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Assessing Water Pollution at Sail River: Insights from Plankton Abundance as an Ecological Indicator in Riau, Indonesia

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Abstract

Plankton is an effective bioindicator for diagnosing freshwater pollution. We assessed the plankton community structure at three Sail River sites representing residential, industrial-urban, and agro-rural influences, and correlated biological indices with physicochemical parameters. Purposeful sampling and standard microscopy were used to identify and quantify taxa; Shannon diversity (H′), equitability index (E), dominance (D), trophic status, and saprobicity were obtained. In total, 106 taxa were recorded (zooplankton: 4 species in 3 higher groups; phytoplankton: 102 species in 20 classes). Phytoplankton abundance ranged from 3.0–9.1 × 10^3 cells L^{-1} across sites (mesotrophic), while zooplankton ranged from 1.9–161 × 10^3 individuals L^{-1}. Phytoplankton diversity was moderate to high (H′ = 2.1–3.2) at less impacted sites and lower at residential sites; zooplankton diversity was low to moderate (H′ = 1.3–1.5). Saprobicity scores indicated β–α mesosaprobic conditions (light to moderate organic impact), consistent with elevated COD and low DO at residential sites. Cyanophyceae and Euglenophyceae were more frequent at sites with higher organic and nutrient loads, while Bacillariophyceae increased with increasing water clarity/flow. Overall, plankton metrics and chemistry indicated local organic stress rather than an “unpolluted” state. We emphasize the need for seasonal replication and more accurate quantification to reduce uncertainty in abundance estimates.

Keywords: Community structure; Plankton; Sail river; Saprobity index

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INTRODUCTION

Rivers provide essential ecological and socioeconomic services, including water supply, irrigation, fisheries, transportation, drainage, recreation, and energy production. At the same time, rivers that flow through densely populated and intensively used landscapes are highly vulnerable to contamination from domestic wastewater, industrial discharge, agricultural runoff, pesticides, suspended solids, nutrients, metals, and other potentially hazardous substances. These inputs can alter water chemistry, reduce habitat quality, disturb food-web interactions, and weaken the ecological functions of river systems. The intensity and distribution of pollution are also influenced by land use within the watershed because residential, commercial, industrial, and agricultural areas generate different types and magnitudes of environmental pressure. For this reason, river-health assessment requires an approach capable of identifying spatial variation in both chemical conditions and biological responses (Mello et al., 2023). In the Sail River watershed, wastewater from settlements, commercial activities, food-related businesses, oil-palm plantations, and industrial operations has been identified as an important source of environmental pressure (Mulyadi, 2005).

Physicochemical measurements are commonly used to evaluate water quality because they provide direct information about environmental conditions at the time of sampling. Parameters such as temperature, water clarity, dissolved oxygen, pH, total suspended solids, nutrients, chemical oxygen demand, iron, manganese, and hardness can indicate changes in habitat quality and pollutant load. However, these measurements may represent only short-term conditions and may not fully capture ecological disturbances that fluctuate over time. Biological monitoring is therefore needed to complement chemical assessment. Aquatic organisms integrate environmental changes through their survival, abundance, distribution, and community structure, making them useful indicators of cumulative or repeated disturbance. A combined biological and physicochemical approach can provide a more complete diagnosis of river condition than either approach used independently, particularly in watersheds exposed to multiple forms of anthropogenic pressure (Mello et al., 2023; Protasov et al., 2019).

Plankton communities are especially relevant for freshwater biomonitoring because they have short generation times, respond rapidly to environmental change, and occupy central positions in aquatic food webs. Phytoplankton are primary producers and respond directly to changes in nutrient availability, light penetration, temperature, pH, suspended solids, organic enrichment, and toxic substances. Zooplankton, as primary and secondary consumers, are additionally affected by food availability, predation, hydrological conditions, and habitat structure. Consequently, changes in the composition and abundance of both groups may reflect shifts in productivity, oxygen conditions, nutrient status, and organic loading. Studies in river systems have shown that plankton assemblages can reveal water-quality gradients and ecological disturbances that are not always apparent from a single chemical measurement (Nandini et al., 2019; Persada et al., 2022). In tropical waters, where rainfall, discharge, and temperature can vary considerably, plankton-based indicators are particularly useful when interpreted together with hydrological and physicochemical information.

The ecological meaning of plankton abundance must nevertheless be interpreted carefully. High abundance may indicate favorable productivity, but it can also result from nutrient enrichment or the proliferation of taxa that tolerate organic pollution and oxygen depletion. Conversely, low abundance may reflect limited nutrients, unfavorable flow conditions, toxic exposure, or strong grazing pressure. Therefore, abundance alone is insufficient to determine whether a river ecosystem is stable or degraded. Community-level metrics provide additional information. The Shannon diversity index describes the variety and proportional representation of taxa, equitability indicates how evenly individuals are distributed among species, and dominance identifies whether the community is controlled by a limited number of taxa. These metrics help distinguish a balanced community from one characterized by ecological stress or the excessive proliferation of tolerant organisms. Previous studies have shown that diversity and saprobity may change along pollution gradients, although their responses are not always identical because community patterns are also shaped by seasonality, food-web interactions, hydrological variation, and taxonomic resolution (Protasov et al., 2019).

The saprobity framework is particularly relevant for assessing organic pollution. Saprobic indices classify aquatic conditions according to the occurrence and abundance of organisms with different tolerances to decomposable organic matter. In general, oligosaprobic conditions indicate low organic loading, whereas mesosaprobic and polysaprobic conditions indicate progressively greater organic enrichment and oxygen demand. In tropical and subtropical aquatic systems, plankton-based saprobic assessment has been used to identify mild to substantial organic pollution and to map spatial variation among sampling stations (Kondrateva et al., 2019; Nandini et al., 2019; Persada et al., 2022; Santika et al., 2022). Organic loading may favor cyanobacteria, euglenoids, protozoa, and other pollution-tolerant organisms, while sensitive taxa decline. Heavy pollution can therefore alter community composition, reduce ecological balance, and change the relationship between primary producers and consumers (Shevchenko et al., 2020). Protozoan communities have also been reported to respond strongly to dissolved oxygen, nutrients, and organic contamination, supporting their use as indicators of river-water quality (El-Tohamy et al., 2024). Nevertheless, the ecological status inferred from saprobity should be evaluated together with diversity, equitability, dominance, and physicochemical measurements because no single index captures all dimensions of river health.

