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PHYTOPLANKTON DIVERSITY AS BIOINDICATOR OF POLLUTION IN JENES RIVER, SURAKARTA

KEANEKARAGAMAN FITOPLANKTON SEBAGAI BIOINDIKATOR PENCEMARAN DI SUNGAI JENES SURAKARTA

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Abstract

This research aims to identify the types of phytoplankton, identify the abundance of phytoplankton, and study the relationship between environmental factors and the abundance of phytoplankton. This research was carried out on January 10, 2023, at the Jenes River, Surakarta. Sampling was carried out at 3 observation stations to identify environmental factors (pH, DO, CO2, salinity, BOD, light intensity, temperature, and brightness). Observations were carried out at three stations, namely upstream, middle and downstream, namely, in the morning (06.00–07.00 WIB) and during the day (12.00–14.00 WIB). Measurements of environmental factors were carried out at the integrated laboratory at Sebelas Maret University, Surakarta. The results of the research showed that the phytoplankton found were 9 families consisting of 11 species with an average abundance of 6,834 individuals/L in the morning day and an average abundance of 13,088 individuals/L during the day. The most abundant phytoplankton in the morning observations was *Ulothrix* sp. Meanwhile, the most abundant phytoplankton in the afternoon observations was *Chroococcus* sp. This abundance is also influenced by environmental factors such as pH, DO, Salinity, BOD, CO_2, and temperature. The research found that the middle station had the highest phytoplankton diversity index during the day (1.6), possibly because it was indicated to be lightly polluted, allowing the life of many phytoplankton such as *Closterium* sp. and *Quadrigula* sp. The highest abundance of phytoplankton in the morning is *Ulothrix* sp., in the afternoon, it is *Chroococcus* sp.

Keywords: Abundance; Environment; Phytoplankton; River; Station

Abstrak

Penelitian ini bertujuan untuk mengidentifikasikan jenis fitoplankton, kelimpahan fitoplankton, dan analisis hubungan faktor lingkungan dengan kelimpahan fitoplankton di Sungai Jenes Surakarta. Penelitian ini dilaksanakan pada 10 Januari 2023 di Sungai Jenes, Surakarta. Pengambilan sampel dilakukan di 3 stasiun pengamatan untuk mengukur faktor lingkungan (pH, DO, CO_2, salinitas, BOD, intensitas cahaya, suhu, dan kecerahan). Pengamatan dilakukan di tiga stasiun yaitu hulu, tengah dan hilir sebanyak 2 yaitu, pagi hari (06.00–07.00 WIB) dan siang hari (12.00–14.00 WIB). Pengujian faktor lingkungan dilakukan di laboratorium terpadu Universitas Sebelas Maret, Surakarta. Hasil penelitian menunjukkan bahwa fitoplankton ditemukan berjumlah 9 famili terdiri dari 11 spesies dengan rata-rata kelimpahan 6.834 individu/L pagi hari dan rata rata kelimpahan 13.088 individu/L pada siang hari. Fitoplankton yang paling melimpah pada pengamatan pagi hari adalah Ulothrix sp., *sedangkan siang hari adalah Chroococcus* sp. *Kelimpahan ini juga dipengaruhi oleh faktor lingkungan seperti pH, DO, Salinitas, BOD, CO_2, dan suhu. Penelitian menemukan bahwa stasiun tengah memiliki indeks keanekaragaman fitoplankton tertinggi pada siang hari (1,6), kemungkinan karena terindikasi tercemar ringan, memungkinkan hidupnya banyak fitoplankton seperti Closterium* sp. *dan Quadrigula* sp. *Kelimpahan fitoplankton tertinggi pada pagi hari adalah Ulothrix* sp., *sementara pada sore hari adalah Chroococcus* sp.

***Kata Kunci**: Bakteri; Bio-enzim; Limbah Jeruk; Metagenom; NGS*

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INTRODUCTION

Water is one of the natural resources that has an important role in meeting the basic needs of life. The life of living things will be closely intertwined with the availability and good quality of water. Humans, animals, and plants need water to survive (Amin & Purnomo, 2021).Water can be used as a habitat for aquatic animals. Plants need water for the photosynthesis process. Based on the World Health Organization (WHO) measurement, the water needed by each individual in developed countries ranges from 60 to 120 L per day (Sujatini et al., 2020). Meanwhile, in developing countries, approximately 30 to 60 L of water per day are needed for each person (Sary et al., 2005). Recently, the water situation has become increasingly concerning as there has been an increase in water pollution, threatening the availability of clean water. According to data from the Central Statistics Agency (BPS) in 2021, there were 10,683 villages that suffered from water pollution. This development is due to the continuous increase in human activities, trig in 2021, igered by the growing population. According to data from the Central Statistics Agency (BPS) in 2021, the population in Indonesia will reach 278.69 million by mid-2023. Meanwhile, according to BPS, the population of Solo City reached 222,364 in 2020 and 522,728 in 2021. This can increase environmental pollution because of the growing number of human needs so more and more industries arise. This can reduce environmental pollution as increasing human needs encourage the emergence of more industries (Salim, 2019).

The increasing number of industries has caused various positive and negative impacts. Conversely, the negative impacts arising from industrial development can adversely affect society and nature. This is because all industrial processes produce waste. Industrial activities can have a negative impact because they produce waste that pollutes the environment, damages biological resources, and affects the health of local communities (Utari et al., 2022). If they are not treated efficiently, these wastes can contaminate the environment and potentially threaten human health (Tanhua et al., 2019). There are still many irresponsible industries that discharge waste into rivers, resulting in water pollution problems that can degrade water quality. Based on data from the Central Statistics Agency (BPS) in 2021, there are 10,683 villages or sub-districts that suffer from water pollution. The most frequent water pollution is in Central Java, with 1,130 villages affected by water pollution. Cases of water pollution caused by industrial waste totalled 4,496 villages/urban villages. Pollution is a change in water conditions caused by various types of waste derived from human activities, including industrial waste and household waste (Kamalia & Sudarti, 2022).

