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The Relationship between Chlorophyll a and Total Phosphorus (Total-P) in Perupuk Lake, Perhentian Raja Sub-District, Kampar, Riau

Hubungan Klorofil a dengan Total-P di Danau Perupuk, Kecamatan Perhentian Raja, Kampar, Riau

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Abstract

The province of Riau has many freshwater bodies that play a very important role in the lives of the surrounding communities. This study aims to determine the relationship between chlorophyll a and Total-P (Total Phosphorus) concentrations, and to evaluate the trophic status of Lake Perupuk in Perhentian Raja District, Kampar Regency, Riau Province. This study was conducted from October to December 2024 at three stations: Station 1 (estuary, without settlements), Station 2 (main lake area with fish cages), and Station 3 (estuary with settlements and agricultural activities). Sampling was carried out five times at one-week intervals at the surface and at a depth of 2 Secchi. The parameters measured included chlorophyll a, Total-P, temperature, transparency (Secchi depth), pH, dissolved oxygen (DO), free carbon dioxide (CO2), and nitrate. The results showed that chlorophyll a concentration ranged from 11.04 to 14.14 µg/L, with the highest value at Station 2 (14.14 µg/L) and the lowest at Station 1 (11.04 µg/L). Total-P concentrations ranged from 0.0168 to 0.0338 mg/L, following the same pattern: highest at Station 3 (0.0338 mg/L) and lowest at Station 1 (0.0168 mg/L). Simple regression analysis showed an insignificant relationship between Total-P and chlorophyll-a (R^2 = 0.0266–0.0774), indicating that, in mesotrophic waters, other factors, such as light and nitrogen availability, also affect chlorophyll-a concentrations. Based on chlorophyll a and Total-P concentrations, Lake Perupuk is categorized as a mesotrophic water body, with supporting parameters within the optimal range for aquatic organisms.

Keywords: Chlorophyll a, Total-P, Mesotrophic, Oxbow Lake, Water quality

Abstrak

Provinsi Riau memiliki banyak badan air tawar yang memainkan peran yang sangat penting dalam kehidupan masyarakat di sekitarnya. Penelitian ini bertujuan untuk menentukan hubungan antara konsentrasi klorofil-a dan Total-P (Fosfor Total) serta mengevaluasi status trofik Danau Perupuk, Kecamatan Perhentian Raja, Kabupaten Kampar, Provinsi Riau. Penelitian ini dilakukan dari Oktober hingga Desember 2024 di tiga stasiun: Stasiun 1 (muara, tanpa pemukiman), Stasiun 2 (daerah utama danau dengan keramba ikan), dan Stasiun 3 (muara dengan pemukiman dan aktivitas pertanian). Pengambilan sampel dilakukan lima kali dengan selang waktu satu minggu di permukaan dan kedalaman 2 Secchi. Parameter yang diukur meliputi klorofil-a, Total-P, suhu, transparansi (kedalaman Secchi), pH, oksigen terlarut (DO), karbon dioksida bebas (CO_2), dan nitrat. Hasil menunjukkan konsentrasi klorofil-a berkisar antara 11,04–14,14 µg/L, dengan nilai tertinggi di Stasiun 2 (14,14 µg/L) dan terendah di Stasiun 1 (11,04 µg/L).

Konsentrasi Total-P berkisar antara 0,0168–0,0338 mg/L, mengikuti pola yang sama: tertinggi di Stasiun 3 (0,0338 mg/L) dan terendah di Stasiun 1 (0,0168 mg/L). Analisis regresi sederhana menunjukkan hubungan yang tidak signifikan antara Total-P dan klorofil-a (R^2 = 0,0266–0,0774), menunjukkan bahwa dalam perairan mesotrofik, faktor lain seperti cahaya dan ketersediaan nitrogen juga mempengaruhi konsentrasi klorofil-a. Berdasarkan konsentrasi klorofil-a dan Total-P, Danau Perupuk dikategorikan sebagai badan air mesotrofik dengan parameter pendukung dalam rentang optimal untuk mendukung kehidupan organisme air.