Interactions between plankton communities and environmental parameters are complex. Dissolved oxygen and chemical oxygen demand can reflect the balance between oxygen production, respiration, and the decomposition of organic matter. Low dissolved oxygen accompanied by high chemical oxygen demand may indicate substantial organic loading and microbial decomposition, conditions that can favor pollution-tolerant taxa. Nitrogen and phosphorus support phytoplankton growth, but excessive nutrient enrichment can produce rapid population increases and reduce community balance. Total suspended solids and turbidity can restrict light penetration and consequently limit photosynthesis, while temperature influences metabolic activity, reproduction, and species distribution. Water acidity or alkalinity may also determine the suitability of habitats for particular plankton taxa. Metals such as iron and manganese are naturally present in aquatic systems, but elevated concentrations may affect plankton physiology and community composition. Because these variables interact rather than operate independently, plankton patterns should be interpreted as responses to a combination of environmental conditions rather than as the result of a single water-quality parameter.

The Sail River flows through areas influenced by residential development, commercial activity, industry, and agriculture in Pekanbaru, Riau Province. These contrasting land-use settings may introduce different pollutant sources and create spatial variation in dissolved oxygen, organic load, suspended solids, nutrients, metals, water clarity, and plankton-community composition. Residential sections may receive domestic wastewater and solid-waste inputs, industrial-urban sections may be exposed to commercial and industrial effluents, and agro-rural sections may be influenced by runoff from cultivated land. Such variation provides an appropriate context for examining whether plankton communities differ among sites subjected to different anthropogenic pressures. Previous studies in Indonesia have demonstrated the value of plankton diversity and saprobity for evaluating trophic condition and pollution status in tropical aquatic systems (Persada et al., 2022; Santika et al., 2022). Other studies have shown that phytoplankton, zooplankton, diatoms, and protozoa can provide complementary information on ecological condition because these groups differ in their sensitivity to organic matter, nutrients, hydrological change, and toxic substances (Barınova & Mamanazarova, 2021; El-Tohamy et al., 2024).

Despite this broader evidence, an integrated assessment of the Sail River remains limited. Existing local and regional studies have more commonly focused on selected physicochemical parameters, general water quality, or individual plankton components. Less attention has been given to the simultaneous evaluation of phytoplankton and zooplankton composition, abundance, diversity, equitability, dominance, trophic status, saprobity, and physicochemical conditions across contrasting sections of the same urban tropical river. This gap is important because plankton abundance may produce a misleading interpretation when it is not examined together with community structure and water chemistry. A high number of plankton organisms does not necessarily indicate good ecological condition, particularly when the community is dominated by a small number of pollution-tolerant taxa. Similarly, acceptable values for individual chemical parameters do not necessarily indicate an ecologically stable community. Spatial comparisons among residential, industrial-urban, and agro-rural settings are therefore needed to determine whether ecological stress is localized or distributed more broadly along the river.

An integrated design is also relevant because different biological groups may provide different assessments of pollution status. Phytoplankton may respond rapidly to nutrients and light availability, whereas zooplankton responses may be delayed or mediated by food supply, predation, and hydrological transport. Diversity, dominance, and saprobity indices may consequently produce complementary rather than identical interpretations. The reliability of biological assessment is also affected by taxonomic resolution, sampling design, seasonal conditions, and the biological groups included in the analysis. Studies comparing multiple ecological indices have therefore recommended interpreting community-level metrics alongside chemical and physical evidence rather than relying on a single biological indicator (Kondrateva et al., 2019; Protasov et al., 2019). Applying this integrated perspective to the Sail River can provide a more defensible interpretation of the ecological implications of human activities along different river sections.

Accordingly, this study aimed to characterize plankton communities and provide a preliminary assessment of ecological condition and indications of organic pollution in the Sail River. Specifically, the study identified the composition and abundance of phytoplankton and zooplankton, calculated diversity, equitability, dominance, and saprobity indices, and applied an abundance-based trophic classification at three sites predominantly influenced by residential, industrial-urban, and agro-rural activities. Selected physicochemical water-quality parameters were also measured, and site-level plankton patterns were descriptively interpreted in relation to these environmental conditions. The novelty of the study lies in the integration of phytoplankton and zooplankton community metrics, saprobity assessment, and physicochemical measurements across contrasting sections of the Sail River.

METHOD

Study Site

This study was conducted on December 2022 located along the Sail River which flows through Sail, Bukit Raya, Lima Puluh, and Tenayan Raya sub-districts. Sail River has a watershed area of ± 30 129 km^2 and a length of ± 29 km. Sail River is a turbid water with a bottom of sand, silt, and gravel with a depth of 5 m and a width of 10 m. Plankton samples were taken at three crossing points (Site A, B and C) on the Sail River. The community utilizes the Sail River for bathing, swimming, and other activities. The community utilizes the Sail River for bathing, washing, and using toilets in addition to fish production. As a result of the many domestic activities around the Sail River, including markets, settlements (shops), cafes, hotels, and so on, many substances are found that can endanger water purity.

