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ANALYSIS OF WATER SUITABILITY FOR FLOATING NET CAGE (KJA) CULTIVATION OF TILAPIA (*Oreochromis niloticus*) IN GAJAH MUNGKUR RESERVOIR, WONOGIRI REGENCY, CENTRAL JAVA PROVINCE

ANALISIS KESESUAIAN PERAIRAN UNTUK BUDIDAYA KERAMBA JARING APUNG (KJA) IKAN NILA (*Oreochromis niloticus*) DI WADUK GAJAH MUNGKUR, KABUPATEN WONOGIRI, PROVINSI JAWA TENGAH

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Abstract

Reservoirs are one of the waters used for fishing activities. One of them is the Gajah Mungkur Reservoir which is used for cultivating tilapia using the KJA system. Activities around the reservoir can affect the quality of the water in it. The aim of this research is to determine the condition of reservoir water quality and to determine the suitability of reservoir waters for tilapia cultivation activities in the KJA system. The method used in this research is the matching and scoring method, which is then used to obtain the water suitability value. The ArcGIS application is also used to map and calculate the area that can be used for cultivation. The parameters measured are temperature, brightness, depth, current speed, basic substrate, pH, DO, CO_2,nitrate, ammonia, and phosphate. The suitability of the waters of the Gajah Mungkur Reservoir at 6 station points is divided into 3 classifications, namely, stations 1 and 2 are in the S3 category (marginally suitable), stations 3, 4 and 6 are in the S2 category (quite suitable) and station 5 is in the S1 category (very suitable). The scores obtained by each station are as follows: station 1 with a score of 34 (70.83%), station 2 with a score of 33 (68.75%), station 3 with a score of 37 (77.08%), station 4 with a score of 40 (83.33%), station 5 with a score of 43 (89.58%), and station 6 with a score of 39 (81.25%). The overall results show that the Gajah Mungkur Reservoir has a suitability value in the S2 category or is moderately suitable.

Keywords: *Tilapia fish, Reservoir Water Quality, Floating Net Cages, Water Suitability*

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Abstrak

Waduk adalah salah satu perairan yang digunakan untuk kegiatan perikanan. Salah satunya yaitu pada Waduk Gajah Mungkur yang digunakan untuk budidaya ikan nila menggunakan sistem KJA. Adanya aktivitas di sekitar waduk dapat mempengaruhi kualitas air didalamnya. Tujuan dari penelitian ini adalah untuk mengetahui kondisi kualitas air waduk dan untuk menentukan kesesuaian perairan waduk untuk kegiatan budidaya ikan nila sistem KJA. Metode yang digunakan dalam penelitian ini yaitu metode matching and skoring kemudian didapat nilai kesesuaian perairan. Penggunaan aplikasi ArcGIS juga diterapkan untuk memetakan dan menghitung luas wilayah yang dapat digunakan untuk budidaya. Parameter yang diukur yaitu suhu, kecerahan, kedalaman, kecepatan arus, substrat dasar, Ph, DO, CO_2, nitrat, ammonia, dan fosfat. Kesesuaian perairan waduk gajah mungkur pada 6 titik stasiun terbagi menjadi 3 klasifikasi yaitu, stasiun 1 dan 2 masuk kategori S3 (sesuai marginal), stasiun 3, 4 dan 6 masuk kategori S2 (cukup sesuai) dan stasiun 5 masuk kategori S1 (sangat sesuai). Nilai yang didapat masing masing stasiun yaitu, stasiun 1 yaitu dengan nilai 34 (70,83%), stasiun 2 dengan nilai 33 (68,75%), stasiun 3 dengan nilai 37 (77,08%), stasiun 4 dengan nilai 40 (83,33%), stasiun 5 dengan nilai 43 (89,58%), dan stasiun 6 memiliki nilai 39 (81,25%). Hasil keseluruhan menunjukan bahwa Waduk Gajah Mungkur memiliki nilai kesesuaian kategori S2 atau cukup sesuai (*moderately suitable*).

Kata kunci : *Ikan nila, Kualitas Air Waduk, Keramba Jaring Apung, Kesesuaian Perairan*

1. Introduction

Indonesia is one of the largest archipelagic countries in the world, a condition that gives Indonesia an advantage in utilizing and managing its various natural resources. So far, the natural resource that has made Indonesia known to the world is its abundant fishery sector, both capture fisheries and aquaculture. The national potential for aquaculture is 17.92 million hectares, consisting of 2.28 million hectares of freshwater aquaculture, 2.96 million hectares of brackish water aquaculture, and 12.12 million hectares of marine aquaculture. However, the utilization rate is only 11.32% for freshwater aquaculture, 22.74% for brackish water aquaculture, and 2.28% for marine aquaculture, with a total production value of around 15.77 million tons in 2018 (Arrazy et al., 2021).

Fish farming using floating net cages (KJA) is a means of maintaining fish or aquatic biota whose frames are made of bamboo, wood, pralon pipes or square-shaped iron, fitted with nets and floats such as plastic drums or styrofoam so that the container remains afloat in the water. The use of floating net cages (KJA) in fish farming is one of the appropriate technological efforts to optimize the utilization of water resources. Tilapia and carp farming in KJA is very financially feasible with extraordinary income (Mulyadi et al., 2015 *in* Harmilia and Ma'ruf., 2022). The use of KJA for freshwater fish farming activities must be accompanied by proper management of the farming operation, particularly regarding water quality, which can affect fish health, growth, and even harvest.

Gajah Mungkur Reservoir (WGM) is a multipurpose dam located in Wonogiri Regency. This reservoir has more than one function. The functions of WGM include flood control, hydroelectric power generation, improving the fisheries sector and tourism activities, increasing irrigation areas downstream, and supplying raw water to the Regional Water Company (PDAM), which then supplies households and industries. The dam also functions to retain dissolved sediments from the upstream area and increase agricultural intensification in the downstream area (Molo et al., 2012 *in* Laksitaningrum et al., 2017). The Gajah Mungkur Reservoir is the center of tilapia cultivation using the KJA system in Wonogiri Regency. The total number of registered cage farming operations is 740 cages in the Wonogiri Fisheries Service area (Utomo et al., 2010 *in* Nissa and Suadi 2022).

