The University of Tehran Press

Pollution

Print ISSN: 2383-451X
Online ISSN: 2383-4501

https://jpoll.ut.ac.ir/

Understanding Plankton Community in the Post-mining Lake of Paringin District for Environmental and Reclamation Assessment

Radisya Ikhsan[1] | Novi Kartika Sari[2]✉ | Achmad Gus Fahmi[3] | Didik Triwibowo[4] | Hanifullah Habibie[4] | Dodik Choiron[4] | Dwi Yuli Hastuti[4]

1. Undergraduated student Environmental Engineering Program, Institut Teknologi Sumatera, Ryacudu Street, Lampung, 35365, Indonesia.
2. Environmental Engineering Program, Institut Teknologi Sumatera, Lampung, 35365, Indonesia.
3. Cosmetic Engineering Program, Institut Teknologi Sumatera, Lampung, 35365, Indonesia.
4. Health Safety & Environment Division, PT Adaro Indonesia, South Kalimantan, 71513, Indonesia.

Article Info

Article type:
Research Article

Article history:
Received: 9 July 2023
Revised: 19 September 2023
Accepted: 17 December 2023

Keywords:
Diversity
Dominance
Plankton
Post-Mining Lake
Saprobic Index

ABSTRACT

Paringin District is one of the coal mining areas in South Kalimantan with the exploitation method of open pit mining. This activity opens rock layers containing sulfur, reacting with water and oxygen, spreading sulfide acid into the environment. Analysis of the water quality of the Post-mining Lake in Paringin District is needed based on the biological parameters. The objective aims to analyze the water quality of the Post-mining Lake, Paringin District, based on plankton's abundance, diversity, and dominance. This research was located in Post-mining Lake, PT. Adaro Indonesia. Data were taken at three sampling points in the pit pond and three depths. Data was taken from 2019 to 2021 using plankton net and analyzed using the enumeration method. The data was processed using the diversity index, dominance index, and saprobic index. Phytoplankton and Zooplankton abundance were dependent on three different depths (p-value>0.05). The most abundant phytoplankton species in all stations was Oscillatoria sp. (>90%) while Nauplius sp. (>30%) for zooplankton. Rainfall in the study area affected the number of individual species very weakly. The highest dominance value of phytoplankton and zooplankton was recorded around the end of 2019 to early 2020 as well as a saprobic index and diversity. Crustacea class considerably exists in all sites, which is Nauplius sp. and Daphnia sp. This situation proved there was a recovery of the plankton population in the lake, no algae blooming and a balance between nutrients and plankton population. In fact, the aquatic habitats are ready to accommodate large ecosystems.

Cite this article: Ikhsan, R., Kartika Sari, N., Gus Fahmi, A., Triwibowo, D., Habibie, H., Choiron, D., & Hastuti, D. Y. (2024). Understanding Plankton Community in the Post-mining Lake of Paringin District for Environmental and Reclamation Assessment. *Pollution*, 10 (1), 183-200.
https://doi.org/10.22059/poll.2023.361962.1985

DOI: https://doi.org/10.22059/poll.2023.361962.1985

INTRODUCTION

Open mining cut operation has become a standard method of coal exploitation and causes pit lakes when the operation area is filled by ground, surface, and rain (Subowo G, 2011). Paringin District is one of the coal mining areas in South Kalimantan with the exploitation method of open pit mining. The open pit mining activity potentially threatens topsoil and soil organic matter (Mamodu et al., 2018). The activity also deteriorated hydrological function and declined biodiversity (Hermansyah et al., 2022). This activity opens rock layers containing sulfur, reacting with water and oxygen to spread sulfide acid into the environment (Ramadhan et al., 2020). In addition, coal mine acid water contaminated with sulfide acid and iron can spread

*Corresponding Author Email: *novi.sari@tl.itera.ac.id*

more widely outside the mining area (Arriaga et al., 2019). The release of sulfide acid into the environment can cause high acidity in soil and water, which could harm the ecosystem (Ross & Arnott, 2022). In addition, acid mine water can cause corrosion and dissolve metals which can potentially increase the value of acidity; this can damage mining infrastructure (Mdumela & Sengani, 2021).