Surakarta is one of the cities that has rapid industrial development, due to the large number of industrial areas. This is supported by the strategic location of Surakarta, which supports many foreign entrepreneurs who set up factories in this city. Rivers in Indonesia, including rivers in inland areas, have been polluted with waste from industrial activities. Industrial activity in Indonesia is a significant problem with air pollution, resulting in an increasing reduction in clean water (Suriadikusumah et al., 2021). One of the polluted rivers in Surakarta is the Jenes River. The Jenes River, located in the Laweyan area of Surakarta, is known as one of the waterways used extensively by the surrounding communities and industries. One of the well-known industrial sectors around the Jenes River is the batik industry, which contributes positively to the local economy (Cokrowati et al., 2014). However, besides the positive impact, the industry also has a negative impact because batik waste directly disposed of in the river can affect the life of living things in it. The batik production process also produces dangerous waste because it contains heavy metals (Panjaitan et al., 2023).

The monitoring of water quality biologically can be known by the presence of various living things as bioindicators. Bioindicators are species or populations of living things, animals, plants or microorganisms that can respond to environmental changes. One of the microorganisms that can be used as bioindicators of water pollution is phytoplankton (Cokrowati et al., 2014). The level of pollution in the river can be known from the value of the phytoplankton diversity index. The phytoplankton community as a water quality monitoring tool will provide more information about the changes in water quality than using chlorophyll concentration as a reference in determining water quality (Anas et al., 2022).

Previous study on plankton have been conducted in river areas in Surakarta City such as phytoplankton diversity and fertility analysis based on their abundance (Darmawan et al., 2018), however, research related to phytoplankton as a bioindicator of pollution quality in Jenes River, Surakarta has not been conducted. There is yet no information on phytoplankton diversity used as an indicator of water quality in Jenes River, Surakarta, so research is needed with the aim of describing the condition of water pollution using phytoplankton as bioindicators. The information obtained from this study is expected to provide an overview of water quality in Jenes River, Surakarta which can then be used as a basis for assessing how to treat and utilize water resources in this river by the local community, government, and related parties.

MATERIALS AND METHODS

This research was conducted on the Jenes River, Surakarta, from January to February 2023, during the rainy season. This research activity included taking air samples and measuring air quality in the Jenes River. Identification of phytoplankton samples was carried out at the UNS Integrated Laboratory and the UNS FKIP Biology Education Laboratory. The sample location was selected using purposive sampling by taking into account the surrounding environmental conditions. Sampling locations were carried out from upstream to downstream of the Jenes River. Station one is located upstream of the river on Ismoyo Street, Serengan, Serengan District, Surakarta City, station two is located on the middle Jenes River on Wiropaten Street, Semanggi, Ps. Kliwon District, Surakarta City, station three is located downstream of the river in Surakarta, Sangkrah, Ps. Kliwon District, Surakarta City (Figure 1). According to BPS data for 2021, the population in Pasar Kliwon District is 78,565. Meanwhile, the population in Serengan District is 47,853 people.

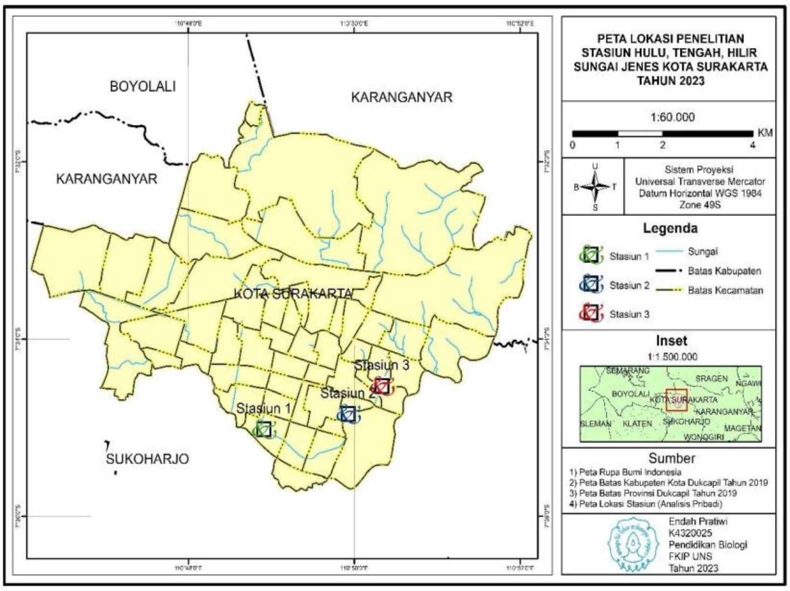

Figure 1. Research locations of the upstream, midstream, and downstream stations of Jenes River, Surakarta

Methods

The research was conducted on Tuesday, January 10, 2023, in the upper, middle, and downstream Jenes River, Surakarta. Phytoplankton analysis was carried out at the Integrated Laboratory of Sebelas Maret University. Phytoplankton samples were taken at 3 different locations in the upper, middle, and downstream Jenes River.

The first station is located in the upper reaches of the river, on Ismoyo Street, Serengan, Serengan, Surakarta. The second station is located in the middle of the river, precisely Wiropaten Street, Semanggi, Ps. Kliwon, Surakarta. The third station is located downstream of the river precisely in Surakarta, Sangkrah, Ps. Kliwon, Surakarta. Analysis of environmental parameters including BOD, and CO_2 was carried out using the titration method. While the salinity test, pH test, light intensity, and brightness test were carried out directly during water sampling.

The tools for taking phytoplankton samples are plankton nets, sample bottles, and 5-litre buckets. Air temperature is measured using a thermometer. A pH meter is used to measure the acidity level of air. DO meters are used to measure dissolved oxygen levels, Secchi chips are used to measure air clarity levels, and binocular microscopes are used to estimate phytoplankton and phytoplankton identification books. The materials used in the research included 10% lugol, sticky labels, markers, distilled water, and styrofoam boxes. Environmental parameters, including BOD and CO_2, were analyzed using titration.