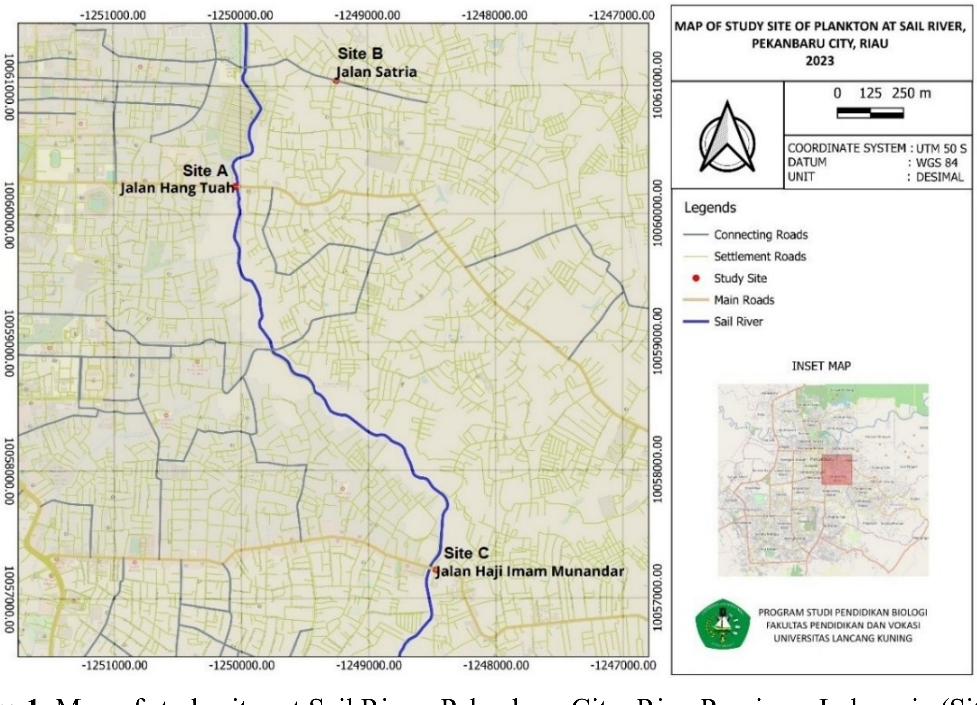

Figure 1. Map of study sites at Sail River, Pekanbaru City, Riau Province, Indonesia (Site A. 0°31'12.0"N 101°29'09.3"E; Site B. 0°31'57.9"N 101°28'04.6"E; Site C. 0°29'51.9"N 101°28'49.1"E)

Plankton Sampling in the Field

The parameters in this study are divided into two, namely the main data in the form of plankton and supporting data in the form of water quality measurements. Plankton sampling was carried out directly from three different river locations. Site A is near dense residential areas and close to domestic activities such as household waste disposal. The topography of Site A is relatively flat with little elevation, allowing for slow water flow with higher temperatures due to the lack of shade vegetation, resulting in more significant water temperature fluctuations. Site B is close to industrial areas and factories. There is potential for contamination from industrial waste. This site is at a slightly lower elevation than site A, allowing for faster water flow. The temperature on this site tends to be more stable with little variation due to the shade from the surrounding trees.

Site C is located in a rural area that is relatively far from direct human activity, but close to agricultural land that uses pesticides. Site B being in the lowlands, close to the river mouth, the water flow is slower and often stagnant. The water temperature here is lower and more stable due to the thick riparian vegetation (Figure 1). This study used a survey method that was determined by purposive sampling. To prevent sample damage, the samples were kept in a cold box filled with ice cubes to keep the temperature of the samples low. The samples were taken using a plankton net measuring 25 µm with a diameter of 15 cm, sampling was carried out horizontally by filtering water using a plankton net pulled along 10 m on the surface of the water for 5 minutes, with repetition 10 times. Next, the samples were stored in sample bottles that had been prepared and labeled and then given 2 drops of 4% formalin solution.

A 25 µm-mesh plankton net with a 15 cm mouth diameter was used for sampling. At each site, ten horizontal surface tows were conducted at an approximate depth of 0–0.5 m. Each tow lasted 5 min and covered a distance of approximately 10 m, resulting in a total tow distance of about 100 m per site. The ten tows collected at each site were pooled into a single composite sample, yielding three composite samples in total, one from each study site. The samples were preserved in buffered formalin at a final concentration of approximately 4%.

Because a flowmeter was not used, the filtered water volume was estimated using $V_1 = \pi r^2 L$, where $r$is the radius of the plankton-net mouth and $L$is the tow distance. With a net radius of 0.075 m and a tow distance of 10 m, the estimated filtered volume was approximately 0.177 m³, or 176.7 L, per tow. Therefore, the total estimated volume filtered during ten tows at each site was approximately 1.77 m³, or 1,767 L. This theoretical volume was used to convert plankton counts into density values, although the estimates may be affected by net clogging, water-current variation, and less than complete filtration efficiency.

Plankton Identification

The sampling process Plankton samples were identified at the Biology Laboratory, Faculty of Education and Vocational Studies, Universitas Lancang Kuning using a microscope with a magnification of 40x10 which was done 10 times in one bottle of plankton samples. After that, plankton identification by (Soedarsono et al., 2002) was carried out by referring to the plankton identification book by (Handayani & Patria, 2005; Prianto et al., 2013; Hamzah et al., 2015) and obtained the types of plankton.

Identification to the lowest feasible taxon using regional keys. Microscopy at 400×. Counting by Sedgwick-Rafter chamber (1 mL) with ≥[state number] fields enumerated per sample; counts converted to cells L^{-1} (phytoplankton) and ind. L^{-1} (zooplankton). Taxonomic quality control: Cross-checked spelling and current nomenclature; ambiguous taxa flagged with "sp."

Measurement of Environmental Parameters

In addition to plankton analysis, there are also measurements of environmental parameters in the form of physical (temperature and brightness) and chemical conditions (pH, DO, TSS, NO_3, NO_2, PO_4, Fe, Mn, COD, $CaCO_3$) of river waters at each study location.

Furthermore, measurements of physical and chemical parameters will be carried out at the Chemistry Engineering Laboratory of Riau University.

Plankton Abundance

Plankton abundance can be calculated based on the American Public Health Association formula in (Susanti, 2010) with the following formula (Equation 1), where N is the total plankton abundance (cells/L and ind/L) and chopped plankton number (n) (cell/L and ind/L), a is area of field of view (1,000 mm^2), v is filtered volume, A is area of glass covered (1,000 mm^3), Vc is volume of water (1 milliliter) under the cover glass, V is the volume of filtered water (100 L).

$$N = n\ x \frac{A}{a} x \frac{v}{Vc} X \frac{1}{V} \qquad (1)$$

Then, the results of plankton abundance level were determined using a standard by (APHA; AWWA; WEF , 2012), (see Table 1).