Kata kunci: Klorofil-a, Total-P, Mesotrofik, Danau Oxbow, Kualitas air

1. Introduction

The province of Riau has many freshwater bodies that play a very important role in the lives of those around them. Kampar Regency is one of the regencies in Riau Province with an area of 10,928.20 km². Public water bodies in Kampar Regency include rivers, reservoirs, and oxbow lakes. An oxbow lake forms when a river changes course due to erosion and sedimentation along its course (Dian, 2013). Lake Perupuk is an oxbow lake located in Kampung Pinang Village, Perhentian Raja Subdistrict, Kampar Regency, Riau Province. This lake covers approximately 4.15 ha, has an average depth of 5 meters, and was formed when the flow of the Kampar River was interrupted. Lake Perupuk has important ecological, socio-cultural, and economic functions. Ecologically, this lake is a habitat for aquatic organisms and maintains hydrological balance. From a socio-economic perspective, the lake is used by the surrounding community for fishing and for tourism development (Siburian, 2020).

Various activities are carried out by the community around Lake Perupuk, including residential settlements, cattle farming, oil palm plantations, and fish farming. These activities have the potential to contribute organic and inorganic materials to the water. Organic inputs undergo decomposition into nutrients such as nitrogen and phosphorus. Increased concentrations of these nutrients can stimulate phytoplankton growth, thereby increasing chlorophyll a concentration in the water (Effendi, 2003). Chlorophyll a is a green pigment in plant cells that plays an important role in photosynthesis in water. Chlorophyll a can be used as an indicator of phytoplankton biomass and water fertility (Agung et al., 2018). Effendi (2003) stated that an increase in chlorophyll a concentration in a body of water is related to the phosphate concentration in that water. Phosphorus is a macronutrient that is very important for the life of aquatic organisms because it functions in the storage and transfer of energy in cells (Agung et al., 2018).

Research on the relationship between chlorophyll a and Total-P has been conducted in several places. Wehalo (2016) reported that chlorophyll a and Total-P have a very strong relationship in the Koto Panjang Hydroelectric Power Plant Reservoir. However, similar research has never been conducted in Lake Perupuk, which differs from other oxbow lakes due to agricultural and residential activities around it. Therefore, this study is important for providing a comprehensive overview of the relationship between water fertility and chlorophyll a in Lake Perupuk and for serving as a basis for sustainable water resource management. The objectives of this study are to determine the relationship between chlorophyll a and total phosphorus in Lake Perupuk and to assess the trophic status of the water.

The benefit of this study is that, by knowing the concentration of Total-P, the concentration of chlorophyll a in Lake Perupuk can be estimated, which can then serve as a basis for future water management.

2. Material and Method

2.1. Time and Place

The research was conducted from October to December 2024 in the waters of Lake Perupuk, Kampung Pinang Village, Perhentian Raja Subdistrict, Kampar Regency, Riau Province. Field observations and measurements of several parameters were conducted at the research site. In contrast, laboratory analyses were conducted at the Water Productivity Laboratory of the Faculty of Fisheries and Marine at the Universitas Riau.

2.2. Methods

The methods used in this study included surveys, direct observation at the research site, and water sampling and water quality measurements. The data collected included primary and secondary data. Primary data were obtained from direct water-quality measurements or in the laboratory. Meanwhile, secondary data consisted of topographical data for Kampung Pinang Village, Perhentian Raja Subdistrict, Kampar Regency, obtained from the literature.

2.3. Procedures

2.3.1. Determination of Station Locations

Research stations were determined using purposive sampling based on location characteristics. Three research stations were established as follows: Station I: This is the water inlet to the lake. There are no residential areas around this station, but there are oil palm plantations (0°21′55″N 101°27′02″E). Station II: This is the central part of the lake with fish farming and oil palm plantations (0°21′53″N 101°27′10″E). Station III: This is the lake's water outlet with residential settlements, fish farming, and oil palm plantations (0°22′12″N 101°27′13″E).

