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Plankton Community Structure in Gajah Mungkur Reservoir Wonogiri, Central Java, Indonesia

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A B S T R A C T

This study aimed to determine the structure of the phytoplankton and zooplankton communities in the Gajah Mungkur Reservoir, Wonogiri, based on diversity, evennes , and dominance parameters. The sampling method was carried out at three different stations: floating net cages, tourist zones, and sanctuary zones. Plankton identification was carried out at the Universitas Diponegoro Fish Resources and Environmental Management Laboratory using a Sedgwick rafter and microscope, whereas community structure analysis was performed using the diversity index (H'), evennes index (E), and dominance index (D). The results showed that plankton diversity at all stations was categorized as medium, with a relatively stable community (H' 1 < H' < 3). The evennes index at all stations was low (E < 0.5), whereas the dominance index was moderate (D 0.5 < D < 0.75). Differences in plankton community structure were influenced by light intensity, nutrient availability, and anthropogenic activities around the sampling sites. These results indicate that the ecosystem quality of the Gajah Mungkur Reservoir is quite good but shows pressure in certain zones.

Keywords: plankton, community structure, Gajah Mungkur Reservoir.

1. Introduction

Planktons are microscopic organisms that live in the water and play an important role in aquatic ecosystems, both as primary producers, indicators of water quality, and part of the food chain (Parakkandi et al., 2021) (Diniariwisan and Rahmadani, 2023). Planktons consist of two main groups: phytoplankton and zooplankton (Inayah et al., 2023). Phytoplankton play an important role in photosynthesis and oxygen provision (Wong et al., 2023), while zooplankton function as primary consumers that connect producers with higher trophic levels (Effendi, 2003).

Plankton community structure can describe the ecological conditions of a water body (Florescu et al., 2022). Indicators such as diversity, evenness, and dominance are used to determine community stability, as well as the level of ecological pressure in a habitat (Odum, 1993). Factors such as depth, light intensity, temperature, and nutrient availability strongly influence plankton distribution and abundance (Sulastri et al. 2018). The Gajah Mungkur Reservoir, one of the largest reservoirs in Central Java, has strategic functions as a source of irrigation, power generation, aquaculture, and recreation (Nissa and Suadi, 2022). High human activity around the reservoir can affect the water quality and plankton community structure (Zhu et al., 2024). Therefore, it is necessary to study the structure of plankton communities to understand the ecological conditions of reservoir waters as a whole (Pratama et al. 2020).

2. Material and Method

2.1 Study Area

This research was conducted in the Gajah Mungkur Reservoir, located in Wonogiri Regency, Central Java Province, Indonesia. This reservoir is an artificial reservoir built on the Bengawan Solo River, with an inundation area of approximately 8,800 ha. The research was conducted at three stations representing different activity zones and depths, namely station1 (Floating Net Cages), a fish-farming zone with high human activity. Station 2 (Tourism Zone) was a public area with fishing and recreational activities. Station 3 (Sanctuary Zone) is a conservation area with minimal anthropogenic disturbance. Purposive sampling was conducted, representing each zone. Sampling positions were determined using GPS and location accessibility.

2.2 Sample Collection

Plankton samples were taken in 3 repetitions at different depths. Samples were taken at depths of 0.25, 0.5, and 0.8 meters depth from the surface of the reservoir waters at each station. Sampling using a 100 ml sample bottle. Water samples were collected during the day when phytoplankton activity peaked because the maximum photosynthesis process occurred due to high light intensity. Sampling was performed using a water sampler from the surface to a predetermined depth. Next, the water was filtered using a 25 µm diameter plankton net to capture plankton, given 4-10 drops of lugol, and stored in a coolbox. The temperature and pH were measured in situ using a mercury thermometer and pH meter, respectively. DO was measured using the titration method (Ali, 2017).