Post-mining activities can leave pits filled with acid mine water in large volumes. Acid mine water cannot support the photosynthetic activity of phytoplankton, thereby inhibiting the growth of phytoplankton (Fengjie L et al., 2022). This situation can interfere with phytoplankton reproduction, reducing the number of phytoplankton individuals (Chaktraborty et al., 2021). A declined phytoplankton population can limit zooplankton food sources, reducing the total number of Zooplankton (Davis et al., 2020). This forming a post-mining lake that cannot support the life of aquatic biota.

The restoration of pit pond water quality will be significant in >10 years (Driscoll et al., 2016). The pit pond in Paringin District has been in operation for 22 years. Therefore, water quality analysis is neccesary to determine the recovery progress of the pit pond. Phytoplankton has an essential role as primary producers in aquatic ecosystems (Risacher et al., 2018). Given that the observation area is situated in a tropical country, the intensity of rainfall has the potential to significantly affect the behavior and distribution of phytoplankton. High rainfall can potentially diminish the quality of life for phytoplankton due to nutrient runoff from the surrounding pit pond area (Berger & Sweers, 1988). These conditions have impacts on plankton and their dominance. Consequently, research is required to investigate the relationship between rainfall and the abundance of plankton. The status of ecological systems can be further evaluated by measuring the diversity of phytoplankton (Berger & Bij De Vaate, 1983). Their diversity and abundance can reflect the ecosystem's resource supply (Effendi et al., 2016). As a post-mining activity, the pit lake is continuously monitored to assess whether the reclamation has succeeded. This study aims to understand the plankton community existing by measuring their diversity, dominance, and abundance in post-mining lake ecosystems.

MATERIALS AND METHODS

The location of this research is in Post-mining Lake, PT. Adaro Indonesia as a pit pond for the study area in Paringin District, Balangan Regency, South Kalimantan Province, Indonesia, Latitude -2.313999°, Longitude 115.481482° for the coordinates of the pit pond. The depth of the pit pond in the study area is 32.45 m with a volume of 2,509,710 m^3 (Sena Pradipta, 2017). This study focuses on analyzing the water quality of a 22-hectare pit pond. The coordinates for sampling and the depth of Post-Mining Lake Paringin can be seen in Figure 1 and Figure 2.

The study employed secondary data from PT. Adaro Indonesia, according to the certified third-party laboratory in the range of 2019 to 2021 for four quartiles in a year (March-Q1, June-Q2, September-Q3, and November-Q4). The samples were obtained from three stations representing the pond's inlet, middle, and outlet. At each sampling station, samples were collected in three depths of 0, 5 and 10 meters. Phytoplankton and zooplankton sampling was captured using a plankton net with a mesh size of 300 µm (Garcia et al., 2021) and were subsequently using the enumeration method (census-SRC) (Kadir et al., 2015).

The total of individual plankton species was analyzed in each quartile, then the diversity index, dominance index, and saprobic index were determined. Species abundance was estimated into seven categories and grades based on population size (Islam et al., 2022). The most abundance (>50%) denoted to A+ grade (very common). More than 15% of the population was A grade (common), while >5% were classified as A- or less common. Other categorizations were population >1% = B or Few, population >0.5% = B- or very few, population > 0.1%= C (rare), and population >0.05%= D (very rare). Species abundance was used to categorize