Meanwhile, the salinity, pH, light intensity, and brightness tests are carried out directly when air samples are taken. Environmental parameter testing includes BOD test, CO_2, salinity test, pH test, light intensity, and brightness test. The sample materials used for the CO_2, BOD test are river water samples, MN_2 SO_4 solution, concentrated H_2 SO_4 solution, alkali iodide azide solution, 0.5% starch indicator solution, 0.025 N N_2 S_2 O_3 solution, 20 mL river water, PP indicator, NaOH, distilled water.

Sampling

Phytoplankton sampling was carried out at 3 stations, the upstream, middle, and downstream. The sampling time was carried out twice, in the morning between 06.00–07.00 WIB and in the afternoon between 12.00–14.00 WIB. Phytoplankton abundance tends to be influenced by the presence of light in the waters, which is related to the time of collection (Siregar et al., 2014). Two different sampling times were chosen to ensure that the plankton samples collected could more accurately reflect the diversity of daytime phytoplankton and daytime phytoplankton groups. The phytoplankton filtering technique is carried out using a plankton net that has a mesh size specification of 25 cm, a plankton net mouth diameter of 30 cm, and a plankton net trapezium height of 75 cm. Water was taken using a bucket with a volume of 10 L. Water filtration was carried out 10 times so that the total volume of filtered water was approximately 100 L. Next, the collection bottle was removed from the plankton net. The filtered plankton in the collection bottle was preserved using 4% formalin and then placed in a cool box and taken to the laboratory for analysis.

Sample analysis in the laboratory begins with the identification process by shaking the sample bottle first so that the distribution is evenly distributed, then using a dropper and dripping it on a 1,000 mm^2 sedgwick rafter. After that, it was observed with a microscope and identified.

Data Analysis

Phytoplankton Abundance

Phytoplankton abundance was calculated using a Sedgwick-Rafter. Phytoplankton abundance assessment often involves techniques like the Sedgwick-Rafter method. The density of phytoplankton is then calculated using the formula provided by the American Public Health Association. This formula involves various parameters including the quantity of phytoplankton per liter (N), cover glass area (T), visual field area (L), number of phytoplankton enumerated (P), number of visual fields observed (p), filtered phytoplankton sample volume (V), phytoplankton under the cover glass volume (v), and volume of filtered phytoplankton sample (w). Some of these parameters are predetermined for the Sedgwick-Rafter method, such as T= 1,000 mm^2 v= 1 mL, and L= 0.25 μ mm^2 (assuming one circle equals the field of view in a microscope with r= 0.5 mm). With these known values, the formula is then applied to calculate the density of phytoplankton in the sample.

Diversity Index

The Diversity Index (H') was calculated using the Shannon-Wiener formulation as follows yaitu $\sum_{i=s}^{s}$ Pi In Pi where Pi represents the probability of species i out of total individuals and ln denotes the natural logarithm. The H' criteria is a method used to assess the level of diversity within an ecosystem based on the Shannon-Wiener index (H'). According to this criteria, if the calculated diversity index (H') is less than 1, it indicates low diversity within the ecosystem. On the other hand, if the diversity index falls between 1 and 3, it suggests moderate diversity. When the diversity index exceeds 3, it signifies high diversity within the ecosystem. Additionally, these diversity levels can also be associated with the quality of water bodies; a diversity index of less than 1 typically corresponds to heavily polluted waters, while an index between 1 and 3 indicates moderately polluted waters. Conversely, a diversity index greater than 3 is often characteristic of non-polluted waters. Therefore, the H' criteria not only helps in understanding the diversity within an ecosystem but also provides insights into the environmental quality of water bodies.

Uniformity Index

To assess the similarity in the distribution of individuals among different species within a community, ecologists often utilize the uniformity index. This index, denoted as 'e', is employed alongside the diversity index (H') and the maximum diversity index (H max). The maximum diversity index, denoted as Ln, is calculated using the natural logarithm of the number of species in the community (S). With these parameters, the uniformity index helps in gauging the evenness or uniform distribution of individuals across various species within the community. By comparing the diversity index with the uniformity index, ecologists can gain insights into both the richness and the evenness of species composition within the ecosystem, thus providing a more comprehensive understanding of community structure and dynamics.

Dominance Index

The Plankton Dominance Index, provides a quantitative measure to assess the dominance of individual species within a plankton community. This index, denoted as 'C', is calculated by summing the squared proportions of individuals of each species relative to the total number of individuals in the community. Specifically, for each species, the number of individuals (ni) is divided by the total number of individuals (N) and squared, with these values then summed across all species. The resulting index value indicates the degree of dominance within the community. When the Dominance Index (C) approaches 0, it suggests a lack of dominance, indicating a more evenly distributed community where no single species prevails. Conversely, when the index approaches 1, it signifies the presence of a dominating species within the community, highlighting a situation where one species overwhelmingly dominates the plankton community composition. By employing this index, researchers can gain insights into the relative importance and dominance patterns of different plankton species within aquatic ecosystems.

Environmental Parameters

Environmental parameters such as pH temperature, salinity, brightness, light intensity, DO, CO_2, and BOD were analyzed by PCA analysis with RASCH software. Principal component analysis (PCA) is a multivariate data selection method that transforms an initial data matrix into a set of simpler combinations but can capture most of the variation from the original data. The main goal is to describe as much variation as possible in the original data using the smallest possible number of principal components.

RESULTS

Observations made in the Jenes River in the morning and afternoon observations could identify types of phytoplankton consisting of 9 families and 11 species with a size of around 2–200 micrometers, namely, *Closterium* sp. (a), *Quadrigula* sp. (b), *Ulothrix* sp. (c), *Oscillatoria* sp. (d), *Synedra filiformis* (e), *Anabaena* sp. (f), *Syendra ulna* (g), *Striatella unipunctata* (h), *Rhizosolenia setigera* (i), *Ceratium hirundinella* (j), *Chroococcus* sp. (k), *Cylindrospermopsis* (l), *Cypris* sp. (m).The types of phytoplankton identified can be seen in Figure 2.