2.3 Analysis Procedures

The plankton community structure was analyzed based on phytoplankton and zooplankton identification data obtained from the three observation stations. The analysis included the diversity index (H'), evenness index (E), and dominance index (D). All calculations were performed using Microsoft Excel 2010. The following is the calculation index used to determine the structure of the plankton community in the Gajah Mungkur Reservoir (Magguran, 2004):

Diversity index $H' = -\sum (Pi \cdot \ln Pi)$ (1)

Evenness index $E = \ln SH'$ (2)

Dominance index $(D) = \sum (Nni)^2$ (3)

2.4 Data Analysis

Plankton identification data were analyzed quantitatively to determine community structure based on diversity, evenness, and dominance at three observation stations representing different characteristics of the Gajah Mungkur Reservoir. Each index was calculated to evaluate the ecological conditions of the water and compare the stations. This method provides a quantitative description of the water conditions at each station.

Table 1-Plankton Community Ecological Index Assessment Criteria

Index	Score	Ecological Interpretation
Diversity index H'	H' < 1	Low diversity; unstable community
	1 ≤ H' ≤ 3	Medium-high diversity; relatively stable community
	H' > 3	Very high diversity; very stable community (sparse)
Evenness index (E)	E < 0,5	Uneven distribution of individuals
	E ≥ 0,5	Individual distribution is even
Dominance index (D)	D < 0,5	There is no dominant species
	0,5 ≤ D ≤ 0,75	Dominant species at moderate levels
	D > 0,75	One or more species are dominant

Source: Magurran (2004).

3. Result and Discussion

3.1 Result

Physical Parameters

The results of research conducted at three stations in the Gajah Mungkur Reservoir with three repetitions showed varying variable concentrations. Sunlight is one of the most important environmental variables for supporting plankton life, especially phytoplankton, which require light for photosynthesis. The availability of light in the water column is influenced by brightness, which is directly related to the level of light penetration. In this study, the brightness value indicated good conditions for light penetration and supported photosynthetic activity. In addition to light, temperature also plays an important role in regulating plankton metabolic rate, growth, and reproduction. The optimal temperature for plankton growth generally ranges from to 25-30°C, depending on the type of species and local environmental conditions. Temperatures that are too low or too high can inhibit physiological processes and reduce plankton abundance (Padisak 2016).

Chemical Parameters

pH and dissolved oxygen (DO) are two water quality parameters that have important effects on plankton growth and survival. The pH affects nutrient availability, enzymatic stability, and the ability of plankton to efficiently absorb nutrients. DO is directly related to zooplankton respiration and metabolic activities of other aquatic organisms (Reynolds et al. 2019). The measurement results in this study showed that the pH value ranged from 7.0 to 7.8, which is included in the neutral to slightly alkaline categories, in accordance with the optimal range for phytoplankton productivity. In addition, DO levels were in the range of 5.7-6.4 mg/L, which still meets the minimum requirements to support plankton life and prevent hypoxic conditions (Zhou et al. 2016). These values indicate that the waters of the Gajah Mungkur Reservoir have a fairly favorable quality for the plankton community, both physiologically and ecosystemically.

Plankton Community Structure

Based on the results of plankton identification conducted at 3 observation stations in Gajah Mungkur Reservoir, phytoplankton that were successfully found included *Pediastrum biwae, Closterium cornu, Closterium juncidum, Closterium grazile, Nitzschia sigma, Synedra ulna, Straurastrum gracile*, *Trachelomonas* sp., *Chroococcus* sp., *Cocconeis* sp., *Mougeotia* sp., and *Navicula padiostra*. Phytoplankton dominated the number of individuals found at all stations, with Closterium juncidum being the most abundant. Meanwhile, zooplankton that were successfully identified included *Trichocerca birotris, Cyclops sp*., and *Mesocyclops leuckarti*. The distribution of zooplankton tended to follow the abundance of phytoplankton as the main food source, with higher concentrations at stations with high primary productivity.

