	FNC (plot)	Source
Carrying Capacity (CC)	14,673	4,891	Kartamihardja and Krismono (2016), Sulaiman et al. (2020)
Actual Condition (AC)	6,358	4,591	Dislapernak Wonogiri (2023)
Rasio CC & AC	43%	94%	

Discussion

The FNC area in the Gajah Mungkur Reservoir has two inlets that affect the water condition: one in Gumiwang Village, Wuryantoro Sub-district, and the other in Sendang Village, Wonogiri Sub-district. The surrounding environment, including agriculture, residential areas, and tourism, also contributes to organic pollution in the FNC area, which can impact water quality. In 2016, there were approximately 1,530 FNC plots in the Gajah Mungkur Reservoir, which increased to 4,591 plots by 2022 (Dislapernak Wonogiri 2023). The cultivation of these FNCs results in the release of 30% of the remaining fish feed and 25-30% of fish waste. Since most FNCs lack waste filters, the waste easily sinks and accumulates into pollutants, posing a potential risk of eutrophication. Due to its significant contribution to the trophic level and pollution, the FNC requires significant attention (Kusen et al. 2014; Setyono and Himawan 2018).

In reservoirs, phytoplankton communities are mainly made up of Bacillariophyceae, Cyanophyceae, and Chlorophyceae (Henderson-Sellers and Markland 1987). According to Odum and Barrett (2005), Bacillariophyta are abundant in water due to their ability to easily adapt to the environment, withstand extreme conditions, and reproduce rapidly. For instance, they can double their population every 18-36 hours, which is twice as fast as other phytoplankton. *Synedra* is commonly found in freshwater bodies like lakes and rivers, as well as in marine environments such as estuaries. As a bioindicator, *Synedra* can evaluate water quality by its sensitivity to environmental factors like temperature, light, pH, and nutrients. The presence of *Synedra* in aquatic ecosystems can provide valuable information about water quality and environmental conditions, which can impact other organisms living in the ecosystem (Barinova and Mamanazarova 2021).

Chroococcus is a type of cyanobacterium that is commonly found in fresh waters, marine waters, and wet soil environments. It is highly tolerant of habitat pollution (Wood et al. 2017; Fitri et al. 2021). This bacterium is able to thrive in both acidic and alkaline water, as well as in extreme environments. *Chroococcus* plays a crucial role in the production of oxygen in biogeochemical cycles and can serve as a bioindicator of water quality. A significant decrease in the *Chroococcus* population could indicate poor water ecosystem health (Masithah and Islamy 2023). Additionally, *Chroococcus* has cyanoremediation properties and can absorb chromium (Cr) from a mixture of domestic and industrial waste (Singh et al. 2019). However, it is important to note that Cyanobacteria, including *Chroococcus*, can produce toxins that pose a threat to individuals using water bodies for drinking, irrigation, and recreational purposes (Chatterjee and More 2023).

The abundance of phytoplankton in the waters of the FNC area in the Gajah Mungkur Reservoir indicates eutrophication due to the high fertility level, with phytoplankton abundance exceeding 15,000 ind/L (Landner 1978). The low diversity index value of less than 2.3 suggests limited diversity and low community stability. According to Shanon Wiener's classification for aquatic environments, a water quality range of 2-3 corresponds to moderate quality (Balloch et al. 1976; Islam et al. 2022). With H' falling within the range of 1-3, the water can be categorized as moderately polluted (Wilhm and Dorris 1966; Islam et al. 2022). An Evenness Index (e) close to 1 indicates relatively even distribution of individuals among Species, with no Species dominating. A value of >0.5 for the evenness index suggests light pollution (Islam et al. 2022). This is evident in the relatively low Dominance Index (C) value (<0.5). When the Dominance Index (C) value is close to 0, there is no dominant Species (Odum 1998), and as C increases, the index of evenness decreases (Kumar and Mina 2018).

The plankton identification results revealed the presence of two types of α-mesosaprobic groups (*Phacus* sp. and *Trachelomonas* sp.), 5 types of β-mesosaprobic group (*Nitzschia* sp., *Amphora* sp., *Navicula* sp., *Synedra* sp., *Scenedesmus* sp.), and 4 types of oligosaprobic group (*Closterium* sp., *Mougeotia* sp., *Spirogyra* sp., *Peridinium* sp.). The saprobic indexes ranges from 0.7 to 1.8, indicating very low to low pollution levels in the waters of the FNC area, with a few organic and inorganic compounds in the Oligo/β-Mesosaprobic to β-mesosaprobic phase. These findings align with Wiryanto's research in 2016, which also classified the pollution level in the Gajah Mungkur Reservoir as low based on the pollution index value.