Overall observations show that the types of plankton found in the Jenes River consist of 9 families and 11 species. Phytoplankton composition at the morning observation research location. This can be seen in Table 1. Meanwhile, the composition of phytoplankton at the daytime observation research location can be seen in Table 2.

The highest phytoplankton abundance value during morning observations was *Ulothrix* sp., totaling 1,897 cells/L. In contrast, the lowest abundance value was *Closterium* sp., with 237 cells/L. During afternoon observations, the highest phytoplankton abundance value was *Chroococcus* sp., with 3,913 cells/L. In contrast, the lowest abundance values were *Ceratium hirundinella* and *Synedra* *filiformis*, with an abundance of 355 cells/L. The abundance of phytoplankton in the morning can be seen in Figure 3. The abundance of phytoplankton in the afternoon can be seen in Figure 4.

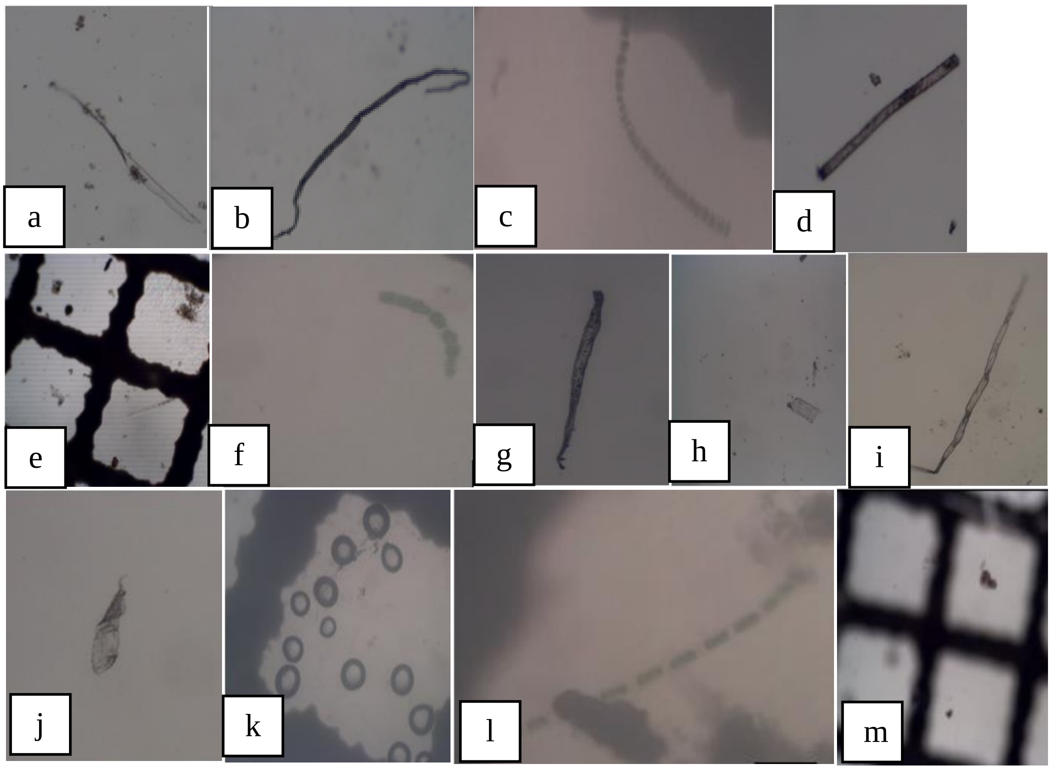

Figure 2. The results of phytoplankton identification are *Closterium* sp. (a), *Quadrigula* sp.(b), *Ulothrix* sp.(c), *Oscillatoria* sp. (d), *Synedra filiformis* (e), *Anabaena* sp. (f), *Syendra ulna* (g), *Striatella unipunctata* (h), *Rhizosolenia setigera* (i), *Ceratium hirundinella* (j), *Chroococcus* sp. (k), *Cylindrospermopsis* (l), *Cypris* sp. (m)

Table 1. Phytoplactone composition at the research location of morning observation

Family	Species
Closteriaceae	*Closterium* sp.
Selenastraceae	*Quadrigula* sp.
Ulotrichaceae	*Ulothrix* sp.
Oscillatoriaceae	*Oscillatoria* sp.
Nostocaceae	*Anabaena* sp.
Fragilariaceae	*Synedra filiformis*
	Synedra ulna
	Striatella unipunctata
Rhizosolenia	*Rhizosolenia setigera*
Ceratiaceae	*Ceratium hirundinella*
Chroococcales	*Chroococcus* sp.
Nostocaceae	*Cylindrospermopsis*
Cyprididae	*Cypris* sp.

Table 2. Phytoplankton composition at the study location of daytime observations

Family	Species
Closteriaceae	*Closterium* sp.
Selenastraceae	*Quadrigula* sp.
Ulotrichaceae	*Ulothrix* sp.
Nostocaceae	*Anabaena* sp.
Fragilariaceae	*Synedra ulna*
	Striatella unipunctata
Rhizosolenia	*Rhizosolenia setigera*
Ceratiaceae	*Ceratium hirundinella*
Chroococcales	*Chroococcus* sp.
Nostocaceae	*Cylindrospermopsis*
Cyprididae	*Cypris* sp.