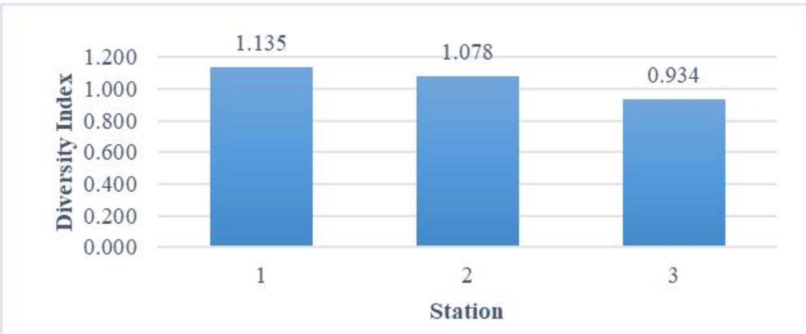

Fig. 1- Plankton Diversity Index in Gajah Mungkur Reservoir

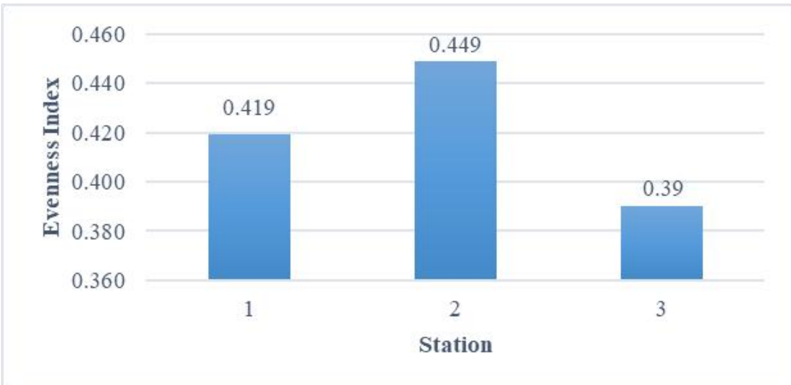

Fig. 2-Plankton Evenness index in Gajah Mungkur Reservoir

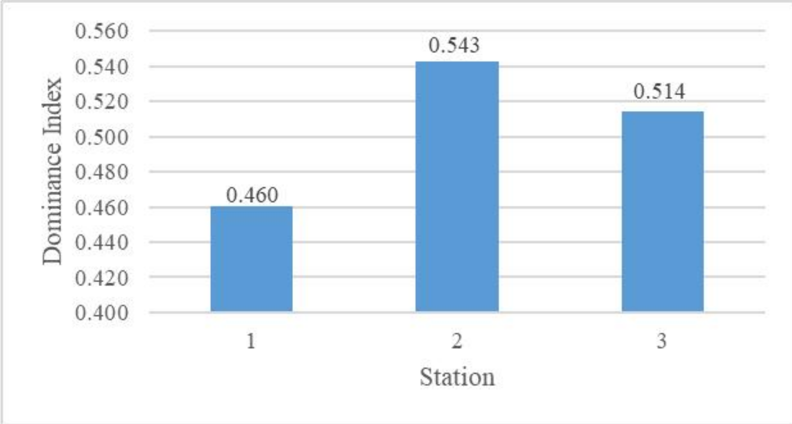

Fig. 3-Plankton Dominance index in Gajah Mungkur Reservoir

The structure of the plankton community in the Gajah Mungkur Reservoir was analyzed based on three main parameters: diversity index (H'), Evennes index (E), and dominance index (D), each of which reflects the stability of the aquatic ecosystem and species distribution. The results showed that the floating net cage (Station 1) had the highest diversity index (H' = 1.135), followed by the tourist zone (Station 2, H' = 1.078), and the lowest diversity index (Station 3, H' = 0.934). These values indicate that the waters in the floating net cages and tourist zone have a moderate to high level of diversity, whereas the sanctuary zone tends to be lower, which can be caused by nutrient limitation. The evennes index at the three stations ranged from 0.390 to 0.449, indicating that the distribution of individuals between species was uneven and that the plankton community tended to be dominated by certain species. Meanwhile, the highest dominance index was found in the tourist zone (D = 0.543), followed by the sanctuary zone (D = 0.514), and the lowest in the Floating Net Cages (D = 0.460). The moderate dominance values at the three stations indicated that no species truly dominated, although some genera such as Closterium juncidum tended to be dominant.