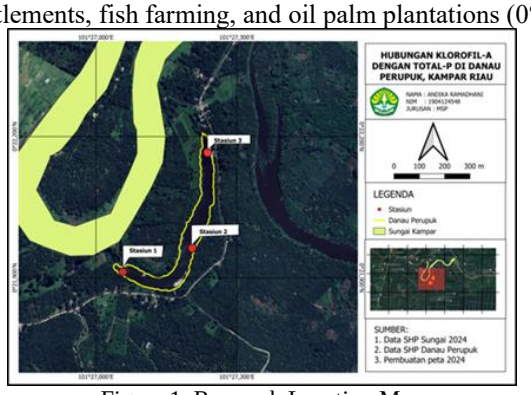

Figure 1. Research Location Map

2.3.2. Water Sampling Chlorophyll a

The study used a cross-sectional survey with a sampling design. Sampling was conducted five times at one-week intervals at two depths: surface and 2 Secchi depths. Water samples were collected using a Kemmerer water sampler for the 2 Secchi depths and directly from the surface for surface samples. A total of 500 ml of water samples were taken and covered with aluminum foil. In the laboratory, the samples were filtered using Millipore paper under vacuum. Millipore paper containing chlorophyll a was ground with 90% acetone solution (5 ml + 3.5 ml), then centrifuged at 2000 rpm for 10 minutes. The absorbance of the supernatant was measured at λ = 665 nm and λ = 750 nm using a spectrophotometer. The chlorophyll a concentration was calculated using the Vollenweider formula: Klorofil-*a* (µg/L) = 11,9 (A665 –A750) $\frac{V}{L} \times \frac{1000}{S}$

Description:

A665 = Spectrophotometer absorption λ 665
A750 = Spectrophotometer absorption λ 750
V = Volume of acetone extract used (mL)
S = Volume of filtered sample (mL)
L = Light path length or cuvette width (1 cm)
11.9 = Constant (constancy)
1000 = Conversion from L to mL

2.3.3. Total-P

A sample of 25 mL was added H_2SO_4 30% and $K_2S_2O_8$ 5%, heated to 100°C, cooled to 60°C. Added pp indicator and titrated NaOH 10 N to pink. Samples were added to aquades up to 25 ml, 5 ml were taken, 0.2 ml of ammonium molybdate and 1 drop of SnCl2 were added. Absorbance was measured at λ = 690 nm using the standard curve. With supporting parameters i.e. temperature measured with a thermometer, pH with pH indicator, brightness with Secchi disk, DO with the Winkler method, free CO_2 with Na_2CO_3 titration, and nitrate with spectrophotometer at λ 543 nm

3. Result and Discussion

3.1. Chlorophyll a

The concentration of chlorophyll a at the surface ranged from 11.04 to 14.08 µg/L, with the lowest concentration at Station 1 (11.04 µg/L) and the highest at Station 2 (14.08 µg/L). At a depth of 2 Secchi, the concentration ranged from 11.37 to 14.14 µg/L (Figure 1). The vertical profile shows that chlorophyll a concentration in the water column is higher than at the surface, especially at Station 2. This is thought to be because nutrient concentrations in the water column are higher, resulting in more optimal photosynthesis (Effendi, 2003). The low chlorophyll a at the surface of Station 1 was due to low phosphate, CO_2, and brightness levels, which inhibited photosynthesis. The high chlorophyll a at Station 2 was associated with high CO_2 and nutrient concentrations. According to Effendi (2003), Lake Perupuk is classified as mesotrophic (8–25 µg/L) based on chlorophyll a, with an average of 11.40–14.14 µg/L.

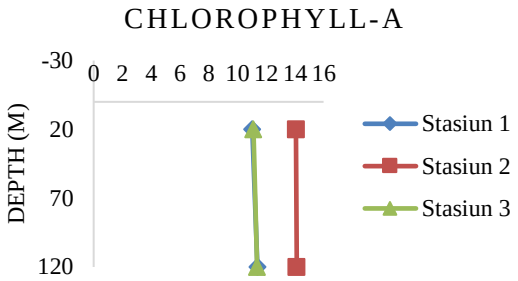

Figure 2. Chlorophyll a Concentration in Lake Perupuk

3.2. Total-P

Concentrations at the surface ranged from 0.0168 to 0.0284 mg/L and in the water, column ranged from 0.0252 to 0.0338 mg/L. Total-P was highest at Station 3 (outlet with residential area) and lowest at Station 1 (inlet). Total-P concentrations in the water column were higher than at the surface at all stations. This is because phosphorus has a higher density than water, so it tends to settle in deeper layers (Walukow, 2010). The high Total-P at Station 3 is associated with fish farming and oil palm cultivation in the surrounding area. During the rainy season, fertilizer residues and agricultural waste are carried into the water. The low Total-P at Station 1 is due to its position as an inlet without significant organic input. Based on the OECD classification, with a Total-P of 0.01–0.035 mg/L, Lake Perupuk is classified as mesotrophic water. The Relationship Between Chlorophyll-a and Total-P (Table 1).