Aquaculture is highly dependent on the availability of water sources and good water quality (Boyd et al., 2012). Cai et al. (2011) stated that aquaculture, in addition to being dependent on location and season, is also vulnerable to the effects of climate change, which reduces water availability and quality and/or increases the risk of extreme weather. Climate change affects the productivity of tilapia in floating net cages in the Gajah Mungkur Reservoir through various problems, including seasonal changes that influence upwelling, extreme rainfall that reduces oxygen levels in the reservoir, and droughts during the dry season that cause the floating net cages to dry up. During extreme weather, mass fish deaths are common. It was recorded that up to 5 tons of tilapia died in floating net cages in the Gajah Mungkur Reservoir in Wonogiri Regency (Nissa and Suadi, 2022). The increase in mass mortality is also a result of oxygen concentration in the water (Fakhrudin et al., 2019). Therefore, water quality is very important in aquaculture.

An analysis of water quality suitability in the Gajah Mungkur Reservoir is needed to determine water quality and its suitability for tilapia farming using the floating net cage (KJA) system. Water quality is an important part of fish farming development, so water quality analysis is essential (Panggabean et al., 2016). According to Harmilia and Khotimah (2018), problems will arise in fish health and farming activities if the water quality of the water used is not good. Purnawan et al. (2015) argue that an analysis of the suitability of water for aquaculture commodities needs to be carried out to determine the level of suitability for the commodities being cultivated. Based on this, this study entitled "Analysis of Water Suitability for Floating Net Cage (KJA) Cultivation of Tilapia (*Oreochromis niloticus)* in Gajah Mungkur Reservoir, Wonogiri Regency, Central Java Province" needs to be conducted.

2. Materials and Methods

2.1. Time and Place

The research was conducted from August to September 2023 at the Gajah Mungkur Reservoir, Wonogiri, Central Java. Sampling was carried out at 6 stations in the reservoir waters. Data analysis was performed at the Faculty of Agriculture Laboratory, Tidar University.

2.2. Tools and Materials

The equipment used in this study included *thermometers, Secchi disks*, pH meters, DO meters, plastic ropes and measuring tapes, *current meters*, buckets, analytical scales, mobile phones, stationery, *Eckman grabs*, *water samplers*, plastic, multi-level sieves, label paper, ovens, and boats. Meanwhile, the materials used in this study were reservoir water, CO_2kit, nitrate kit, ammonia kit, and phosphate kit.

2.3. Sampling Method

Physical and chemical parameters measured in situ were taken at three depths using a water sampler in the form of water samples at 6 stations and then recorded directly in each parameter, while parameters that had to be analyzed in the laboratory/ex situ in the form of substrate were taken by collecting reservoir substrate samples and then brought to the laboratory. In situ parameter measurements were conducted in the morning from 08:00 to 16:00 WIB. The research was conducted from morning to afternoon, considering plankton activity and industrial activity (Hutabarat, et al., 2013). Meanwhile, observations in the laboratory began at noon, specifically from 11:00 a.m. until completion. Sampling was carried out during the dry season in August-September. Sampling and measurement were carried out in accordance with the standards for each parameter.

2.4. Research parameters

The parameters observed during the study were *in situ* (direct) and *ex situ* (laboratory). *In situ* (direct) measurements of water quality parameters included temperature, depth, current velocity, brightness, pH, DO, nitrate, phosphate, CO_2 , and ammonia. Meanwhile, *ex situ* (laboratory) measurements included substrate.

2.5. Data Analysis

Water suitability analysis was conducted by creating a table of suitability parameters in the form of physical and chemical parameters, which are the main requirements for supporting cultivation activities. The data obtained at the Gajah Mungkur Reservoir was entered into a table and then analyzed. The method used was the matching and scoring method, which matched the data with expert determinations, gave scores based on suitability, and multiplied the weight of each parameter based on the extent of its influence on the quality of water. The analysis of water suitability in this study used 11 physical and chemical parameters referring to the journal (Haris and Yusanti, 2019). The weighting for each parameter is determined based on the dominance of that factor in determining the suitability of fish farming land (Nurchayati et al., 2021). The data assessment criteria can be seen in Table 1.

Table 1.
Land Suitability Assessment

Land Quality/Characteristics	Suitability				
	Very Good (S1)	Good (S2)	Less Good (S3)	N	Weight
Temperature (˚C)	28 – 29	27–30	25–31	<25 : >31	3
Brightness (cm)	25–30	30–25	35–50	>50	1
Depth (cm)	1–1.5	1.5–2	2 – 2.5	>2.5	1
Flow Velocity (m/min)	0.1 – 1	1–1.5	1.5–2.5	>2.5	1
Basic Aquatic Substrate	Muddy sand	Mud	Sandy coral	Reef	1
pH	6.5–7.5	5.5–8	4–9	<4: >9	2
DO	>5	3–5	1 – 3	<1	3
CO_2	<5	5 – 6	6 – 7.5	>7.5	1
Nitrate (NO_3)	0.5–1	1–1.5	1.5 – 2	>2	1
Ammonia	< 0.3	0.3–0.4	0.4–0.5	0.5–1	1
Phosphate	<1	1–1.5	1.5–2	>2	1

Source: Haris (2019) and Hidayah (2019)