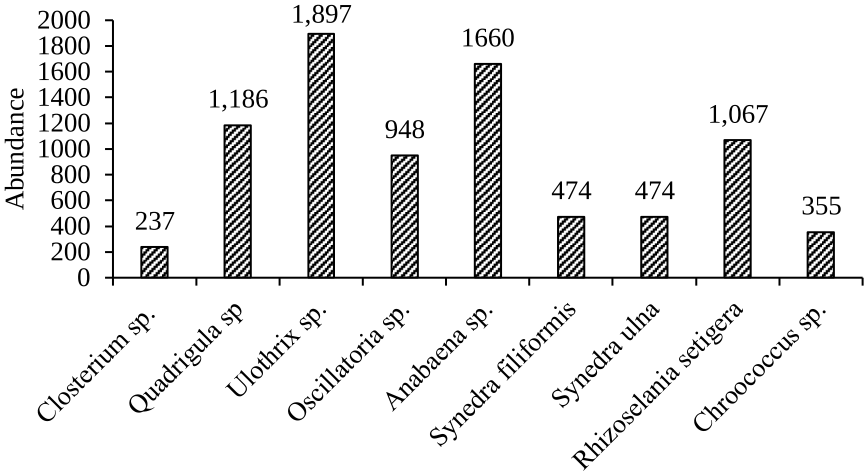

Figure 3. Phytoplankton abundance diagram in the morning observation

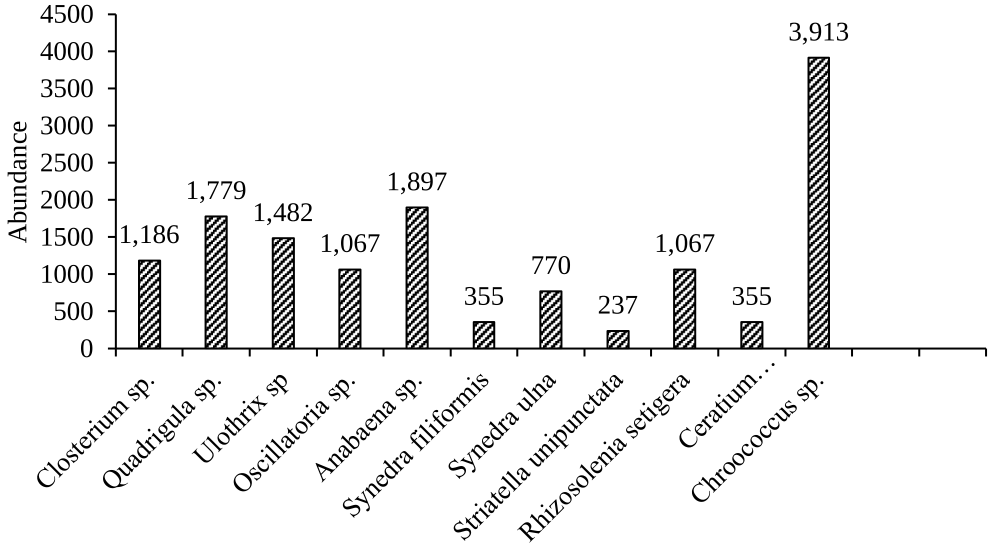

Figure 4. Phytoplankton abundance diagram for daytime observation

The phytoplankton diversity index value obtained based on the Shannon-Wiener index calculation shows that the upstream, middle, and downstream stations had a moderate diversity index in the morning observations. The diversity index for morning observations can be seen in Table 3. Meanwhile, during afternoon observations, the upstream station has a medium diversity index, the middle station has a medium diversity index, and the downstream station has a low diversity index. The observation index during the day can be seen in Table 4.

Table 3. Shannon-Wienner diversity index (H') morning observation

Observation station	Diversity index value	Categories	Pollution category
Upstream	1.1	Moderate	Moderately contaminated
Middle-stream	1.1	Moderate	Moderately contaminated
Downstream	1.2	Moderate	Moderately contaminated

Table 4. Shanon-Wienner diversity index (H') daylight observation

Observation station	Diversity index value	Categories	Pollution category
Upstream	1.10	Moderate	Moderately contaminated
Middle-stream	1.60	Moderate	Moderately contaminated
Downstream	0.90	Low	Highly contaminated

The phytoplankton uniformity index value calculated using the Shannon-Wiener index from morning and afternoon observations at upstream, middle, and downstream stations is included in the medium category. This uniformity index can be seen in Tables 5 and 6.

Table 5. Shanon-Wienner uniformity index (H') morning observation

Observation station	Uniformity index value	Categories
Upstream	0.40	Moderate
Middle-stream	0.41	Moderate
Downstream	0.40	Moderate

Table 6. Shanon-Wienner uniformity index (H') daylight observation

Observation station	Uniformity index value	Categories
Upstream	0.40	Moderate
Middle-stream	0.40	Moderate
Downstream	0.40	Moderate

The dominant type of phytoplankton during morning observations was *Closterium* sp. In the afternoon observations, *Closterium* sp. and *Quadrigula* sp. were the dominant types. The phytoplankton dominance index observed in the morning at the upstream, middle, and downstream stations can be seen in Figure 5. Meanwhile, the phytoplankton dominance index observed during the day at the upstream, middle, and downstream stations can be seen in Figure 6.

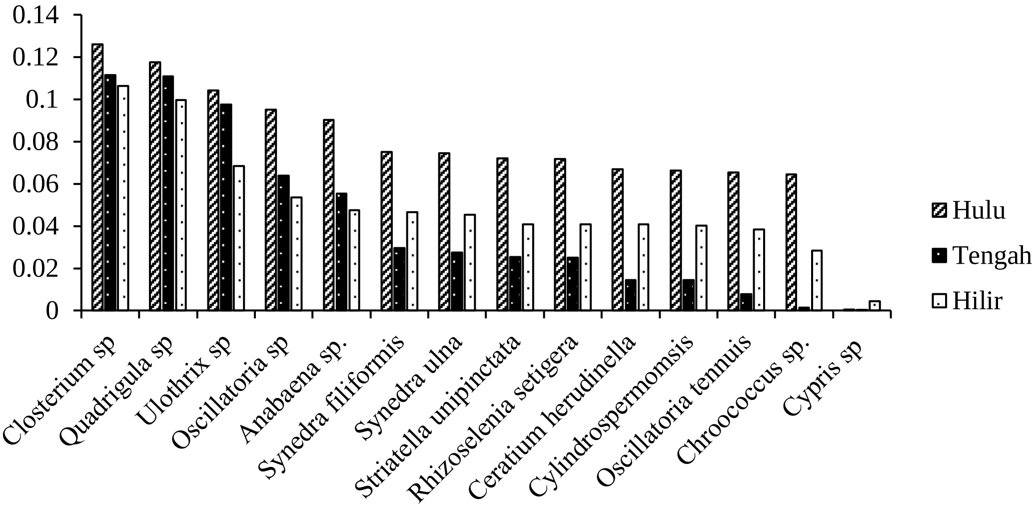

Figure. 5. Phytoplankton dominance index of morning observations from location upstream, midstream, downstream