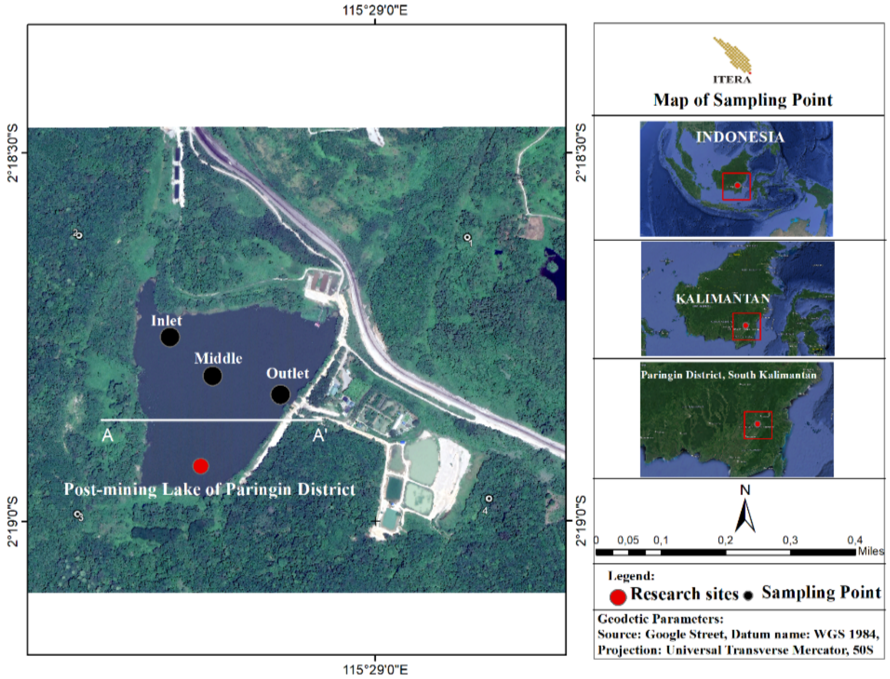

Fig. 1. The coordinate points for sampling

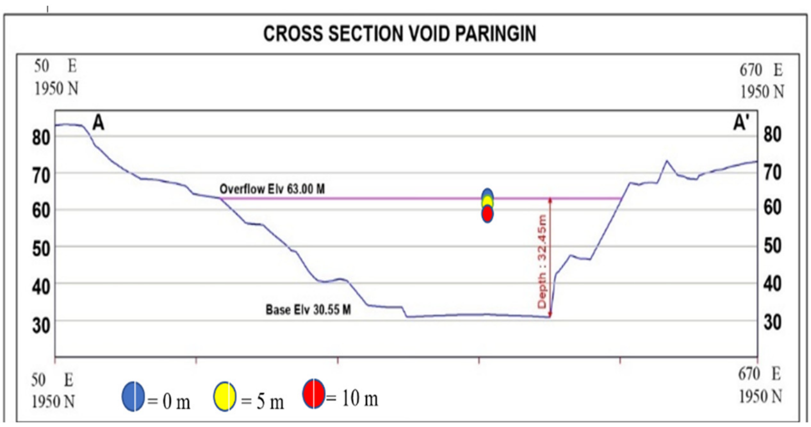

Fig. 2. The Depth of Post-mining Lake Paringin (source: PT. Adaro, 2019)

species based on the number of individuals in the observation area (Islam et al., 2022).

The Shannon-Wenner diversity index was determined using the following formula (1).

$$H' = -\sum_{i=1}^{n}\left(\left(\frac{ni}{N}\right) ln\left(\frac{ni}{N}\right)\right) \quad (1)$$

where: H' = Diversity index; ni = species number of each species; N = common organisms abundance. The diversity index was classified with the following classification: <1: Low diversity; 1<<3: Medium diversity; >3: High diversity. The diversity index was used to determine the level of diversity of plankton species in the study area (Hidayat et al., 2022).

The Simpson dominance index was determined as follows (Hidayat et al., 2022):

Table 1. Evaluation of the saprobic contamination

Polluter	Pollutant level	Saprobity level	Saprobity index
Organic	very high	Poly saprobic	-3.0–(-2.0)
Organic	high	Poly meso saprobic	-2.0–(-1.5)
Organic	high	α meso/poly saprobic	-1.5–(-1.0)
Organic	high	α meso saprobic	-1.0–(-0.5)
organic and inorganic	medium	α/β meso saprobic	-0.5–0.0
organic and inorganic	medium	β/α meso saprobic	0.0–0.5
organic and inorganic	Low	β meso saprobic	0.5–1.0
organic and inorganic	Low	β meso/oligo saprobic	1.0–1.5
organic and inorganic	very low	oligo/meso saprobic	1.5–2.0
organic and inorganic	very low	oligo saprobic	2.0–3.0

Source: (Resiana et al., 2021)

$$D = \sum_{i=1}^{n} \left(\frac{ni}{N} \right)^2 \qquad (2)$$

where: D = Simpson dominance index; ni = The proportion of each type I; N = The total number of individuals of all species in the habitat. The dominance index was classified with the following classification: <0.4: low; 0.4<<0.6: medium; >0.6: high. The dominance index was aimed to describe the dominance of a species in the study area (Hidayat et al., 2022).