Each water suitability parameter is assigned a rating of S1 with a value of 3 or very good, S2 with a value of 2 or good, S3 with a value of 1 or less than good, and N with a value of 0 or unsuitable. The score is a rating number based on the DKP (2020) guidelines. The weight is based on the consideration of dominant variables according to (Nurhidayah, 2019). The score for each station is determined by adding the values of the 11 parameters, which are derived from the multiplication of the values and weights, as shown in the following formula:

$$KP = N \times B$$

Explanation:
KP : Water Suitability
N : Parameter value
B : Parameter weight

The determination of water suitability in percent is obtained by dividing the score obtained by the maximum score of 48 multiplied by 100% or in the following formula:

$$\frac{\text{Skor total}}{\text{Skor maksimal}} \times 100\% =$$

Based on the above equation, the percentage value determining water suitability according to Trisakti (2003) in (Nurchayati et al., 2021) is divided into four classes, namely:
Class S1: Highly Suitable (85-100%)
Class S2: Moderately Suitable (75–84%)
Class S3: Marginally Suitable (Marginally Suitable) Score 65–74%
Class N: Not Suitable Score < 65%

After obtaining data in the form of percentages, the average suitability level of the Gajah Mungkur Reservoir waters can be determined by adding up all station values in percentages and then dividing by the number of stations, which is 6. For tilapia farming using floating net cage systems, does it meet the criteria of highly suitable, moderately suitable, marginally suitable, or unsuitable? The results obtained can then serve as a source of information for the development of KJA aquaculture systems that need to be identified, and an evaluation of several potential development areas is required. Evaluation activities need to be carried out based on considerations of water suitability, resources, and the environment for KJA aquaculture production (Haris and Yusanti, 2019).

2.6. Arc GIS

The water quality data obtained was entered into the ArcGIS application. Scores and suitability values were also entered so that the system could group (*reclassify*) stations based on their quality. Different colors for each station area indicate differences in water quality at that station. The results were then displayed in the form of a map or image in the form of colored layers with the shape of the Mungkur reservoir. There are two types of ArcGIS map displays, namely water quality parameters consisting of 11 images and a display of each station based on reservoir suitability and area, which is derived from combining the values of the 11 parameters.

3. Results and Discussion

a. Overview of the Research Location

The Wonogiri Multipurpose Dam, better known to the public as the Gajah Mungkur Reservoir (WGM), is a reservoir located 3 km south of Wonogiri Regency, Central Java Province. Gajah Mungkur Reservoir was built in 1981. Its main functions are hydroelectric power generation and irrigation. The main uses of Gajah Mungkur Reservoir, Wonogiri, have expanded beyond hydroelectric power generation to include additional activities such as fishing (floating net cage aquaculture), water transportation, a culinary center specializing in fish dishes, and tourism. The reservoir has a maximum water surface area of 8,800 hectares with a maximum water depth of 29 meters (Public Works Department, 2010).

Figure 1. Gajah Mungkur Reservoir Dam; Source: Personal documentation, 2023

The water quality of the Gajah Mungkur Reservoir during the dry season has the following parameter values: temperature ranging from 27.32 to 29.54 ℃, brightness ranging from 12.25 to 45.75 cm, depth ranging from 0.76 to 12 m, current velocity ranging from 0.038 to 0.223 m/s, sand and muddy sand substrate types, pH ranging from 6.97 to 8.68 ppm, DO ranging from 7.2 to 8.41 mg/l, CO2 values range from 1.83 to 17.63 mg/l, nitrate levels range from 0 to 1.81 mg/l, ammonia levels range from 0.25 to 0.33 mg/l, and phosphate levels range from 0.08 to 0.36 mg/l. The diversity of measurement results at each station has an influence or impact on aquatic life, in this case, it is used to measure the suitability of the water for tilapia farming using floating net cage systems (KJA).

b. Water Quality Conditions

Water quality observations at Gajah Mungkur Reservoir, which were conducted at six stations at three different depths and averaged at each point, generally showed varying water quality. The water quality conditions of Gajah Mungkur Reservoir are presented in Table 6, which contains water quality data.

Table 2.
Water quality of Gajah Mungkur Reservoir

Parameter	Compliance						Average	Class
	1	2	3	4	5	6		
Temperature (˚C)	29.36	29.54	29.44	29.12	28.81	27.32	28.93	**S1**
Brightness (cm)	39.75	41.75	37	45.75	18.75	12.25	32.5	**S2**
Depth (cm)	12	4	7.8	11.14	0.76	1.5	6.2	**N**
Flow Velocity (m/s)	0.12	0.118	0.038	0.223	0.0715	0.0905	0.10	**S1**
Substrate	Sand	Mud sand	Mud sand	Mud sand	Sand	Sand	Mud sand	**S1**
pH (ppm)	6.97	8.15	8.14	7.79	8.38	8.68	7.75	**S2**
DO (mg/l)	7.47	7.4	7.3	8.41	7.87	7.25	7.62	**S1**
CO_2(mg/l)	17.63	2.33	2.8	4.5	1.83	4	5.51	**S2**
Nitrate (mg/l)	1.81	1.66	0	0.08	0	0	0.59	**S1**
Ammonia (mg/l)	0.33	0.33	0.25	0.25	0.25	0.33	0.304	**S2**
Phosphate (mg/l)	0.35	0.26	0.36	0.18	0.36	0.08	0.265	**Bachelor's**

Source: Personal Data (2023)
Note: S1: Very suitable; S2: Fairly suitable; S3: Marginally suitable; N: Not suitable

c. Water Quality Parameters

Water quality parameters for water suitability are accompanied by color images created using ArcGIS software as follows:

a. Temperature

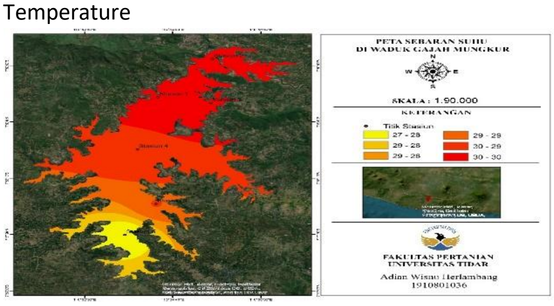

Figure 2. Distribution of reservoir temperature in 2023

Temperature is a water quality parameter that affects the condition of organisms in aquatic environments (Adamimawar, 2022). Strong sunlight intensity causes temperatures to rise easily in shallow waters (Lucas and Southgate, 2012 in Muarif, 2016). Tilapia is a type of pisces, which is an ectothermic animal, meaning that its body temperature is influenced by the ambient temperature (Dewi et al., 2020). At stations 1 to 4, the reservoir temperature tended to be stable at 29.36, 29.57, 29.44, and 29.12, respectively, and was categorized as S2 or fairly suitable. The temperatures at stations 5 and 6 were lower, at 28.81 and 27.32 degrees Celsius. Despite having shallow waters, these two stations have lower water temperatures due to the decreasing intensity of sunlight because the water quality samples at these two stations were taken in the afternoon, from 4 to 5 p.m., when the intensity of sunlight had already begun to decline. This is in line with Najamuddin's (2015) opinion that temperature differences within a certain time frame in a body of water can be influenced by seasonal differences, sunlight intensity, and rainfall. After averaging the temperatures at the Gajah Mungkur reservoir as a whole, the average temperature was 28.93, which falls into the S1 category or very suitable, making it optimal for tilapia farming. According to Mas'ud (2014), the optimal temperature range for freshwater fish farming is 28-32°C. Meanwhile, according to Gupta and Acosta *in* Azhari (2018), the ideal temperature range for tilapia farming is 25-30°C. If the water temperature is too low, it can cause a decrease in appetite and inhibit the metabolic rate of the fish, thereby reducing the survival rate of the organism. Conversely, if the water temperature is too high, the fish will be susceptible to disease, experience stress, and exhibit abnormal behavior (Ridwantara et al., 2019). According to Fidela et al. (2024), temperature affects the activity and metabolism of tilapia. When the temperature is lower than normal, the fish's movements become slow and passive, and the number of operculum openings decreases and weakens. Meanwhile, at temperatures above normal values, fish movements become irregular, and operculum openings become faster and unstable. This is caused by enzymes and metabolism in fish, as well as the concentration of dissolved oxygen in the water.

b. Brightness

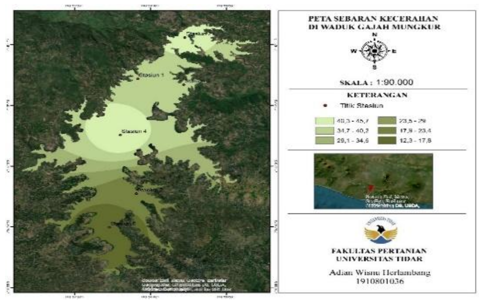

Figure 3. Distribution of reservoir brightness in 2023

The intensity of sunlight penetrating a body of water can be used to indicate the brightness of that body of water (Nugraheni et al., 2022). Water brightness is influenced by several factors, including weather, observation time, water color, turbidity, and suspended solids in the water (Zulfia and Aisyah, 2013). Stations 1, 2, 3, and 4 had good brightness, ranging from 37 to 45.75 cm. At the time of observation, the water at stations 1 to 4 was clear and greenish in color. Good brightness for fish life is 30-40 cm (Monalisa and Infa, 2010). High brightness levels create high oxygen levels due to photosynthetic activity by phytoplankton, which produces oxygen (Asni, 2015). This is consistent with the high oxygen levels at station 4. In this study, low brightness levels were found at stations 5 and 6, at 18.75 cm and 12.25 cm, respectively. At these stations, the water was very turbid due to shallow water, river sedimentation, and the fact that these two stations are located in the tidal area of the reservoir, which is directly adjacent to rice fields and farmland, making it possible for soil or mud to be easily lifted and mixed with the reservoir water. This is consistent with Adamimawar's (2022) opinion that low water brightness values can be caused by shallow water conditions, resulting in the muddy bottom rising to the water surface, thus blocking light penetration. Water with high brightness or greater transparency will have a higher temperature, and vice versa (Pramleonita et al., 2018). The overall water brightness of the Gajah Mungkur reservoir has an average value of 32.5 cm and falls into category S2 or is sufficient and meets the water quality standards based on SNI (2009), namely good water brightness for tilapia production, which is more than 30 cm.

c. Depth

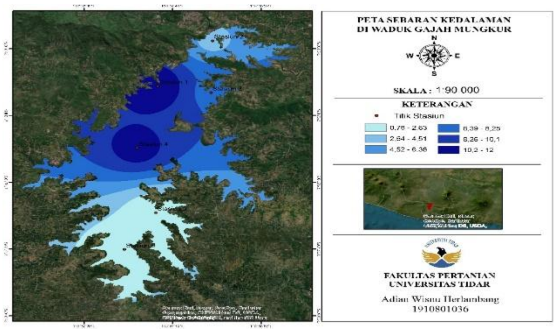

Figure 4. Distribution of reservoir depth in 2023

Fish farming activities using floating net cage systems must take water depth into account because reservoir water levels are constantly changing due to tides, so floating net cages must be placed in the right location (Harmilia et al., 2022). Station 1 has the highest depth of 12 m and is the center of KJA cultivation. Reservoir siltation can affect the natural balance. The natural balance can be influenced by changes in the area of land use utilized as a water buffer (Nursa'ban, 2008). At stations 5 and 6, KJA cultivation is not possible due to the very shallow water depth of 0.76 m and 1.5 m. Although the classification table categorizes them as S1 or very suitable, these stations turn into expanses of soil and grass when the dry season arrives. The appropriate depth for KJA is more than 2 m. If it is less than that, it is not suitable (Rofizar et al., 2017). According to Sari (2011), waters that are too shallow are prone to the accumulation of waste from feed residues and fish metabolism. When cultivating KJA, the distance between rivers, lakes, and reservoirs with a net base should be at least 1 meter at low tide (WWF-Indonesia, 2015). The deeper the water surface in the pond or water body, the wider the fish's movement space. Overall, the Gajah Mungkur reservoir has an average depth of 6.2 m and is categorized as N or unsuitable. Ideally, floating net cage aquaculture should be located in waters with a depth of more than 2 meters (Nurhayati., 2018). The height of floating net cages for tilapia farming ranges from 1.5 to 2 meters (Amrullah and Turrahmah, 2023). According to Yuspita (2022), KJA bases with excessive depth pose technical challenges, such as the placement of anchors used to secure the KJA in place. Excessively deep KJA make cage installation difficult and require significant costs for construction (Sari., 2001).