Table 1. The Relationship Between Chlorophyll-a and Total-P

Station	Chlorophyll-*a*	Total-P	Regression Equation	R^2
1	X	Y	y = 10,564 + 31,152x	0,0774
2	X	Y	Y = 13,036 + 37,664x	0,0275
3	X	Y	y = 12,656 + 0,4043ln(x)	0,0266

Based on a simple regression analysis, the relationship between Total-P concentration and chlorophyll a was insignificant during research in Lake Perupuk. This is because Lake Perupuk is mesotrophic, with moderate phosphorus availability in the water, which is not a major limiting factor for chlorophyll a formation. This is in line with Walukow's (2010) opinion that, in eutrophic waters, phosphorus is no longer the main factor influencing chlorophyll a levels. Therefore, the concentration of chlorophyll a in Lake Perupuk is strongly suspected to be more influenced by other factors, such as physical and chemical parameters.

3.3. Water Quality

Temperature measurements during the study at Lake Perupuk ranged from 28 to 30.2°C (Figure 3). Walukow (2010) stated that the optimal temperature range for the life and development of aquatic organisms is 25-32°C. The surface water temperature range recorded at Lake Perupuk during the study, namely 28-30.2°C, supports this opinion, indicating that the temperature during the study was still capable of supporting the life of aquatic organisms.

The results of acidity level (pH) measurements found during research in Lake Perupuk were 6 (Figure 4). Based on the pH values obtained, the waters of Lake Perupuk are acidic but can still support aquatic organisms. The acidity level during the study was the same at the surface and at a depth of 2 Secchi, at 6. According to Effendi (2003), aquatic organisms generally live in waters with a pH of 5–9, with an optimal pH range of 6-8. The pH of Lake Perupuk, around 6, indicates that water conditions are still within acceptable limits and support aquatic life.

The average dissolved oxygen concentration measured during the study ranged from 4.776 to 5.358 mg/L. The dissolved oxygen concentration at the surface was relatively higher than in the water column. This is because light penetrates more deeply at the surface, enabling maximum photosynthesis. This is supported by Walukow (2010), who states that photosynthesis by phytoplankton and aquatic plants produces dissolved oxygen in water. Based on the dissolved oxygen concentrations obtained during the study, it can still support the life of these aquatic organisms. This is in accordance with Wetzel (2001), who states that the minimum content sufficient to support the normal life of aquatic organisms is 4 mg/L.

The average free carbon dioxide concentration during the study ranged from 10.3 to 10.6 mg/L. The average free CO_2 results during the study still support the life of aquatic organisms in Lake Perupuk. This is in line with the opinion of Walukow in Lumbangaol (2014), who stated that the maximum free carbon dioxide content in water is 10-15 mg/L. According to Octasari et al. (2018), the ideal carbon dioxide (CO_2) level for the survival of aquatic organisms is approximately 15 mg/L. Levels above this are very dangerous because they inhibit oxygen (O_2) binding