The saprobic index as described by Resiana et al., (2021), was used to determine the level of water pollution in the study area based on phytoplankton species. The Saprobic index was determined using the following formula (3):

$$X = \left(\frac{C + 3D - B - 3A}{A + B + C + D} \right) \qquad (3)$$

Where: X = Saprobic coefficient; A = Number of species of poly saprobic organisms; B = Number of species of α meso saprobic organisms; C = number of species of β meso saprobic organisms; D = number of species of oligo saprobic organisms; A, B, C, and D were determined according to table of saprobic organisms classification according to (Resiana et al., 2021). The Evaluation of the saprobic index value was defined according to the total of phytoplankton species (see Table 1).

Regional rainfall was determined by processing daily rainfall data. Daily rainfall was obtained from Sanggu Station, Gusti Syamsir Alam Station, and South Kalimantan Station. Daily rainfall data was processed using the Thiessen Polygon method with the following formula (4) (Ajr & Dwirani, 2019):

$$P = \frac{A1.P1 + A2.P2 + \ldots + An.Pn}{A1 + A2 + \ldots + An} \qquad (4)$$

Where (Ezza Qodriatullah Ajr & Fitri Dwirani, 2019): P = Average of daily rainfall; Pn =

Rainfall at each station; and An = Area bounded by each polygon

Statistical analysis was employed non-parametric correlation analysis (p-value<0.05). The Spearman rank correlation test was carried out following these interpretation (Putrawiyanta, 2020): Value of 0,00-0,25 = Very weak; 0,26-0,50 = Enough; 0,51-0,75 = Strong; 0,76-0,99 = Very strong. Another statistical analysis was performed quarterly by the Kruskal-Wallis one-way analysis of variance method and examined at the 5% level of statistical significance. Data was then characterized by plankton's abundance, diversity, and dominance in all sampling of locations, depths, and seasons (wet and dry seasons).

RESULTS AND DISCUSSION

A list of plankton collected from the research sites is presented in Table 2. In Q3 2020 there was no data collected due to limited activity during the COVID-19 pandemic. A total of 14 plankton species were identified from all locations. A total of individual plankton was earned by 136,779,415 ind/m^3. It was obtained from 2019 by 92,017,458 ind/m^3, 2020 by 44,735,799 ind/m^3, and 2021 by 26,158 ind/m^3. The total of individual plankton base on sampling point was earned 34,935,693 ind/m^3 in the inlet point, 45,250,852 ind/m^3 in the middle point, and

Table 2. Total of individual species in the research sites

Species	Total of individual species in the research sites (ind/m^3)									
	Inlet			Middle			Outlet			Total
	0 m	5 m	10 m	0 m	5 m	10 m	0 m	5 m	10 m	
	Phytoplankton									
Nitzschia sp.	A-	A-	A-	A	A	A-	A-	A-	A-	A+
Navicula sp.	B	B	B	A-	B-	B	B	B	B	A
Filopaludina sp.	B	A-	C	A-	A-	A-	A-	B	A-	A+
Oscillatoria sp.	A+	A+	A+	A+	A+	A+	A+	A+	A+	A+
	Zooplankton									
Macrocyclops sp.	B-	A-	B	A-	B	D	A-	B-	D	A
Mesocyclops sp.	A	A-	C	B	B-	A	B	A-	A-	A+
Nauplius	A+	A	A+	A+	A+	A	A	A	A	A+
Thermocyclops sp.	A	A	A	A+	A-	A-	B	B	B	A+
Brachionus sp.	A	A-	A	A	A	A	A	A	A	A+
Pila sp.	D	D	D	D	D	D	D	D	D	D
Ceriodaphnia sp.	D	C	B-	B	B-	D	B	C	C	A-
Trichocerca sp.	B	D	D	A-	D	C	B	C	B	A-
Daphnia sp.	B	B	A-	D	B-	B	B	B	B	A

Note: A+ = The most abundance (>50%) (very common). A = > 15% of the population (common). A- = >5% or less common. B = >1% or Few, B- = >0.5% or very few, C = population > 0.1% or rare, D = >0.05% (very rare).