d. Flow Velocity

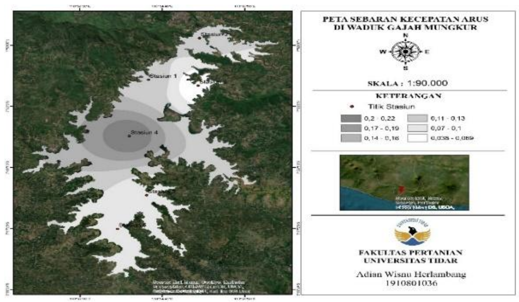

Figure 5. Distribution of reservoir flow velocity in 2023

Current is the movement of water mass caused by wind. The speed of current in open water bodies such as reservoirs is greatly influenced by wind (Nontji, 2002). The speed of current in this reservoir ranges from 0.038 to 0.223 m/s. The high current velocity at station 4 is due to the station's location in the middle of the reservoir, where the wind is very strong. This is in line with the opinion of Faizin et al. (2018), who stated that the wind in the middle of the reservoir is quite strong because it is not obstructed by cliffs or trees around the water body, thereby increasing the current velocity in the reservoir. Water bodies with high current speeds, temperature, and DO conditions are relatively stable at night or during the day (Sriwidodo et al., 2013). The current speed at the six stations is categorized as S1 or very suitable with an average of 0.10 m/s. However, it is relatively higher than the normal current. KJA should be placed in waters with good water movement, which is around 0.016 m/s (Irwan et al., 2015 *in* Haris and Yusanti 2018). According to Kinanti et al. (2014), current velocity affects particle deposition at the bottom of the water. Strong or high current velocity, above 0.10 m/s, tends to cause larger particles to settle, while slow current velocity, below 0.10 m/s, tends to cause smaller particles to settle. This study was conducted during the dry season when the wind in the reservoir waters was quite strong, resulting in strong water currents. This meant that the fish cages in the reservoir did not require turbines or additional aeration equipment to produce oxygen. This was evident from the high oxygen or DO values at all six stations, which were categorized as S1 or very suitable. Towards the edges, the currents in the water become weaker. Fish cages located closer to the center of the reservoir receive stronger currents, therefore requiring stronger construction in this location. This is in contrast to fish cages located near the shore, where the currents are dampened by other fish cages, so the currents have a minimal impact on the fish cages. Optimal current strength can also reduce *fouling* organisms on the walls of tilapia fish cages (Affan, 2012). Water currents play an important role in carrying plankton or moving plankton so that it can spread throughout the water because plankton does not have a means of moving on its own (Harsono, 2011).

e. Bottom Substrate

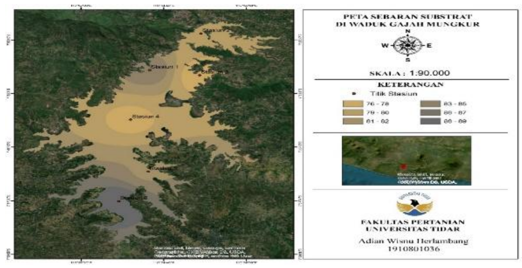

Figure 6. Distribution of the reservoir's base substrate in 2023

Substrate is an influential parameter in determining freshwater fish farming areas using floating net cage systems. Organic content and substrate composition describe the substrate type. Nutrient content in the water is good for sustainable farming (Syaputra, Mardhia and Syafikri, 2020). After laboratory testing, two types of substrate were found in this reservoir, namely sand and muddy sand. Stations 1, 5, and 6 had sandy substrates, while stations 2, 3, and 4 had muddy sand substrates. Fine substrates such as mud and sand provide food and shelter for organisms living at the bottom of the water. The substrate in a water body is directly or indirectly influenced by the speed of the current. The condition of the substrate is a factor that greatly determines the composition of benthic animals in a water body (Jati, 2005). According to Ngabito and Auliyah (2018), an unsuitable substrate will disrupt the life of aquatic organisms. Substrates that are easily lifted in water can cause low water clarity and light penetration. In KJA cultivation itself, the most suitable substrate is sandy or small rocky substrate so that it does not easily become cloudy during cultivation. All stations at the Gajah Mungkur reservoir are categorized as S1 or very suitable for cultivation. Sufficient water depth and suitable substrate types affect water quality, such as temperature and clarity, as seen at stations 1, 2, 3, and 4, where despite having sandy and muddy sand substrates, the water tends to be clear and bluish-green due to sufficient water depth. Although not directly affecting fish growth and development, the substrate does affect the taste of the fish when consumed, namely the muddy taste that appears in freshwater fish meat, which is thought to originate from water quality and the presence of sediment in the form of substrate mud found in ponds and plankton dissolved in water and eaten by fish during their lifetime (Wibowo et al., 2021).

f. pH (*Power of hydrogen*)