Table 1. Standard for abundance level of water within the number of plankton abundance

Water type	Abundance level	Number of plankton
Oligotrophic	Low	0 – 2,000 cell/L
Mesotrophic	Medium	2,000 – 15,000 cell/L
Eutrophic	High	>15,000 cell/L

Plankton Density

The plankton density detected by the Sedgwick rafter counter cell (SRCC) was then calculated using the following formula (Equation 2), which was derived from (Witariningsih *et al*., 2020) where DA is absolute density of plankton cells of genus A (cells/m^3), V1 is filtered water volume (m^3), V3 is volume of sample fraction (mL), V2 is plankton sample volume (mL), π = 3.14 or 22/7, r is the radius of the net mouth (m) and t is depth of vertical withdrawal of the net (m) (without flow meter $V1 = \pi r\ 2\ tt$).

$$DA = \frac{1}{V1}\ X\ \frac{V2}{V3} (number\ of\ genus\ A\ cells\ \text{x} \frac{1000}{number\ of\ grids\ observed}) \qquad (2)$$

Diversity Index

The diversity index value is used to determine the level of plankton diversity in a population. The diversity index is calculated using the Shannon-Wiener method (H') (Witariningsih et al., 2020). The formula follows Equation 3, where H' represents diversity index, and pi represents number of cells - i divided by total number of cells (Ni / N).

$$\text{H} = -\sum \text{pi In pi} \qquad (3)$$

Then, the diversity index level was determined using a standard by (Rahmatullah et al., 2016) (Table 2).

Table 2. Standard for diversity index of plankton

Diversity index score (*H'*)	Category level
$H' \leq 2.0$	Low
$2.0 < H' \leq 3.0$	Medium
$H' \geq 3.0$	High

Equitability Index

The equitability index is used to determine the distribution of biota in a water area, especially plankton, if the level of equitability is high, it can be said that the distribution of biota in the total water body (Pratiwi, 2017). To calculate the plankton equitability index using Equation 4 (Soebhakti et al., 2017), where E represent equitability index, H' represents diversity index, and H' max represents ln S (S is number of species found).

$$\text{E} = \frac{\text{H}'}{\text{H}'\text{Max}} \qquad (4)$$

Then, the equitability index level was determined using a standard by Rahmatullah et al. (2016), (see Table 3).

Table 3. Standard for equitability index of plankton

Equitability index (*E*)	**Category level**
$0 < E \leq 0.50$	Under pressure
$0.50 < E \leq 0.75$	Unstable
$0.75 < E \leq 1$	Stable

Dominance Index

The dominance index is used to see the presence or absence of dominance levels by certain species in the plankton community. The calculation of the dominance index can be determined using the dominance index (Witariningsih et al., 2020), as follows Equation 5, where D represents dominance index, Ni represents number of cells - i, and N represents total number of cells.

$$D = \left(\frac{n_i}{N}\right) \qquad (5)$$

Then, the dominance index level was determined using a standard by Rahmatullah et al. (2016), (see Table 4).

Table 4. Standard for dominance index of plankton

Dominance index score (*D*)	**Category level**
0 – 0.50	Low
0.50 – 0.75	Medium
0.75 - 1	High

Saprobity Index

Through trosap analysis, the saprobity value of a water body is determined using the saprobity index. The amount of pollution load in the ecosystem in the study area will be described by this saprobity index. The formula (Equation 6) is used to calculate the saprobity index (Odum, 1993) where IS represents saprobity index, A is number of species of polisaprobic organisms, B is the total number of α-mesosaprobic organism species, C is the total number of species of β-mesosaprobic organisms and D is the total number of species of oligosaprobic organisms. The degree of water pollution is directly correlated with the saprobity index score (Dresscher & van der Mark, 1974).

$$IS = \frac{1C+3D-1B-3A}{1A+1B+1C+1D} \qquad (6)$$

The Table 5 below explains how the saprobity index is interpreted for each pollution level.

Table 5. Standard for saprobity index of plankton

Polutant	**Pollution level**	**Saprobity level**	**Saprobity index**
Organic matter	Very high	Polysaprobic	-3.0 until -2.0
	High	Poly/α-mesosaprobic	-2.0 until -1.5
		α-meso/ polysaprobic	-1.5 until -1.0
		α-mesosaprobic	-1.0 until -0.5
Anorganic matter	Medium	α/β-mesosaprobic	-0,5 until 0,0
		β/α-mesosaprobic	0,0 until 0,5
	Low	B-mesosaprobic	0,5 until 1,0
		B-meso/polysaprobic	1,0 until 1,5
	Very low	Oligo/β-mesosaprobic	1,5 until 2,0
		Oligosaprobic	2,0 until 3,0

This study covers the environmental conditions of river waters in three sub-districts in the Sail River area, with a focus on plankton habitat. The data comprises physical parameters (temperature, current velocity, Total Suspended Solids - TSS, Total Dissolved Solids - TDS, and brightness) and chemical parameters (Dissolved Oxygen - DO, pH, phosphate, and nitrate). The analysis of these environmental conditions was based on results provided by the laboratory responsible for analyzing the physical and chemical parameters of the river waters.

RESULTS AND DISCUSSION

Plankton Abundance

The highest abundance of zooplankton at the Site A and Site B was *Oithona* sp. and the lowest abundance was Calanus sp. The highest abundance of zooplankton at Site C was Calanus sp. and the lowest abundance was *Eurytemora affinis*. As for the abundance of phytoplankton, the highest abundance found at Site A was *Phacus chloroplastes*. while at Site B the highest abundance were *Fragillariaopsis* sp., *Closteriopsis longissime*, *Selenastrum gracile*, *Excentrosphaera viridis*, *Pediastrum duplex*, *Dactylococcopsis acicularis*, and *Tribonema utriculosum*. Then, at Site C, the highest abundance was *Bacillaria paradoxa*, *Characium acuminatum*, *Protococcus viridis*, *Schizogonium* sp. (Table 6).

Table 6. Table of plankton diversity and abundance in three points at Sail River, Pekanbaru City, Riau, Indonesia