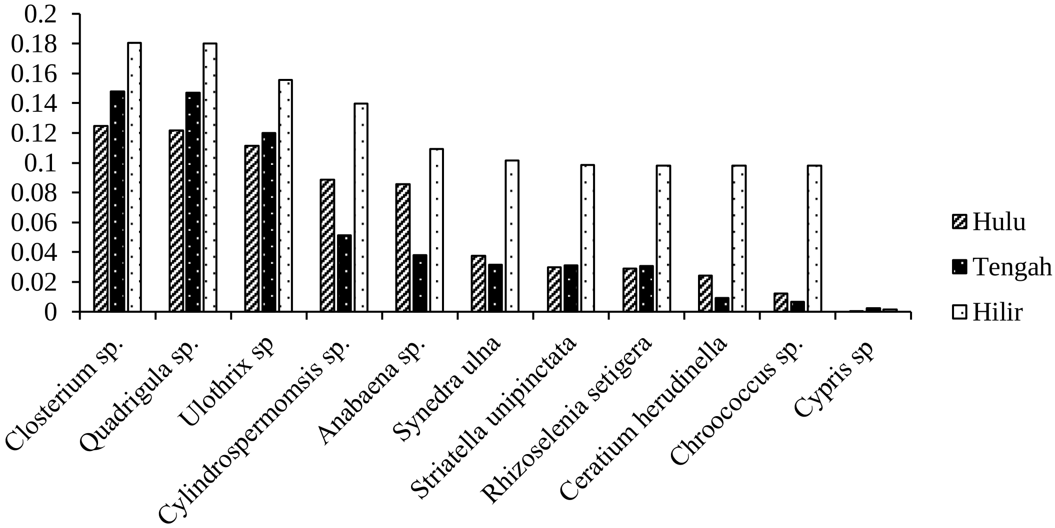

Figure 6. Indeks Phytoplankton dominance index of daylight observations from location upstream, midstream, downstream

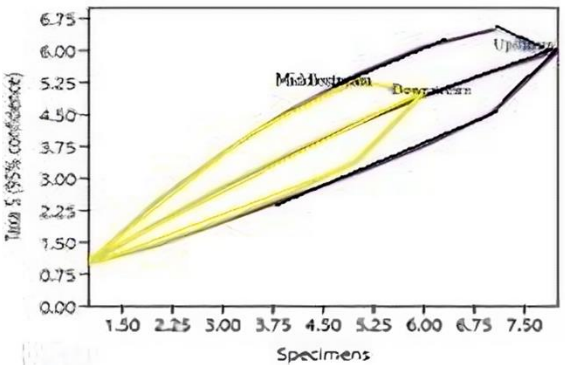

Figure 7. *Compare diversities* morning observation

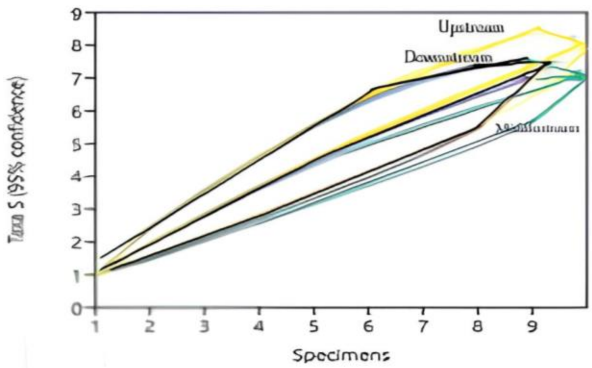

Figure 8. *Compare diversities* daylight observation

Comparison of the phytoplankton diversity index in the Jenes River during morning observations shows that the downstream station shows the highest comparison with a comparison value of 8. Meanwhile, the comparison of the phytoplankton diversity index during daytime observations shows the highest comparison at the upstream station of the river, namely with a comparison value of 6 and the middle and downstream stations show the same comparison value is 5.25. A comparison of the phytoplankton diversity index in the Jenes River can be seen in Figure 7 and Figure 8.

Environmental parameters observed and measured in this research include temperature, pH, salinity, brightness, light intensity, DO, CO_2, BOD. The highest BOD levels were found in the middle part of the Jenes River during daytime observations. The results of measuring environmental parameters Table 7.

Table 7. Environmental parameter measurement results

Station	Test	pH	Temperature (°C)	Salinity	Brightness	Light Intensity (Lux)	DO	CO_2	BOD
Lower	1	7.5	28	0.15	13.251	145.40	3.59	0.34	5.59
Jenes	2	8	30	0.10	13.77	155.70	3.90	0.27	7.54
Middle	1	7.7	29	0.08	13	165.70	4,1	7.92	3.6
Jenes	1	7.9	30	0.90	14.89	167	4.15	1.06	4
Upper	1	7.4	29	0.04	11.75	155.60	5.25	1.41	2.65
Jenes	2	7.9	29	0.05	11.97	157.90	4.60	1.05	3.25