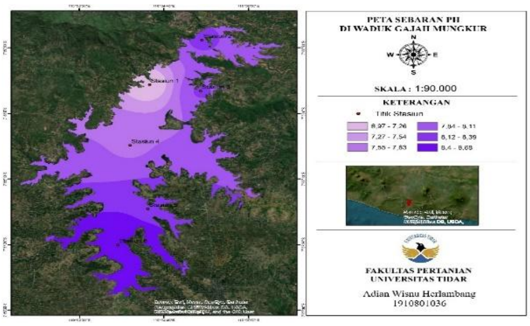

Figure 7. pH distribution of reservoirs in 2023

Acidity or pH is one of the criteria for determining the quality of water. The pH parameter has a major influence on aquatic biota. The results of the study show that the pH ranges from 6.97 to 8.68 ppm. Cholik *et al* (1988) stated that the level of pH in water is influenced by the level of free CO2 and acidic compounds from the decomposition and weathering of dead organisms. The pH at stations 5 and 6 tended to be higher due to contamination from motor vehicle fuel, as evidenced by the discovery of many used bottles with the smell of gasoline and diesel fuel. According to Safitri (2013), waste from households and fossil fuels into a water body can affect the pH value. The pH of a water body is also influenced by the level of CO2 dissolved in the water. Photosynthesis is a process that greatly determines the level of CO2 in a water body. pH and CO2 have an inverse relationship, which is consistent with the fact that the low pH at stations 1 and 4 has a higher CO2 level than other stations. When photosynthesis occurs during the day, CO2 is used extensively in the process. A decrease in CO2 concentration will decrease the concentration of H+, thereby increasing the pH of the water (Nedi., 2001). According to Ade (2018), every organism has a minimum and maximum pH tolerance limit to support its growth. If the pH is too acidic or alkaline, the dissolved oxygen content in the water will decrease, causing a decrease in oxygen supply, which results in organisms having disturbances in their respiratory activities and loss of appetite (Setiawan, 2022). The average pH in the Gajah Mungkur reservoir is 7.75 ppm, which is categorized as S2 or adequate. This is in accordance with KepMen KP No.45 of 2006, which states that the pH value that tilapia can tolerate for optimal life is 5-8.5 ppm (Andriani et al., 2018). According to Suyanto (2003) *in* Dahril et al. (2017), suboptimal pH can cause fish stress, susceptibility to disease, and low productivity and growth. Fish can live at a minimum pH of 4, and pH above 11 will cause death. Water with pH levels that are too high or too low can cause a decrease in appetite and the appearance of mucus in fish (Nurhidayat, 2020). The appearance of slime on fish is an attempt to defend themselves against toxic substances entering their bodies, but excessive slime production actually inhibits gas exchange through the gills. In addition to slime, the fish's body becomes pale, the gill filaments stick together, and bleeding can occur (Suparjo, 2010).

g. *Dissolved* Oxygen (DO)

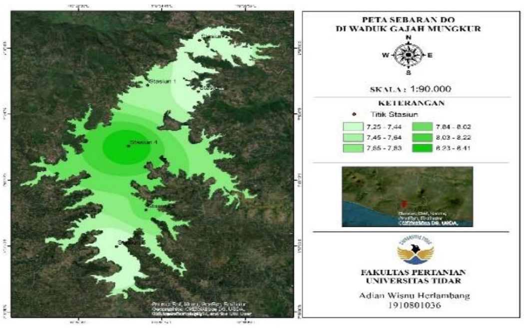

Figure 8. Distribution of DO in reservoirs in 2023

DO (*Dissolved Oxygen*) or dissolved oxygen is the concentration of oxygen in dissolved form in water, which is formed from photosynthesis or water movement and by direct diffusion from the air (Lestari et al., 2020). Oxygen plays a very important role as an indicator of water quality because the reduction and oxidation of organic and inorganic materials require dissolved oxygen. DO is an indicator for measuring oxygen levels in a water body. The DO value of the Gajah Mungkur reservoir ranges from 7.2 to 8.41 mg/l. The DO at station 4 is quite high compared to other stations because the waves and high current velocity at this station create very high water movement activity. This is in line with the opinion of Saputri et al. (2014), namely that DO in water is influenced by several factors such as water turbidity, temperature, salinity, and the movement of water and air masses such as currents, waves, and tides. The relationship between temperature and oxygen is that the higher the temperature, the lower the oxygen content in the water. The average DO value in the Gajah Mungkur reservoir is 7.62, and all stations fall into category S1 or very suitable because they have levels above 5 mg/l and are in accordance with SNI 6495: 2011, which states that good DO for tilapia growth is above 3 mg/l. Meanwhile, according to Indonesian National Standard 7550: 2009 *in* Siegers et al. (2019), dissolved oxygen for optimal tilapia growth is 7 mg/l. In addition to currents, good oxygen levels are caused by phytoplankton, microalgae, and other aquatic plants in the cultivation ponds that perform photosynthesis, thereby producing oxygen ($_2$) ,resulting in increased oxygen levels in the water. The water in the Gajah Mungkur Reservoir has a very suitable oxygen level for KJA cultivation. With a good oxygen level, no additional equipment is needed to increase the oxygen level during cultivation. The availability of sufficient oxygen in the water provides maximum opportunity for fish to utilize oxygen in the respiration process, which functions to burn food to produce energy for swimming, growth, and reproduction of dissolved carbon dioxide. Prakoso and Chang (2018) state that low dissolved oxygen levels, or levels below the minimum threshold, can inhibit fish growth, food consumption, and physiological condition.