Class	Species	Sail River (ind/L)		
		Site A	Site B	Site C
Zooplankton				
Copepoda	*Calanus sp.*	113,941.7	96,800.0	156,291.7
Copepoda	*Oithona sp.*	161,333.3	188,558.3	155,283.3
Heterotrichea	*Stentor sp.*	121,000.0	136,125.0	133,100.0
Maxillopoda	*Eurytemora affinis*	146,208.3	168,391.7	124,025.0
Phytoplankton				
Bacillariophyceae	*Aulacoseira alpigeno*	8066.7	5041.7	5041.7
	Aulacoseira crenulata	5041.7	8066.7	6050
	Aulacoseira subaretica	5041.7	4033.3	7058.3
	Bacillaria paradoxa	3025	5041.7	9075
	Climacosphenia moniligera	6050	5041.7	4033.3
	Cocconeis scutellum	7058.3	8066.7	5041.7
	Cyclotella meneghiniana	7058.3	5041.7	5041.7
	Cyclotella bodanica	8066.7	3025	3025
	Cymbella ehrenbergii	3025	5041.7	3025
	Dactyliosolen sp.	3025	5041.7	8066.7
	Eunotia bilunaris	7058.3	5041.7	4033.3
	Eunotia rhomboidea	5041.7	3025	3025
	Fragillariaopsis sp.	6050	9075	8066.7
	Melosira varians	4033.3	5041.7	6050
	Navicula distans	3025	3025	5041.7
	Ophiocytium cochleare	6050	3025	7058.3
Bacillariophyceae				
	Ophiocytium parvulum	5041.7	4033.3	4033.3
	Rhizosolenia imbricata	8066.7	5041.7	4033.3
	Skeletonema subsalsum	5041.7	6050	5041.7
	Surirella elegans	9075	8066.7	5041.7
	Synura uvella	3025	5041.7	8066.7
	Tabellaria fenestrara	5041.7	7058.3	3025
	Thalassionema nitzschioides	5041.7	3025	7058.3
	Thalassiosira fluviatilis	6050	8066.7	4033.3
Branchiopoda				
	Podon polyphemoides	6050	5041.7	5041.7
Charophyceae				
	Staurastrum prionotum	6050	5041.7	4033.3

Class	Species	Sail River (ind/L)		
		Site A	**Site B**	**Site C**
Chlorophyceae				
	Characium acuminatum	5041.7	6050	9075
	Closteriopsis longissime	8066.7	9075	3025
	Cosmarium decoratum	3025	3025	4033.3
	Excentrosphaera viridis	8066.7	9075	6050
	Fragillariaopsis sp.	3025	5041.7	4033.3
	Leponcilis sp.	5041.7	6050	7058.3
	Oedogonium pyriforme	4033.3	4033.3	6050
	Oedogonium urceolatum	4033.3	5041.7	7058.3
	Pediastrum duplex	7058.3	9075	3025
	Penium cylindrus	9075	6050	4033.3
	Protococcus viridis	7058.3	5041.7	4033.3
	Schizogonium sp.	5041.7	5041.7	6050
	Selenastrum gracile	6050	9075	3025
	Stigeoclonium subsecundum	7058.3	6050	8066.7
	Tetraedron muticum	6050	5041.7	5041.7
	Tetraedron sp.	4033.3	5041.7	4033.3
	Zygnemompsis spiralis	3025	5041.7	4033.3
Chroococcophyceae				
	Chroococcus dispersus	3025	4033.3	5041.7
	Dactylococcopsis acicularis	7058.3	9075	6050
	Dactylococcopsis smithii	5041.7	6050	3025
Chrysophyceae				
	Chrysosphaerella longispina	6050	4033.3	4033.3
Conjugatophyceae				
	Cylindrocystis brebissoni	8066.7	4033.3	3025
	Cylindrocystis crassa	6050	4033.3	3025
	Eustridium subhypochondrum	5041.7	7058.3	3025
Coscinodiscophyceae				
	Coscinodiscus sp.	5041.7	7058.3	4033.3
Cyanophyceae				
	Anabaena subcylindrica	7058.3	6050	8066.7
	Gloetrichia natans	3025	3025	5041.7
	Nodularia spumigena	7058.3	3025	5041.7
	Oscillatoria acutissima	7058.3	4033.3	5041.7
	Oscillatoria limosa	3025	5041.7	6050
	Oscillatoria princeps	5041.7	4033.3	3025
Cyanophyceae				
	Oscillatoria tenuis	3025	3025	5041.7
	Oscillatoria limnetica	3025	5041.7	7058.3
	Spirulina major	6050	7058.3	6050
Euglenophyceae				
	Oscilatoria limnosa	7058.3	8066.7	6050
	Phacus chloroplastes	10083,3	4033.3	4033.3
	Phacus curvicauda	4033.3	5041.7	3025
Flagilariophyceae				
	Flagilaria robusta	4033.3	7058.3	5041.7
Florideophyceae				
	Batrachosperium sp.	3025	3025	4033.3
	Stigonema mamillosum	3025	3025	5041.7
Klebsormidiophyceae				
	Elakatothrix gelatinosa	3025	4033.3	3025

Class	Species	Sail River (ind/L)		
		Site A	Site B	Site C
Ulvophyceae				
	Spirogyra setiformis	4033.3	7058.3	7058.3
Xantophyceae				
	Tribonema utriculosum	6050	9075	4033.3
	Chlorellidiopsis separabilis	3025	6050	7058.3
Zygnemophyceae				
	Closterium aciculare	5041.7	4033.3	6050
	Closterium cornu	3025	4033.3	7058.3
	Closterium lunula	3025	5041.7	6050
	Closterium pusillum	5041.7	5041.7	6050
	Closterium spirostriolatiform	7058.3	5041.7	4033.3
	Closterium striolatum	3025	5041.7	4033.3
	Pleurotaenium subcoronulatum	4033.3	3025	4033.3
	Pleurotaenium verrucosum	4033.3	5041.7	6050

The lack of zooplankton abundance that found from the zooplankton composition is less than phytoplankton. This is a natural condition of the water because zooplankton is at the second trophic level that feeds on phytoplankton and is also a source of energy (food) for Crustaceans at the third level. Another factor that causes low zooplankton populations is the presence of carnivorous and omnivorous fish living in the waters (Indrayani et al., 2014). This is in accordance with the existing conditions which carnivorous fish such as Toman fish habitat in Sail River. The highest zooplankton abundance is at Site B and Site C where the availability of food in this river is sufficient and in accordance with the needs of zooplankton. As is known that food is the main factor affecting zooplankton growth. Food for zooplankton is phytoplankton, in this river there is a sufficient amount of phytoplankton abundance that causes zooplankton to grow well because food is available for zooplankton (Hasanah et al., 2014). While the lowest abundance is at Site A, this is because the amount of phytoplankton abundance is insufficient for zooplankton to survive in the river, besides that it is also a factor of physicochemical parameters that affect the abundance of phytoplankton.