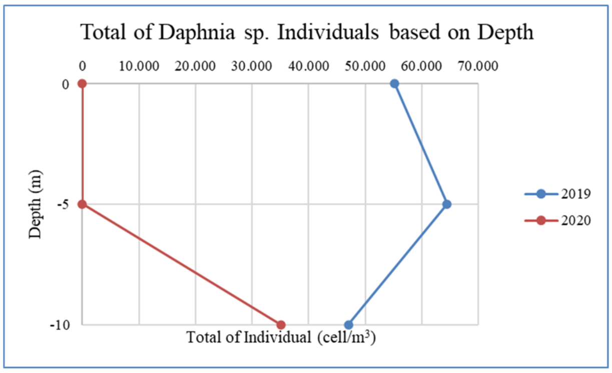

Fig. 3. Total of Daphnia sp. individuals based on depth

41,562,216 ind/m^3 in the outlet point. The average was obtained at 3 years by 375,262±46,001,642 ind/m^3. The average each year was obtained from 2019 by 800,219 ind/m^3±2,632,024.16 ind/m^3, 2020 by 325,557 ind/m^3±3,637,801.19 ind/m^3, and 2021 by 11 ind/m^3±3,625,652.34 ind/m^3. The maximum of phytoplankton was recorded 17.341.245 ind/m^3 in outlet point at Q4 2019 by Oscillatoria sp. The maximum of zooplankton was earned 405.972 in inlet point at Q1 2020 by Nauplius. The dominant phytoplankton was characterized as Bacillariophyceae class. Most Zooplankton were represented by the Crustacea class. The total individual phytoplankton was found to be 116,692,877 ind/m^3. while in zooplankton was found 20,039,186 ind/m^3.

Based on Kruskal-Wallis Test, phytoplankton and Zooplankton abundance were dependent on three depths (p-value>0.05). The highest number of individual Phytoplankton species in all stations was Oscillatoria sp. (>90%) (104,270,838 ind/m^3) or followed by Nitzschia sp. (1,510,693 ind/m^3) and Navicula. (5,02,616 ind/m^3) (See Table 2). The average of Oscillatoria sp. was earned 1.053.241 ind/m^3±2.944.317 ind/m^3. Furthermore, the highest number of individual Zooplankton species in three locations and three depths was Nauplius sp. (>30%) (6,745,419 ind/m^3), followed by Thermocyclops sp. (2,122,377 ind/m^3), and Mesocyclops sp. (1,165,247 ind/m^3). The average of Nauplius was earned 68.135 ind/m^3±100.784 ind/m^3.

The highest number of phytoplankton species was recorded at the inlet point and a depth of 10 m; meanwhile, the most abundant zooplankton species were recorded at the midpoint and a depth of 0 m. The data for the 2019 to 2021 quartiles showed that the number of plankton species rose significantly in Q4 2019. The result indicated that Oscillatoria sp. (Cyanophyceae class) and Nauplius sp. (Crustacea class) as dominant plankton had enlarged in Q4 2019.

Daphnia sp. was a species of the class Crustacea. The presence of Daphnia sp. was constantly discovered as well. Daphnia sp. was very sensitive to depth. The abundance was depicted by following graph.

Figure 3 illustrates the daphnids growing and reproducing rapidly during 2019-2020. However, the environmental situations must fit within relatively narrow limits. Those are sensitive to the changes in water chemistry and critically rely on pH 7-8, DO > 3 mg/l, temperature 22-31°C, and the appearance of metal toxicants (Bianchini & Wood, 2008). At the -10 m depth of 2020, has been improved in the total of Daphnia sp. individuals until it reaches 35,084 ind/m^3. This situation was caused by the level of ammonia, pH, and temperature in the lake water was reached in a state of balance for daphnia reproduction (Huang et al., 2017). Unfortunately, Daphnia sp. was not found in Q1-Q4 2021. This phenomenon happened because there was a lake overflow and land preparation and planting for reforestation effort. Post-mining activities that occur was tree coverings with a total of 10,000 trees.That made the water quality being lower temporarely because the soil loss might be carried to the lake.