h. CO_2

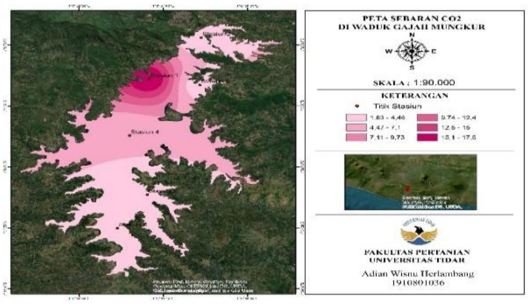

Figure 9. CO_2distribution reservoir 2023

The availability of dissolved carbon dioxide in water is influenced by several factors, including groundwater, decomposition of organic matter, respiration of aquatic organisms, chemical compounds in water, and from the air. Phytoplankton uses CO_2 for photosynthesis and produces oxygen (Effendi., 2003). The CO_2 value in the Gajah Mungkur reservoir ranges from 1.83 to 17.63 mg/l. There is a significant difference at station 1, which has the highest CO_2 level at 17.63 mg/l. This is due to the decomposition of organic matter from aquaculture feed residues and the respiration of organisms, as this station is located at the center of tilapia aquaculture. Tilapia in aquaculture ponds undergo respiration, which increases their carbon dioxide levels. High CO_2 concentrations affect fish kidney function (Pramleonita et al., 2018). Despite the very high CO_2 levels, Station 1 is still able to conduct KJA aquaculture because it is supported by adequate oxygen levels. Fish can tolerate high CO_2 levels above 10 mg/l if the oxygen content in the water is high (Haris and Yusanti, 2019). The average CO_2 level in the reservoir obtained is still suitable for fish farming, with an average of 5.51 mg/l. This falls into the S2 category, which is considered adequate. A carbon dioxide level of 5 mg/l in water is still tolerable for aquatic animals, with a good concentration for aquatic biota growth being between 5-7 mg/l (Kordi and Tancung, 2007). CO_2 levels can affect pH values, with station 1 having the lowest pH due to very high CO_2 levels. In general, CO_2 levels are influenced by sunlight intensity, temperature, and pH, and are inversely proportional to oxygen. However, there are other factors that influence carbon dioxide levels, such as plant photosynthesis, aquatic organism respiration, water aeration, and other complex gases or oxidation. According to Arifin (2017), the CO_2 level in water for tilapia farming should be less than 15 mg/liter. High levels of carbon dioxide in water will suppress fish respiration and inhibit oxygen binding by hemoglobin, which can cause stress in fish.

a. i. Nitrate

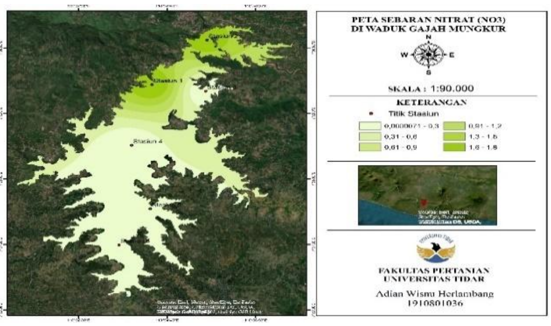

Figure 10. Distribution of nitrate in reservoirs in 2023

Nitrate is a macronutrient that controls primary productivity in euphotic zones. Nitrate levels in this reservoir range from 0 to 1.81 mg/l. At stations 1 and 2, nitrate levels are higher than at other stations due to the accumulation of aquaculture waste in the form of sediment. In sediments, nitrate is produced from the biodegradation of organic materials into ammonia, which is then oxidized into nitrate. Nitrate can naturally originate from waste such as agricultural waste or feed residues, which can be decomposed into nutrients by bacteria (Putri et al., 2019). Nitrate levels can also be influenced by depth; nitrate levels increase with depth (Fonny and Hanif 2011), which is the case at station 1. High nitrate levels increase phytoplankton, which is useful for feeding the surrounding biota, and also increase oxygen levels due to photosynthesis by the plankton (Risamasu and Prayitno, 2011). Very high nitrate levels can cause water eutrophication and subsequently lead to blooming, which is a triggering factor for the rapid growth of aquatic plants such as water hyacinth. Excessive nitrate levels will cause phytoplankton blooming (Sarif et al., 2019). No aquatic plants such as water hyacinth were found in the Gajah Mungkur Reservoir, and the water tended to be clear. The average nitrate level in this reservoir is 0.59 mg/l, which falls into category S1 or very suitable, and it can be concluded that it is suitable for marine biota, because the nitrate level does not exceed 0.9-3.2 mg/l (Yolanda, 2016). When compared to the water quality standard of PP. No. 82 of 2001, which is class II for freshwater fish farming activities, it is still far from the specified limit of 10 mg/l (Astuti and Supono, 2016). Excessive amounts of nitrate can cause poisoning in fish (Purnamaningtyas, 2014).

j. Ammonia

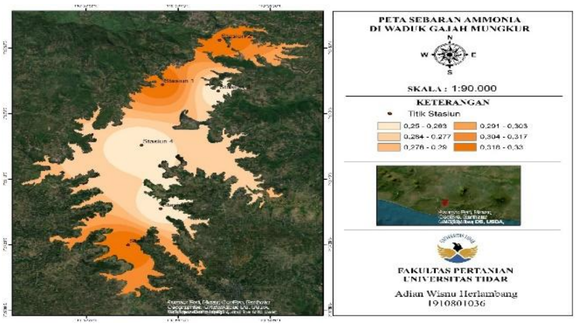

Figure 11. Distribution of ammonia in reservoirs in 2023

Ammonia in water comes from urine and feces or waste, microbiological oxidation of organic substances, and industrial wastewater and community activities (Putri et al., 2019). The ammonia level in this reservoir ranges from 0.25 to 0.33 mg/l. High feeding intensity has an impact on increasing ammonia levels in water, as occurred at stations 1 and 2. The metabolic waste produced by fish in the form of feces or excrement, which then settles at the bottom of the water, will increase ammonia levels (Saputra et al., 2017). In addition, high ammonia levels in water can be caused by extreme waste disposal into rivers, such as industrial waste (Harmilia et al., 2022). This is what happened at station 6, which is a fishing boat dock and rice field area. Furthermore, the high ammonia levels at the outlet location or station 2 are caused by the accumulation of waste from the KJA location in the grow-out ponds and seedling ponds located south of the reservoir outlet gate. Low levels of ammonia do not have a negative impact on fish, but if the levels increase and become too high, it can kill fish and even damage the aquatic ecosystem (Levit, 2010). The average ammonia level in this reservoir is 0.304 mg/l, which falls into category S2 or is fairly acceptable. Effendi *in* Harmilia (2022) states that good freshwater has an ammonia level of no more than 0.02 mg/l. This limit is in line with SNI 7550:2009, which states that the maximum ammonia level for fish farming must be below 0.02 mg/l. According to Sucipto and Prihatono (2007), ammonia is toxic to fish, therefore the recommended ammonia content for tilapia farming should not exceed 0.016 mg/l.