The diversity of fish in the Gajah Mungkur Reservoir is influenced by the inlet and outlet. According to data from the Dislapernak Wonogiri (2023), the types and numbers of fish living in the reservoir are detailed in Figure 3. Additionally, Dinas Kepemudaan dan Olahraga dan Pariwisata Kabupaten Wonogiri (2021) data from the District of Wonogiri indicates the presence of 13 types of fish from six families: Cyprinidae, Pangasiidae, Eleotrididae, Cichlidae, Channidae, and Bagridae. The most commonly found fish in the reservoir belong to the Cyprinidae family, which is the dominant family in the reservoir according to Sajina et al. (2021).

The Gajah Mungkur Reservoir supplies water to regional drinking water companies, which must meet class 1 quality standards. According to Government Regulation Number 22 of 2021, the Dissolved Oxygen (DO) value for class 1 water should be equal to or greater than 6 mg/L. The waters of the Gajah Mungkur Reservoir are classified as class 2 for activities such as irrigation, tourism, fisheries, hydropower, and others, which have the same quality standards. The quality standards for fisheries activities are class 2 and class 3. A low DO concentration can hinder the self-purification process of water (Wardhani and Sugiarti 2021). In stagnant waters like reservoirs or lakes, DO concentration decreases with increasing depth due to reduced oxygen supply from photosynthesis and diffusion processes (Leidonald et al. 2019). Additionally, the use of oxygen for organic matter decomposition, sediment, and rainfall also contributes to the depletion of DO concentrations (Noori et al. 2018).

The quality standards for fisheries activities refer to water quality standards Government Regulation Number 22 of 2021; the brightness value for fisheries activities is 2.5-4

m. The results of brightness measurements at locations in the waters of the Gajah Mungkur Reservoir FNC area are not much different from the Perum Jasa Tirta I year capacity study report (2018) that the transparency in the Gajah Mungkur Reservoir, which is around 20.5-49 cm. A good brightness value for fish cultivation is around 30-40 cm (Rahmayanti et al. 2021); if the brightness reaches less than 25 cm, DO will decrease drastically. According to Effendi (2003), the ability of sunlight to penetrate the river bed is influenced by the turbidity of the water. The water depth at the FNC location is at least 5 meters from the bottom of the net at the lowest low tide with a water flow range of 20-40 cm/s (Direktorat Jenderal Perikanan Budidaya 2017). The location of FNC activities is on the edge of the Gajah Mungkur Reservoir so that during the dry season, the waters recede, and the water depth varies at each point.

Human activities in the waters around aquaculture sites significantly increase BOD and decrease DO and PO_4-P (Ghazali et al. 2022). An increase in BOD concentration, such as water intake, indicates a high accumulation of organic matter (Ling et al. 2017). Wardhani and Sugiarti (2021) stated that the high concentration of BOD in the waters of the Jatiluhur Reservoir is caused by fish culture waste in FNC originating from feed and fish faeces. The high level of COD indicates a high level of water pollution caused by organic matter. Meanwhile, according to Wiryanto (2016), the high BOD value is influenced by FNC and reservoir tourism activities. COD concentrations in FNC areas have higher values and significantly differ from non-FNC (Ghazali et al. 2022).

The cultivation of FNC in the Gajah Mungkur Reservoir has had a positive impact on the socio-economic status of the surrounding community. However, intensive FNC cultivation, driven by profit, has led to negative effects on the reservoir's aquatic ecosystem. Excessive feeding to boost production has resulted in leftover feed entering the water, causing nutrient enrichment. As a result, the current condition of the reservoir is eutrophic, leading to mass fish deaths and increased water pollution. To maintain the reservoir and lake ecosystem, the amount of FNC should not exceed the carrying capacity of the reservoir/lake. Additionally, the management of FNC cultivation should implement fisheries management using an ecosystem approach, which will help maintain water and fish quality, and ensure sustainable FNC activities through effective monitoring.

The water quality in the FNC cultivation area of the Gajah Mungkur Reservoir meets the quality standards of Government Regulation Number 22 of 2021 physically and chemically. However, the COD and BOD parameters exceed the water quality standards for fisheries activities, class II and class III, even though the waters are classified as eutrophic. To control the amount of waste and prevent it from exceeding the reservoir's carrying capacity, the development of FNC cultivation should be regulated and limited. The number of FNCs should be controlled to allow time for water recovery (Setyono and Himawan 2018). Determining the reservoir's carrying capacity is the first step in estimating the optimal number of FNCs to avoid negative impacts from FNC activities. Cross-sector and agency coordination is necessary to monitor the reservoir environment. The coordination between the government/private sector and fisheries should be as equal partners (Simangunsong and Hidayat 2017). In the future, it is important for the government and relevant stakeholders to commit to implementing FNC management using an ecosystem approach to ensure sustainable FNC cultivation for maintaining food security.

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