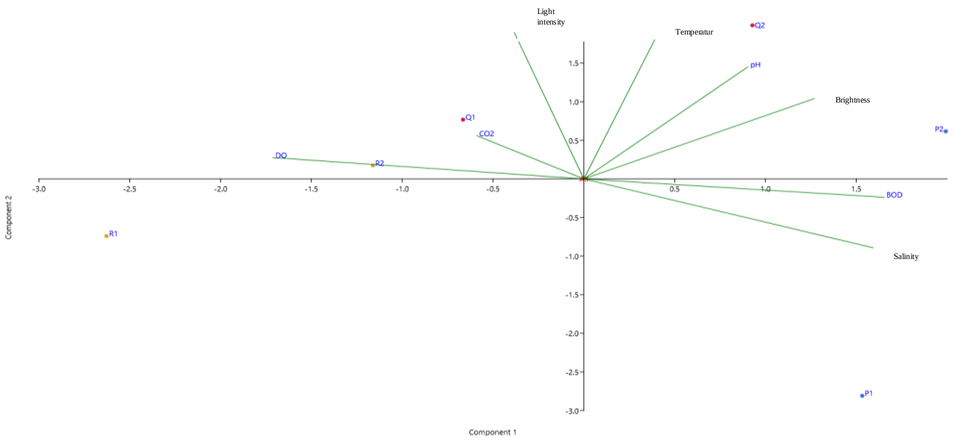

Figure 9. PCA test of environmental parameters

In this research, the chemical factors measured were the degree of acidity (pH), dissolved oxygen (DO), salinity, brightness, light intensity, CO_2, and BOD. Based on the results of the analysis of the relationship between phytoplankton diversity and water quality, it shows that the relationship between DO, light intensity, CO_2, light intensity and salinity on phytoplankton diversity is classified as negative or unidirectional, forming an angle of more than 900. Meanwhile, temperature, pH, brightness and BOD have a positive relationship. or in the same direction at an angle of less than 900 to the diversity of phytoplankton. The relationship between these environmental parameters can be seen in Figure 9.

DISCUSSION

Types of Plankton Found in the Jenes River

The results of the overall observations showed that the types of plankton found in the Jenes River consist of 9 families and 11 species. Identification results show significant variations in morphology and habitat characteristics. For example, *Closterium* sp. has long, curved cells with a widespread habitat in brackish and fresh waters (Resiana et al., 2021). Meanwhile, *Quadrigula* sp. shows the possibility of pollution based on the abundance of the *Cyanophyta* division. The *Chlorophyceae* class, represented by *Ulothrix* sp., are microalgae that tend to grow in waters that float on the water's surface and can carry out photosynthesis. Several phytoplankton species, such as *Oscillatoria* sp. and *Synedra* sp., were identified as an indicator of pollution and decreased water quality. At the same time, Selenia's rapid adaptation to tropical environmental conditions highlights the dependence of phytoplankton on high temperatures and salinity (Cokrowati et al., 2014). The presence of species such as *Anabaena* sp. also provides an overview of changes in watercolor that may occur when there is a rapid increase in the black population (Junda et al., 2012). It was found that some phytoplankton species, such as *Ceratium hirundinella*, have limited growth in certain seasons, and their blooms can result in severe impacts, such as mass mortality of organisms and even red tides, depending on water environmental conditions (Tungka et al., 2017). These observations show that the type and abundance of phytoplankton in the Jenes River are closely related to the physical and chemical conditions of waters in Indonesia. For example, the presence of species such as *Oscillatoria* sp. and *Synedra* sp. can be an indicator of pollution and deterioration of water quality. In addition, the adaptation of species such as *Selenia setigera* to tropical environmental conditions shows the dependence of phytoplankton on high temperatures and salinity. This shows the importance of understanding and monitoring physical and chemical parameters to balance Indonesia's aquatic ecosystem.

Phytoplankton Abundance

Based on the result of observation on the abundance of phytoplankton species, it shows that the abundance of phytoplankton of each species is not stable. The diatom species were found to be natural food for fish, but only the *Chaetoceros* sp. mass was cultured, which is popular as natural food for *Rotifera*, shellfish, pearl oysters, and shrimp larvae. The abundance of *Closterium* sp. during the morning was greater at 1,186 cells/mL. The *Quadrigula* sp. was also more abundant in the afternoon than in the morning at 1779 cells/mL. *Ulothrix* sp. was also more abundant in the afternoon. *Oscillatoria* sp. also had a greater abundance in the afternoon. *Anabaena* sp. species were also more abundant during the day. *Synedra filiformis* had an abundance in the morning. *Synedra ulna* species had a greater abundance in the afternoon at 770 cells/L. *Striatella unipunctata* was not found in the upstream area. *Rhizosolenia setigera* species had the same abundance of 1,067 mL/L. *Ceratium hirundinella* was only found in high abundance in the Jenes River during the day. *Ceratium* sp. is able to survive in low-nutrient conditions (Syafriani & Apriadi, 2018). During the day the nutrient content in Jenes River waters is low because it has been polluted by batik waste (Ramadhan et al., 2023). *Chroococcus* sp. is a species with high abundance, especially during the day. The abundance of phytoplactones is influenced by the availability of nutrients and the ability of phytoplactones to utilize them (Anas et al., 2022). *Chroococcus* sp. is mostly found in the upstream area of the river which has a lower depth than the middle and downstream parts of the river. *Chroococcus* sp. is a *Cyanobacteria* found in shallow water streams (Hamagami et al., 2019).

Index of Diversity

According to the range of diversity values H' <1 can be classified into the category of low diversity, 1≤H'≤ 3 is classified as moderate diversity, and H' >3 is classified into high diversity.

Factors that affect the value of the diversity index are caused by water physical conditions, the availability of nutrients, and the different utilization of nutrients from each individual, as well as the ability of each type of plankton to adapt/tolerate environmental changes (Wiyarsih et al., 2019).

According to the research results, the highest diversity index was observed in the afternoon at the middle river station presumably because the observation station was an area that indicated low contamination, while in the morning observations at the upstream, middle, and downstream stations the diversity index was moderate and categorized into moderate pollution. However, in the afternoon observation at the downstream station has a low diversity index because it is indicated to be highly polluted. The diversity index of a community has a high value indicating that the ecosystem in the area has a balanced environment, while the low diversity value indicates that the aquatic ecosystem is unstable and less supportive of biota life (Wiyarsih et al., 2019).