Table 2 shows many components of plankton of natural non-acidic lakes and sensitivity to environmental changes, such as Daphnia and Crustacea. To know further regarding the ecosystem water quality has been recovered, the study of phytoplankton and zooplankton adaptation would be conducted in some calculations below.

The diversity value of the phytoplankton and Zooplankton showed a fluctuation pattern, according to Table 3. Diversity time series characteristics were not shown in the different patterns at all stations. The highest diversity value of phytoplankton was found in Q3 2021 (3), followed by Q2 2021 (1.67) and Q3 2019 (1.58). The medium diversity and moderately stable community were detected, while Q4 2019 was categorized as low diversity and unstable. The phytoplankton diversity at all points sampling in the research area was predicted in the medium category (p-value <0.05). The highest diversity value of Zooplankton was recorded in Q4 2019 (2.1), followed by Q2 2021 (1.66) and Q1 2020 (1.46) in a row. Those are categorized as medium diversity and moderate stable community, while Q4 2020 was classified as low diversity and unstable community. The zooplankton diversity at all points sampling in the research area was predicted in the medium category (p-value <0.05). The diversity in 2021 was considerably higher than in other quartiles. This indicates that the post-mining lake recovered gradually. Medium diversity was indicated meteorological and nutritional factors are suitable for food synthesis, growth, and reproduction of plankton (Adebayo-Tayo et al., 2019).

The dominance value of the phytoplankton and zooplankton showed a fluctuating pattern (See Table 3). Dominance time series characteristics were not shown in different patterns at three sampling points and depths. The dominance index of phytoplankton varies between 0.16 and 1. The most dominant phytoplankton was in Q4 2019 (0.99), Q2 2020 (0.98), and Q4 2020 (0.92), respectively. The phytoplankton dominance at all points sampling in the research area was predicted in the medium category (p-value <0.05). The dominance index of Zooplankton varies in a range of 0 to 0.62. The dominance value of Zooplankton was recorded higher in Q2 2020 (0.62) rather than those of Q1 2019 (0.58), Q4 2010 (0.41), and others. The zooplankton dominance at all points sampling in the research area was predicted in the low category (p-value <0.05). Dominance is dependent on critical ecological processes such as competition, predation, and succession, and therefore changes in these processes can alter the species Dominance index through changes in evenness (Adebayo-Tayo et al., 2019).

In Q4 2019, the dominance value of phytoplankton rose to high dominance, as well as Zooplankton in Q2 2020. The results showed that the total phytoplankton species in Q4 2019 was dominated by the Cyanophyceae class. The Crustacea class dominated the number of zooplankton species in Q2 2020.

Providing in Figure 4 can be seen that the species that dominated Q4 2019 is Oscillatoria sp. It confirms that the physical and chemical quality of the post-mining lake can support the life of the species Oscillatoria sp. well (Marlenny S & Firsty R, 2018). Oscillatoria sp. tends to approach the source of sunlight. As a result, the dominance of Oscillatoria sp. on the surface of the lake water increases. Consequently, Oscillatoria sp. covers the surface of the lake water (Berger & Sweers, 1988). The temperature of the lake water at the bottom and in the middle can be lower than that at the surface. Decreasing these temperatures could potentially reduce the number of zooplankton. The hatching of zooplankton eggs requires a temperature range of 22-31°C. If the temperature falls below 22°C, the zooplankton eggs may fail to hatch (Infante & Abella, 1985). The Kruskal-Waliss test did not reveal a significant difference in the total of individual Oscillatoria sp. at the 0 m, 5 m, and 10 m depths (p-value <0.05). This potentially occurred because there was no migration of the species performed in the morning or night in the water column over the two seasons (Bon et al., 2021).