The distribution and structure of plankton communities are strongly influenced by the physicochemical conditions of water, such as light intensity, depth, temperature, nutrient availability, and level of anthropogenic activity (Ferreira et al. 2017). High diversity values in floating net cages and tourist zones are likely related to the increased nutrient supply from fish farming activities and land runoff, which can enrich water and support phytoplankton primary productivity (Guiry and Guiry, 2018). In contrast, the low diversity values in the sanctuary zone are presumably due to limited nutrient inputs and minimal human disturbance, which lead to simpler community structures. These results suggest that plankton communities respond differently to variations in environmental stress in different water zones.

Abundance (ind/L)=VN

Description:

NNN = total number of plankton individuals (total/phytoplankton/zooplankton)

VVV = volume of filtered water in liters (30 liters: 3 replicates × 10 L)

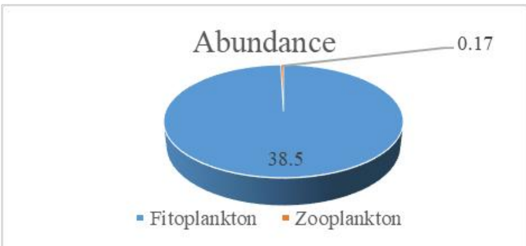

Fig. 4-Percentage of Phytoplankton and Zooplankton Abundance in Gajah Mungkur Reservoir Station 1

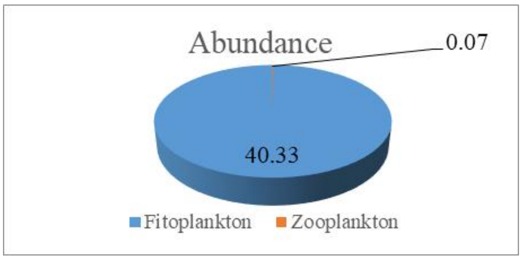

Fig. 5-Percentage of Phytoplankton and Zooplankton Abundance in Gajah Mungkur Reservoir Station 2

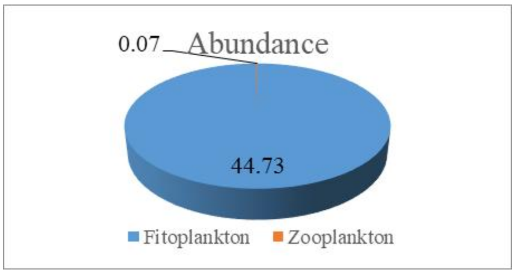

Fig. 6-Percentage of Phytoplankton and Zooplankton Abundance in Gajah Mungkur Reservoir Station

A high total abundance occurred at Station 3 (sanctuary zone), and zooplankton were found in very low numbers at all stations. Phytoplankton dominance was evident at all stations, which was consistent with sampling during the day when photosynthetic activity was high. Siregar et al. (2014), mentioned that phytoplankton activity is strongly influenced by light intensity, where during the day phytoplankton tend to move to the surface layer of water to carry out photosynthesis actively.

Water Condition

Water conditions in the Gajah Mungkur Reservoir during the observation showed water characteristics that were classified as mesotrophic to eutrophic in terms of the combination of physicochemical parameters observed. (Padisak et al. 2016). Based on the trophic status classification of lentic waters, these brightness and DO values indicate that the Gajah Mungkur Reservoir is in the mesotrophic to eutrophic category, characterized by moderate to high productivity and possible nutrient supply from anthropogenic activities, such as fish farming and land runoff. These conditions generally support the diversity of plankton communities but also have the potential to increase the risk of eutrophication if pollutant loads are not controlled (Nurnadia et al. 2022).

3.2 Discussion

The results showed that the structure of the plankton community in the Gajah Mungkur Reservoir was different in each observation zone, which was influenced by variations in environmental conditions and human activities around the waters. The Floating Net Cage Zone (Station 1) had the highest diversity value (H' = 1.135), which reflects a relatively stable community with a high level of primary productivity. This can be attributed to the high supply of nutrients derived from fish farming activities, such as feed residues and excretions, which enrich the water and support phytoplankton growth. In contrast, the sanctuary zone (Station 3) showed the lowest diversity value (H' = 0.934), which could be attributed to the low nutrient availability and lack of anthropogenic disturbance. Although the water quality was relatively good, low primary productivity may have limited the number and variety of plankton living in this zone. Low evennes index (E) values at all stations (<0.5) indicated that there were species that dominated the community, with an uneven distribution of individuals between species. This is reinforced by the higher dominance index (D) values in the tourist and sanctuary zones compared to the KJA zone, indicating moderate dominance by some species, such as Closterium juncidum. Closterium juncidum is commonly found in calm freshwater, such as reservoirs, is tolerant of nutrient-rich waters (eutrophic), and is often found in waters containing high organic matter (Wehr et al. 2015), supported by Kadim and Arsad (2016), which states that the Closterium genus has high adaptability to productive and eutrophic water conditions.