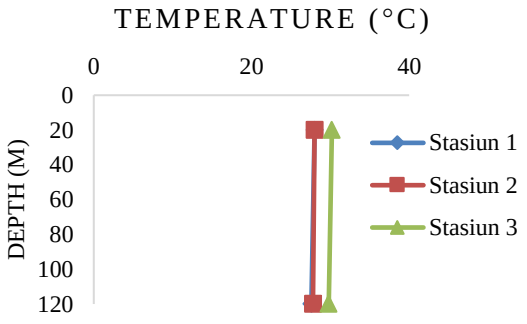

Figure 3. Vertical Temperature Profile in Lake Perupuk

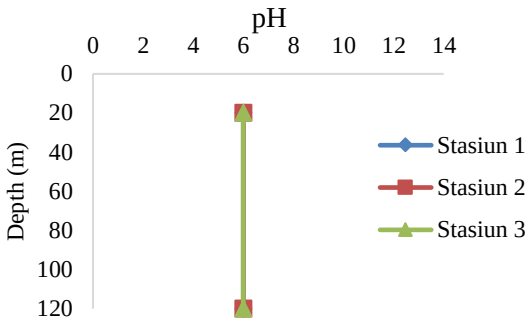

Figure 4. Average pH in Lake Perupuk

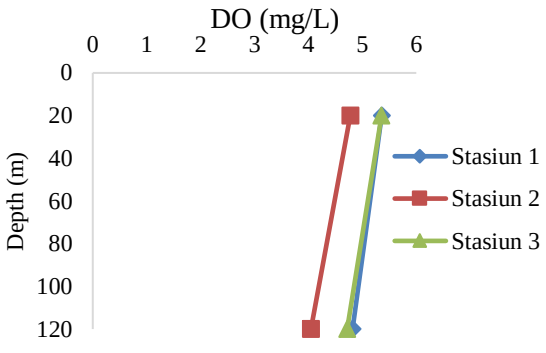

Figure 5. Vertical Profile of Dissolved Oxygen in Lake Perupuk

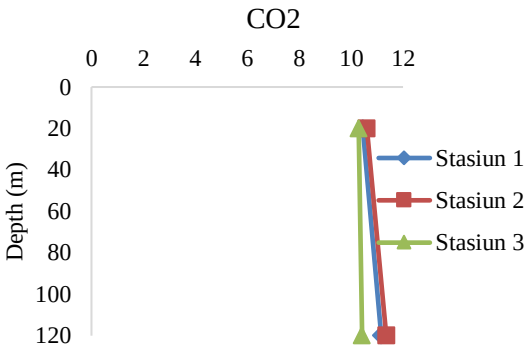

Figure 6. Vertical Profile of Free Dissolved Carbon Dioxide in Lake Perupuk

The average free carbon dioxide (CO_2) concentration measured during the study at Lake Perupuk ranged from 8 to 11 mg/L at all three observation stations. Vertically, CO_2 concentrations tended to increase with depth, especially in the lower water layers. This pattern was relatively similar across all stations, although there were differences in concentration values at certain depths. The lower CO_2 concentration in the surface layer is thought to be related to the photosynthetic activity of phytoplankton and aquatic plants that utilize CO_2, as well as gas diffusion into the atmosphere. Conversely, the increase in CO_2 concentration in the deeper layers is caused by the respiration of aquatic organisms and more intensive decomposition of organic matter, as well as limited water mass mixing at that depth.

The average orthophosphate concentration measurements during the study ranged from 0.0168 to 0.0338 mg/L at the three observation stations. The average phosphate concentration at Station 3 was higher than at the other stations. This is because Station 3 receives organic matter from oil palm plantations and fish farming activities in the surrounding area, which is subsequently decomposed into nutrients.

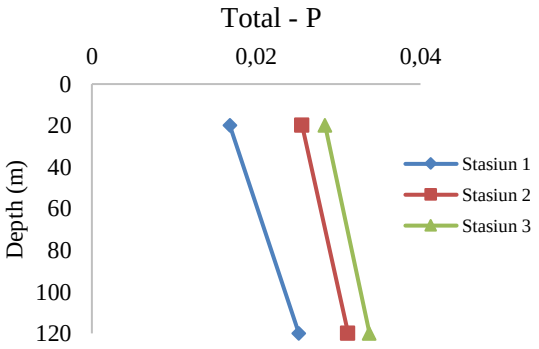

Figure 7. Vertical Phosphate Profile in Lake Perupuk

Effendi (2003) classified low water fertility levels as 0-0.02 mg/L, moderate water fertility levels as 0.02-0.05 mg/L, and high fertility levels as 0.051-0.1 mg/L, with very fertile hypertrophic fertility ranging from 0.101-0.2 mg/L. Based on these criteria, Lake Perupuk is classified as mesotrophic to eutrophic, with phosphate concentrations ranging from 0.0168 to 0.0338 mg/L.

4. Conclusions

Based on research in Lake Perupuk, chlorophyll a concentration ranged from 11.396 to 14.136 µg/L, with the highest value at Station II and the lowest at Station I. The high chlorophyll a concentration at Station II was influenced by the abundance of phytoplankton driven by high total phosphorus (Total-P) and nitrate levels. The vertical profile showed that chlorophyll a concentration tended to be higher at a depth of 2 Secchi at stations with high brightness levels, allowing for better light penetration for photosynthesis. The relationship between chlorophyll a and Total-P follows a non-linear pattern, indicating that light availability is also an important factor in addition to nutrients in the chlorophyll formation process.

In general, Lake Perupuk is categorized as mesotrophic based on chlorophyll a value. Other water quality parameters, such as temperature (28°C-30.2°C), pH (6), dissolved oxygen (4.776-5.358 mg/L), and free carbon dioxide (10.45-10.608 mg/L), remain within ranges that support aquatic life. Therefore, the water conditions of Lake Perupuk remain productive and suitable for supporting phytoplankton growth, although regular monitoring is necessary to anticipate the possibility of increased eutrophication.

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