The highest zooplankton abundance of the three points expressed per individual was *Oithona* sp. found at Site B, with water conditions that are mesotrophic (moderate). The abundance of zooplankton that dominates is one of the species *Oithona* sp. This is because the *Oithona* sp. is a species from the protozoa division where the presence of this division in the waters greatly determines the stability of the aquatic ecosystem (Yuliati et al., 2018). When viewed in terms of food, where the food of zooplankton is phytoplankton, this is inversely proportional to the condition of phytoplankton abundance at Site A, where the abundance of phytoplankton at Site A is the lowest abundance compared to the abundance at Site B and Site C, but as is known from the results zooplankton is higher in abundance at Site A, This is due to environmental conditions at the time of sampling, namely in rainy conditions so that with these conditions zooplankton at Site A can survive these rainy conditions compared to zooplankton at Site B and Site C, besides that due to chemical-physical parameter factors that support the survival of zooplankton, namely the high parameter value of each parameter at Site A compared to Site B and Site C. As for the lowest abundance was *Calanus* sp, this is due to several low physico-chemical factors that affect the survival of plankton in the river (Yuliana, 2012).

The highest phytoplankton abundance of the three points expressed per individual was Phacus chloroplastes found at Site A (N = 10083.3 ind/L), with water conditions that are mesotrophic (moderate), where the abundance of phytoplankton dominates is from the class of euglenoidea (Ramadansyah & Rozyati, 2022). This condition is because Euglenoidea is waters with high organic matter content due to the nature of Phacus (Euglenophyta) which is sensitive to rich organic matter content.

Euglenophyceae (Phacus) and Oscillatoria blooms are linked to organic loading and low DO, their prevalence at Site A corroborates domestic inputs. Diatoms (Bacillariophyceae) benefit from higher flow and light, explaining Site C patterns. Indices coherence Lower H′ and J′ under higher COD/low DO (Site A) reflect stress and potential competitive dominance of tolerant taxa. Increasing H′ and J′ with clarity/DO at Site C indicate more even resource partitioning. Mesotrophic phytoplankton abundances align with low–moderate, arguing against widespread eutrophication. localized organic enrichment rather than nutrient over-enrichment is the dominant pressure. Copepod dominance by Oithona in turbid, organically enriched water is documented, the shift to Calanus at clearer Site C supports bottom-up and habitat-structure effects.

Diversity Index

The highest zooplankton diversity index is found at Site A and Site C with the amount of diversity (H') which is 1.38 and the lowest diversity (H') at Site B which is 3.04. As for the diversity index (H'), the highest phytoplankton is found at Site C with a total diversity (H') of 3.28 and the lowest at Site A with a total diversity of H' which is 2.07.

Zooplankton diversity ranges in the medium category (H'= 1.38-1.48), offers significant ecological insights and potential study implications. Zooplankton play a critical role in aquatic ecosystems as primary consumers, linking primary producers (e.g., phytoplankton) with higher trophic levels, including fish and other predators. Thus, understanding their diversity is essential for evaluating ecosystem health and stability (Lukman, 2019). As for phytoplankton diversity (H') ranges in the high-low category, where high diversity is at Site C, where high or stable diversity indicates that the species of organisms are highly variable and supported by environmental factors that are very good for all species living in the habitat, besides that the value of the diversity index has a large value if all individuals come from different genus or species (Rahmatullah et al., 2016).

Equitability Index

The highest is found at Site A and Site C with a total equitability (E) of 1.99 and the lowest at Site B with a total equitability (E) of 1.95. For the equitability index (E) in phytoplankton, the highest is found at Site A and Site C with a total equitability (E) of 0.98 and the lowest at Site B with a total equitability (E) of 0.87. The zooplankton are in the stable category at all three points at Sungai Sail Riverline, where a balanced or stable community indicates that the ecosystem has high diversity and there is no dominant species, meaning that the distribution of the number of individuals is the same or evenly distributed. While the equitability (E) of phytoplankton is in stable-suppressed, where stable equitability is at the Site C, where a balanced or stable community indicates that the ecosystem has high diversity and there is no dominant species, meaning that the distribution of the number of individuals is the same or evenly distributed. Equitability is depressed at Site A and Site B. Where the lower the equitability value, the lower the species equitability in a community, meaning that the distribution of each individual per species is said to be unbalanced, with a tendency for certain types to dominate (Rahmatullah et al., 2016).

Dominance Index

Dominance (D) in zooplankton is highest at the Site B with a total dominance (D) of 0.26 and the lowest at the Site A and Site C with a total dominance (D) of 0.25. Dominance (D) in phytoplankton is highest at the Site B with a total dominance (D) of 1.97 and the lowest at the Site A and Site C with a total dominance (D) of 0.01. The dominance (D) of zooplankton is in the low category (D = 0.25-0.26), suggests an ecological state characterized by relatively balanced species distribution, where no single species significantly outcompetes others. This finding has several ecological, environmental, and management implications, which are explored below (Rahmatullah et al., 2016).

Saprobity Index

The saprobity index of zooplankton and phytoplankton is very low at Site C with a total of 1.8 and a low saprobity index at Site A of 0.9, which Site C is the inlet of the residential area that carries organic and inorganic waste, so this study is in line with the waters of the mountain situ polluted by anthropogenic waste that affects the value of the saprobity index. and also, in taking water samples the weather is not favorable and the water discharge rises so that the overflow of waste from upstream in the form of household waste. The level of saprobity is strongly influenced by the proximity of water bodies to human settlements, sedimentation, and organic and inorganic pollutants that enter the waters (Dresscher & van der Mark, 1974). In general, the saprobity index value in the Sail River which ranges from 0.9 to 1.8 causes these waters to be classified as β/α-mesosaprobic category with organic and inorganic pollutant loads, included in the mild pollution level because it is in the range up to 1.8 (Oktavia et al., 2015).