k. Phosphate

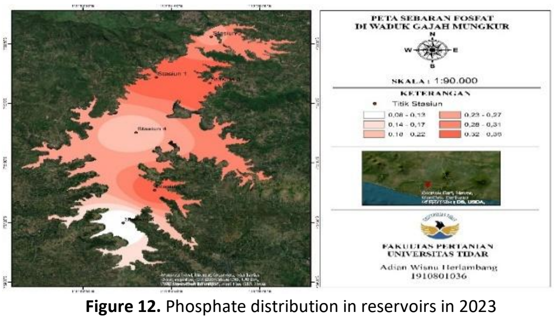

Figure 12. Phosphate distribution in reservoirs in 2023

Phosphate can be used as an indicator to determine the fertility of reservoir water and is useful for phytoplankton (Patty, 2014). The phosphate content of this reservoir ranges from 0.08 to 0.36 mg/l. At the Gajah Mungkur reservoir, the phosphate content at all stations falls into category S1, or very suitable. According to Boyd *in* Effendi (2003), phosphate in natural waters rarely exceeds a level of 1 mg/l. This is consistent with this study because at all 6 stations, there were no phosphate levels exceeding 1 mg/l. However, there were three stations that tended to have higher phosphate levels than other stations, namely stations 1, 3, and 5, which could be caused by the water content in the area being influenced by several factors. Station 1 is the center of tilapia fish farming and also a tourist attraction at the Gajah Mungkur reservoir, so it is likely to be contaminated by oil spills from ships and household waste generated from the wooden houses of fish farmers. Meanwhile, at stations 3 and 5, high phosphate levels may be caused by pesticide waste from plantations and agricultural waste. This is in line with the opinion of Tanjung et al. (2016) that phosphate content in water can originate from natural processes, detergent waste, pesticides, lubricating oil, and agricultural waste. High phosphate levels can also be caused by the accumulation of discarded feed, feces, and dead fish from fish farming activities. According to Effendi (2003), phosphate is not toxic to humans, animals, or fish. The presence of phosphate in natural waters such as reservoirs is very important, especially in the formation of proteins and metabolism for organisms. However, high phosphate levels can cause eutrophication in the form of algae blooms, which have a negative impact on aquaculture. The average phosphate value in the Gajah Mungkur reservoir is 0.265 mg/l, which falls into category S1 or very suitable. According to Astuti and Supono (2016), a phosphate level of 0.05 mg/l in water is classified as very nutrient-rich. The phosphate content for natural water bodies is less than 1 mg/l, so the phosphate quality of this reservoir still falls into the natural water category (Boyd, 1988).

d. Water suitability

Classification of water suitability of the Gajah Mungkur reservoir for tilapia farming based on the scoring of 11 physical-chemical water quality parameters as follows.

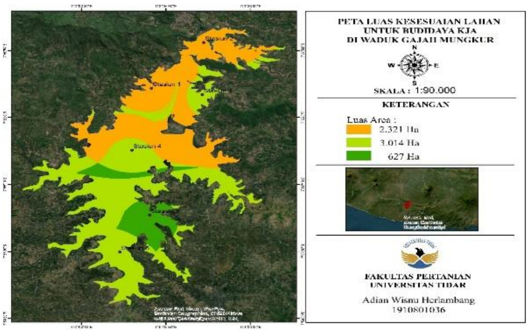

Figure 13. Water suitability of the reservoir in 2023

The values obtained for each station based on scoring according to DKP guidelines (2020) with a maximum value of 48 and percentage using the water suitability formula according to Haris and Yusanti (2019), the results obtained from this study are that station 1 has a value of 34 or 70.83%, station 2 has a value of 33 or 68.75%, station 3 has a value of 37 or 77.08%, station 4 has a value of 40 or 83.33%, station 5 has a value of 43 or 89.58%, and station 6 has a value of 39 or 81.25%. The suitability of the Gajah Mungkur Reservoir water at 6 station points refers to the provisions of Nurchayati, (2021). In this study, the reservoir was divided into three classifications and distinguished by color in the image. Station 1 and 2 were classified as S3 or marginally suitable and depicted in orange, stations 3, 4, and 6 were classified as S2 or moderately suitable and depicted in light green, and station 5 was classified as S1 or highly suitable and depicted in dark green. The water area based on its suitability level can be calculated using points obtained from the ArcGIS application and then converted into specific units. In this study, the values obtained were converted into hectares (Ha).

The Gajah Mungkur Reservoir has an area suitability based on calculations using the ArcGIS application, namely category S1/highly suitable covering 627 hectares, category S2/moderately suitable covering 3,014 hectares, and category S3/marginally suitable covering 2,321 hectares. Overall, the waters of the Gajah Mungkur Reservoir have an average value of 78.47%, which means they are class 2 or *moderately suitable* for tilapia farming. The limiting factor in this reservoir is the depth of the reservoir at stations 5 and 6, which, despite having good suitability and water quality, does not have sufficient depth, causing the water to turn into a vast grassland during the dry season, making it impossible to cultivate KJA. Another limiting factor is the zoning regulations at the Gajah Mungkur Reservoir, which prohibit aquaculture in certain areas even though the conditions and water quality are suitable ( ). Gajah Mungkur Reservoir is divided into three zones: fishing zone, cultivation zone, and danger zone (Ferdinan et al., 2016). Currently, only station 1 is used for KJA cultivation because it is located in the cultivation zone.

4. Conclusion

Based on the results of research conducted at the Gajah Mungkur Reservoir, the following conclusions can be drawn:

1. The water quality ( ) of Gajah Mungkur Reservoir for KJA aquaculture during the dry season shows good conditions and is suitable for tilapia aquaculture using the KJA system ( ).

2. Gajah Mungkur Reservoir is divided into three suitability classes: stations 1 and 2 are classified as S3 (marginally suitable), stations 3, 4, and 6 are classified as S2 (sufficiently suitable), and station 5 is classified as S1 (highly suitable).

3. 's assessment of the water quality of the Gajah Mungkur Wonogiri Reservoir during the dry season (August-September) received an overall score of 78.46%, which falls into Class 2 or Moderately Suitable, with a score range of 75-84%.

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