These differences in community structures indicate that plankton respond sensitively to environmental changes. Physical and chemical parameters, such as temperature, pH, brightness, and dissolved oxygen, have a direct influence on the abundance and composition of plankton communities. Based on the classification of trophic status according to Carlson (1977), the combination of DO, brightness, and productivity values shows that the Gajah Mungkur Reservoir is in the mesotrophic to eutrophic category, which means that the water has a moderate to high level of fertility and is still able to support a diverse plankton community, although it still has the potential for eutrophication if the nutrient loads increase.

These results confirm that regular monitoring of plankton community structure can be used as an ecological indicator for assessing the quality and stability of aquatic ecosystems, as well as for assisting in the sustainable management of reservoir resources. Apart from being an ecological indicator, the presence of plankton can also reflect trophic status and potential eutrophication disturbances in a water body. Abundant phytoplankton, such as *Oscillatoria* sp. and *Microcystis aeruginosa*, found in this study are a group of Cyanophyceae known as early indicators of eutrophication and algal blooms. The dominance of these species in some zones indicates an excessive supply of nutrients, particularly phosphate and nitrogen, often from fish farming activities and land runoff (Guiry and Guiry, 2018). The presence of zooplankton, such as *Brachionus* sp. and *Daphnia* sp., is also an important indicator of the balance of the aquatic food chain.

Zooplankton serves as a controller of phytoplankton populations and a source of food for fish, so fluctuations in the zooplankton community can affect the stability of the ecosystem as a whole. The high abundance of zooplankton in the KJA and tourist zones indicates that the trophic chain in these waters is still functional, although it has begun to show signs of an imbalance in species composition. On the other hand, water quality parameters such as stable water temperature in the range of 29.5-31°C, neutral to alkaline pH (7.0-7.8), and fairly high DO (5.7-6.4 mg/L) indicate that the physico-chemical waters still support plankton life. However, brightness values ranging from only 1-2.3 meters indicate that light transparency is limited, which can inhibit photosynthesis at certain depths, as well as being an indication of organic particle suspension and phytoplankton blooms. Thus, the structure of the plankton community in the Gajah Mungkur Reservoir is not only influenced by the physicochemical conditions of the water but also by human activities occurring around the utilization zone. This combination of ecological data and trophic status data provides a strong scientific basis for adaptive water management. Efforts to control nutrient inputs and periodically evaluate plankton communities are needed to prevent water quality degradation and promote the sustainability of reservoir ecosystem functions.

4. Conclusion

The results of this study show that the structure of the plankton community in the Gajah Mungkur Reservoir varies between utilization zones and is influenced by differences in environmental conditions and anthropogenic activities. The floating net cage zone had the highest diversity value (H'), followed by the tourist and sanctuary zones. The low value of the evennes index (E) at all stations indicates an uneven distribution of species, whereas the moderate dominance index (D) indicates that no species dominates absolutely. The plankton composition consisted of phytoplankton of the Chlorophyceae, Cyanophyceae, and Bacillariophyceae classes, as well as zooplankton of the Rotifera, Copepoda, and Cladocera classes. Species, such as *Closterium juncidum* and *Oscillatoria* sp., are important indicators of aquatic trophic conditions. Based on water quality parameters and plankton communities, the Gajah Mungkur Reservoir is classified as being in mesotrophic to eutrophic conditions, which still supports plankton growth and diversity, but has the potential risk of eutrophication if not managed properly. Therefore, ecosystem-based water management and regular monitoring of the plankton community are very important to maintain ecological balance and the sustainability of the reservoir's function as an aquatic resource.

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