Table 7. Abundance, Saprobity level, Diversity index (*H'*), Equitability index (*E*), and Dominance index (*D*) of plankton for each point at study sites

Species	Parameter	Site A	Site B	Site C
Zooplankton	Abundance	High	High	High
	Saprobity	Low	Low	Very Low
	H'	1.38	1.36	1.48
		Medium	Medium	Medium
	E	1.99	1.95	1.99
		Stable	Stable	Stable
	D	0.25	0.26	0.25
		Low	Low	Low
Phytoplankton	Abundance	High	High	High
	Saprobity	Low	Low	Very Low
	H'	2.07	3.04	3.28
		Low	Low	High
	E	0.98	0.87	0.98
		Under pressure	Under pressure	Stable
	D	0.01	1.97	0.01
		Low	High	Low

Environmental Condition (Physical and Chemical Parameter Measurements)

To characterize the environmental conditions associated with plankton communities, selected physical and chemical water-quality parameters were measured at the three Sail River sampling sites. The physical assessment included water temperature and transparency, while the chemical assessment comprised dissolved oxygen (DO), pH, total suspended solids (TSS), nitrate (NO_3^-), nitrite (NO_2^-), phosphate (PO_4^{3-}), iron (Fe), manganese (Mn), chemical oxygen demand (COD), and hardness expressed as $CaCO_3$. These measurements provide complementary information on habitat conditions, nutrient availability, suspended matter, organic loading, and potential chemical stress. The site-level values and relevant reference limits are presented in Table 8 and were subsequently interpreted descriptively in relation to the observed plankton-community patterns.

Table 8. Physicochemical characteristics of water at the three Sail River sampling sites

No	Parameter	Unit	Max. result	Point A	Point B	Point C
Physical parameter						
1	Temperature	°C	–	28°	25°	28°
2	Brightness	cm	–	D1 = 7 D2 = 5	D1 = 19 D2 = 8	D1= 20 D2 = 12
Chemical parameter						
3	DO	mg/L	Min. 6	4,488	5,304	7,440

No	Parameter	Unit	Max. result	Point		
				A	B	C
2	pH	-	6-9	5.2	6.1	5.8
3	TSS	mg/L	-	0.03	0,02	0,02
4	NO_3	mg/L	10	0.0646	0.0646	0.0542
5	NO_2	mg/L	-	0.0759	0.0759	0.0654
6	PO_4	mg/L	0,5	0.0686	0.0730	0.0642
7	Fe	mg/L	0,3	0.251	0.205	0.194
8	Mn	mg/L	0,4	0.871	0.922	0.652
9	COD	mg/L	-	120	50	50
10	$CaCO_3$	mg/L	-	150	100	100

Different values are obtained that affect the structure of the plankton community, where the temperature at the three points is the optimal temperature for the growth of plankton organisms. The temperature that can be tolerated by organisms in the waters ranges from 20-30°C, and the optimal temperature for phytoplankton growth in the waters ranges from 25-30°C, while the optimal temperature for zooplankton growth ranges from 15-35°C. However, when compared to the abundance of plankton (zooplankton and phytoplankton), the temperature at the Site C did not affect the abundance of plankton (zooplankton and phytoplankton), because from the results of plankton data obtained, plankton (zooplankton and phytoplankton) at the Site A has the lowest abundance compared to the Site B and the Site C While for the Site C, the temperature affects the abundance of plankton (zooplankton and phytoplankton). This is because at the time of plankton sampling at the Site C the weather conditions were not favorable (rain), thus affecting the abundance of plankton (zooplankton and phytoplankton) (Ilham et al., 2020).

In addition, at the Site B the temperature is low because it is enclosed by shady trees, physical parameter factors such as brightness at three types of points have different values as well as at the Site C with an initial brightness of 20 cm and a final brightness of 12 cm, indicating that the brightness at the Site C has a higher value than the Site A and the Site B , This is due to the rain that fell at the time of the brightness measurement so that heavy water flows from the first to the downstream, while for the Site A and Site B the sunlight is normal so the brightness is lower, where the initial brightness of the Site A is 7 cm and the final brightness is 5 cm, while at the Site B the initial brightness is 19 cm and the final brightness is 8 cm (Ilham et al., 2020).

The condition of water chemical factors can also affect the structure of the plankton community, where according to the results of the study that has been obtained that DO has no effect, because phytoplankton abundance will increase with higher levels of dissolved oxygen in water bodies, but this is inversely proportional or not in accordance with the results obtained that the DO produced from the three points is actually lower, while the abundance is high. Temperature and ph levels could be the other factors can influence the community structure at the study site (Puspita, 2016).

pH has no effect, because the pH = 5.8 is relatively low at the Site C, while at the Site B it is optimal (pH = 6.1), but the high pH value also determines the dominance of phytoplankton which affects the level of primary productivity in the aquatic environment. However, from the results of the study, there was no plankton that dominated (Faturohman et al., 2016).

NO_3 has no effect because phytoplankton grows optimally if the required nitrate levels are between 0.9 - 3.5 mg/L. However, when viewed from the results of the study, NO_3 is not included in the optimal levels and when viewed from the levels of each NO_3 in the three types of columns that the nitrate levels at the Site C are lower than the B and Site C s so that if the NO_3 levels are lower at the Site C then the abundance of plankton will be less but this is inversely proportional to the results of plankton abundance in this study. But if the optimal level of NO_3 >5 then anthropogenic will occur (Dewanti et al., 2018).

PO_4 has no effect because the high content of PO_4 in the waters will cause blooming in phytoplankton and result in the dominance of plankton organisms. For blooming that occurs in phytoplankton, this does not occur at all three points and for dominance when viewed from the highest PO4 levels, namely at the Site B, when viewed from study information conducted that the Site B in the Sail River is the remnants of household waste, while in the waters of the Sail River 0.07 mg/L. The range of phosphate content for natural waters is less than 1 mg/l, then the Sail River is still in natural waters (Yolanda, 2020).

Nitrite levels in waters are rarely >1 mg/L. Nitrite levels greater than 0.05 mg/L can be toxic to organisms. Pattern of nitrite distribution in waters. In general, the distribution pattern of nitrite can be seen in the area of Site A and Site B were the station with the highest nitrite concentration at the study site and Site C is the station with the lowest nitrite concentration value. The A and Site Bs also have quite high nitrite concentrations. The high nitrite concentration when viewed from environmental factors is thought to be caused by low dissolved oxygen concentrations at the sampling point. The concentration of nitrite compounds will increase with lower dissolved oxygen (Kasri & Fajri, 2012).

Fe has no effect because Fe has many positive impacts. With this, when viewed from the measurement results at the three points with a maximum limit of 0.2 mg/L, the good point for living plankton was at Site A and Site B, which is characterized by the abundance of plankton in it, but this is inversely proportional where the abundance of plankton at Site C is actually lower than Site A which has high Fe levels (Effendi, 2003).