The highest diversity index occurred during daytime observations at the station of the middle Jenes River. At this station, it was dominated by *Closterium* sp. and *Quadrigula* sp. Both species belong to the phylum *Clorophyta*. *Closterium* sp. and *Quadrigula* sp. species are found in the middle Jenes River because this river has a slow current and a high brightness that allows the life of phytoplankton species *Closterium* sp. and *Quadrigula* sp. to be able to photosynthesize and be able to survive. In addition, these two species were found in the middle Jenes River because this river has a high pH in accordance with the habitat of these species. Therefore, this middle station is included in a river that has water that is classified as having an acidic pH, because it is characterized by many species of *Closterium* sp. and *Quadrigula* sp. that are able to survive.

Index of Uniformity

To find out how much similarity in the individual number distribution of each species at the community level, it is necessary to measure the uniformity index. Based on the research that has been done, the uniformity index at the upstream station is 0.4, the middle station is 0.41, and the downstream station is 0.4. This shows a moderate uniformity index. This condition is influenced by environmental factors and the ability of phytoplankton to adapt to the existing environment (Wiyarsih et al., 2019). A uniformity index close to zero indicates an unstable community while if it is close to one the community is stable, and the number of individuals between species is the same (Ambeng et al., 2023). Based on the obtained uniformity index, the habitat conditions of the Jenes River have a relatively unstable uniformity index. Unstable uniformity in this river is caused by several factors, including batik wastewater pollution. At the downstream station, the river water has been polluted by a lot of batik waste. It can be seen that the water is very murky compared to other stations. In addition, the current and flow of the river also greatly affect the uniformity of phytoplactones in this river. Currents and water flow can carry plankton from one area to another, resulting in spatial variations in plankton abundance.

Index of Dominance

The dominance index value obtained from the results of the study showed varying values at each location, in the morning observation of the upstream station the dominance index value was 0.7, the middle station 0.04, and the downstream station 0.05. In the afternoon observation, the dominance index of the upstream station showed 0.06, the middle station 0.05, and the downstream station 0.1. The highest dominance index value in the morning observation is at the upstream station with a value of 0.7. This value is categorized as medium. The lowest dominance index value was in the afternoon observation at the upstream station with a value of 0.06. A dominance index clouse to 0 indicates the absence of dominance of a particular genus, while if the dominance index value is close to 1 then there is a dominating genus. Therefore, it can be concluded that in the Jenes River, the upstream, middle and downstream observation stations have no domination.

Correlation Between Phytoplankton Diversity and Water Quality

The relationship between physics che, chemistry, and water dynamics in Indonesia is very close. The physical and chemical properties of air masses, such as temperature, salinity, conductivity, and dissolved oxygen levels, are essential factors in determining the characteristics of a body of water

(Riter et al., 2018). Therefore, in addition to considering the biotic components, it must also observe the abiotic elements in the waters which can be done by exploring the interdependent relationship between organisms and abiotic factors, which can help better understanding the water quality. In this study, the chemical factors measured were acidity (pH), dissolved oxygen (DO), salinity, brightness, light intensity, CO_2, and BOD. Based on the results of the analysis of the relationship of phytoplankton diversity to water quality show that the relationship of DO, light intensity, CO_2, light intensity, and salinity to phytoplankton diversity is negative or unidirectional by forming an angle of more than 900. While temperature, pH, brightness, and BOD have a positive or unidirectional relationship by forming an angle of less than 900 to phytoplankton diversity (Figure 9).

Figure 9 represents the contribution of variables to calculate the variability in the principal components. Variables associated with PC 1 are located on axis one. In Figure 9 the parameters that are close to axis 1 are DO and BOD. The DO content in a body of water is also very important to determine the level of pollution in the river that affects phytoplankton diversity. The higher the DO, the higher the level of phytoplankton diversity . However, if the BOD value is higher, the level of pollution is also higher. Meanwhile, close to axis 2 are the parameters of light intensity and temperature. Light intensity greatly affects the ability of phytoplankton to photosynthesize. The amount of household waste such as plastic waste and detergent foam is a contributing factor to the obstruction of sunlight from entering the waters so that the photosynthesis process of phytoplankton is inhibited. The inhibited photosynthesis process will also affect the diversity of phytoplankton.

Based on the measurement results of environmental parameters associated using principal component analysis (PCA) with phytoplankton diversity (Figure 9) show that the correlation value is strong between temperature and pH. Time differences such as morning and afternoon are things that affect temperature differences, while waters that have low pH indicate that these waters are less productive and poor for phytoplankton growth. At the downstream station, the morning observation (P1) was not affected by the BOD and salinity predictors. The downstream station of the afternoon observation was not affected by the predictors of temperature, pH, and brightness. The middle station of the afternoon observation (Q2) was not affected by the predictors of DO, CO2, and light intensity. The upstream station of the morning observation (R1) was not affected by the predictors of DO, CO2, and light intensity. The upstream station of the afternoon observation (R2) is not affected by the predictors Temperature, pH, and brightness.

CONCLUSION

Based on the research conducted, it was found that the highest diversity index during the day at the middle station was 1.6. It is because this station is indicated to be lightly polluted, so there are still many phytoplankton that are alive. The dominating phytoplankton species *are Closterium* sp. and *Quadrigula* sp. These species can survive in this station because this station has a pH that is suitable for the habitat of the two species. The highest abundance of phytoplankton in the morning observation is *Ulothrix* sp. While in the afternoon observation, the highest is *Chroococcus* sp. Physical-chemical parameters that affect phytoplankton abundance can be divided into 2 clusters. This grouping is based on the station distribution of influencing parameters. The first cluster is at the middle Jenes station (Q1) morning observations are characterized by CO_2 while the second cluster is at the upper Jenes station (R2) afternoon observations are characterized by DO and salinity. It is recommended to carry out continuous monitoring of ecological indices and report phytoplankton at various stations and at different times. This is important to identify patterns of change that may occur due to seasonal changes or anthropogenic activities that can affect air quality.

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