Mn has an effect because manganese in small amounts is beneficial for growth and tissue formation, with this can be seen from the maximum level of 0.4 mg/L points that have less manganese levels will have a high abundance, this is in line with the results of manganese measurements at the Site C (0.871) which has a level of 0.1 with a higher abundance at the Site B (0.922) of the column compared to the Site A (0.652) (Effendi, 2003).

COD is influential because high COD values result in poor oxygen content in water bodies thus disrupting aquatic ecosystems. Sungai Sail Riverline as a primary drainage channel certainly receives liquid waste from activities in the watershed. Domestic waste from households can be in the form of kitchen scraps such as fish meat, fish bones, laundry water containing food scraps and detergent and soap residues (Febrina & Ayuna, 2015). In addition, COD sources at Sail River are also suspected to come from hotel and hospital waste. The results of monitoring by (Andika et al., 2020) that hotel and hospital waste in Pekanbaru City contains COD concentrations that have exceeded the standard.

TSS has a significant effect on aquatic ecosystems because high TSS levels can reduce the availability of dissolved oxygen in the water. This reduction can lead to anaerobic conditions, causing the death of aerobic organisms. In the research results, TSS levels at points B and C were lower than at point A, which positively influenced the plankton abundance at those points. Conversely, at point C, the high TSS concentration resulted in low plankton abundance, highlighting the negative impact of elevated TSS levels on aquatic biota (Juhar & Chalid, 2018). For freshwater ecosystems, many environmental agencies recommend TSS levels below 25-80 mg/L to prevent negative impacts on aquatic life, depending on the water body (Winnarsih et al., 2016).

$CaCO_3$ has an effect because $CaCO_3$ with a soft category is good enough to support plankton life, so when viewed from the level of awareness at the three sample points the lowest level is at Site A and this is in line with the abundance which is a high multiple of Site B and Site C. The formation of $CaCO_3$ (calcium carbonate) compounds in water is influenced by the chemical equilibrium between calcium ions (Ca^{2+}), carbonate ions (CO_3^{2-}), and bicarbonate ions (HCO_3^-), such as dissolution of CO_2 in water, dissociation of carbonic acid, calcium ions in solution and precipitation, which The calcium carbonate formed can precipitate out of solution, especially in conditions where the concentration of Ca^{2+} and CO_3^{2-} ions is high or if the water becomes oversaturated with $CaCO_3$. Precipitation is more likely when the water is warmer, has a higher pH, or when the concentration of dissolved CO_2 is low (Atkins & de Paula, 2014).

Taken together, the physicochemical and biological data indicate site-specific differences in ecological condition along the Sail River. Site A showed the clearest indication of organic stress, as reflected by the highest COD concentration, the lowest dissolved oxygen level, the lowest water transparency, and the lowest phytoplankton diversity. The high abundance of *Phacus chloroplastes* at this site is consistent with conditions influenced by organic enrichment, although a general increase in Cyanophyceae was not clearly demonstrated. In contrast, Site C had the highest dissolved oxygen concentration and water transparency, together with the highest phytoplankton diversity, suggesting comparatively more favorable habitat conditions. Nitrate and phosphate concentrations differed only slightly among sites and did not indicate a strong spatial nutrient gradient. Therefore, the observed plankton-community patterns were more plausibly associated with the combined effects of organic load, oxygen availability, water transparency, and site-specific habitat characteristics. Zooplankton patterns should be interpreted cautiously because relative dominance and associations with environmental variables were not tested statistically.

CONCLUSION

A total of 106 plankton taxa were identified in the Sail River during sampling in December 2022, comprising both phytoplankton and zooplankton communities. Phytoplankton diversity was highest at Site C, while zooplankton diversity remained low to moderate across the three sites, with no clear evidence of strong single-species dominance. The combined saprobity and physicochemical results indicated mild organic pollution and site-specific environmental stress rather than an entirely unpolluted condition.

Site A showed the strongest indication of organic pressure, characterized by the highest COD concentration, the lowest dissolved oxygen level, the lowest pH, and the lowest water transparency. Sites A and B had dissolved oxygen concentrations below the reference value, while elevated manganese concentrations were recorded at all sampling sites. In contrast, Site C showed comparatively more favorable conditions, including higher dissolved oxygen, greater water transparency, and higher phytoplankton diversity. These patterns suggest that plankton-community structure was descriptively related to variations in organic load, oxygen availability, acidity, and habitat conditions.

Because the study was conducted during a single sampling period and relied on site-level composite samples, the findings represent a preliminary ecological assessment of the Sail River. Seasonal monitoring, independent replication, improved taxonomic verification, and multivariate analysis are required to identify consistent environmental drivers and provide a more robust assessment of the river's ecological status.

RECOMMENDATION

Future research should focus on seasonal and long-term monitoring of plankton community dynamics in the Sail River to better understand temporal variations in water quality and ecosystem stability. Further studies are also recommended to investigate the relationship between anthropogenic activities, such as domestic waste disposal, urban runoff, and land-use changes, with plankton diversity and abundance. In addition, the application of molecular identification methods and multivariate statistical analyses could provide more accurate identification of plankton species and stronger interpretation of environmental influences on plankton communities. Comparative studies between polluted and unpolluted river systems are also suggested to improve the use of plankton as bioindicators of freshwater ecosystems.

Several barriers and limitations may influence the results of this study. Environmental factors such as rainfall intensity, river flow fluctuations, seasonal changes, and uneven distribution of plankton populations may affect sampling accuracy and community composition. Limitations in sampling frequency and spatial coverage could also reduce the representation of actual river conditions. In addition, some physico-chemical parameters may vary rapidly over time, causing differences between observed water quality and real environmental conditions. The identification of plankton species based solely on morphological characteristics may also lead to potential misidentification, especially for species with similar morphology.

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AUTHOR CONTRIBUTIONS STATEMENT

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Irwan Effendi				✓	✓		✓			✓		✓		✓

CONFLICT OF INTEREST STATEMENT
Authors state no conflict of interest.

DATA AVAILABILITY
- The data that support the findings of this study are openly available in [Pollution Research. 37 (4): 859 – 871] at https://doi.org/10.13170/depik.13.2.35403
- The data that support the findings of this study will be available in [Berkala Perikanan Terubuk. 40 (2): 96-113] [https://adoc.pub/kualitas-perairan-muara-sungai-siak-ditinjau-dari-parameter-.html].

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