The species that dominated Q2 2020 was Nauplius (See Fig. 5). It can be stated that the physical and chemical quality of lake water in the research lake can keep up the life of the species Nauplius sp. well (Vaschetto et al., 2021). However, the fact that the total of individual Nauplius at three depths did not differ significantly (p-value <0.05). Other researchers also

Table 3. Diversity, dominance, and saprobic indices measurement of phytoplankton and zooplankton

Quartile		Inlet			Middle			Outlet		
		0 m	5 m	10 m	0 m	5 m	10 m	0 m	5 m	10 m
Q1 2019	P. Diversity	1.36	0.271	1.275	1.298	1.336	0.611	1.698	0.966	1.651
	Z. Diversity	1.336	0.611	1.698	0.966	1.651	1.296	1.663	2.146	0.937
	P. Dominance	0.37	0.58	0.262	0.536	0.228	0.439	0.222	0.131	0.515
	Z. Dominance	0.37	0.58	0.262	0.536	0.228	0.439	0.222	0.131	0.515
	Saprobic	1.66	1.67	2	2	2	1.5	2	2	2
Q2 2019	P. Diversity	0.933	1.494	1.494	0.607	0.435	1	1.107	0.436	0.645
	Z. Diversity	1.589	1.63	1.853	1.468	0.898	2	1.485	1.694	1.04
	P. Dominance	0.566	0.25	0.25	0.712	0.791	0.425	0.469	0.833	0.68
	Z. Dominance	0.292	0.25	0.187	0.264	0.46	0.345	0.356	0.298	0.375
	Saprobic	1	1	1	1	1	1.5	2	1.5	1
Q3 2019	P. Diversity	1.58	1.008	0.966	1.356	1.384	1.414	0.836	0.868	0.407
	Z. Diversity	1.67	1.56	1.456	1.354	1.489	1.465	1.595	1.363	1.67
	P. Dominance	0.234	0.523	0.52	0.372	0.308	0.27	0.525	0.5	0.806
	Z. Dominance	0.25	0.301	0.297	0.345	0.301	0.343	0.317	0.383	0.271
	Saprobic	1	1.5	1	1.5	1	1.5	1	1	1
Q4 2019	P. Diversity	0.517	0.235	0.556	0.025	0.166	0.194	0.137	0.058	0.175
	Z. Diversity	1.471	2.154	0	1.701	1.584	1.476	1.708	1.532	1.583
	P. Dominance	0.813	0.92	0.715	0.994	0.948	0.938	0.958	0.984	0.94
	Z. Dominance	0.26	0.167	0	0.257	0.255	0.33	0.237	0.287	0.298
	Saprobic	1.222	1.2857	1	1	1	1	1	1	1
Q1 2020	P. Diversity	0	0.47	0.22	1.33	1	0.48	1.46	0.69	0.47
	Z. Diversity	1.69	1.27	1.44	1.95	1.58	0.66	1.81	1.28	1.66
	P. Dominance	1	0.74	0.91	0.37	0.4	0.7	0.27	0.5	0.79
	Z. Dominance	0.23	0.33	0.29	0.18	0.25	0.53	0.21	0.31	0.21
	Saprobic	1	1	1	1	1	1	1	1	1
Q2 2020	P. Diversity	0.23	0.42	0.45	0.06	0.18	0.58	0.75	0.47	0.45
	Z. Diversity	1.38	1.06	1.48	1.57	1.16	0.88	1.49	0.88	1.43
	P. Dominance	0.9	0.83	0.8	0.98	0.93	0.68	0.64	0.81	0.76
	Z. Dominance	0.31	0.51	0.3	0.3	0.41	0.62	0.29	0.62	0.33
	Saprobic	1	1	1	1	1	1	1	1	1

Continued Table 3. Diversity, dominance, and saprobic indices measurement of phytoplankton and zooplankton

Quartile		Inlet			Middle			Outlet		
		0 m	5 m	10 m	0 m	5 m	10 m	0 m	5 m	10 m
Q4 2020	P. Diversity	0.23	0.6	0.42	0.66	0.97	0.87	1.08	1.3	0.97
	Z. Diversity	1.51	1.83	1.62	1.49	1.34	1.78	1.22	1.52	1.34
	P. Dominance	0.92	0.77	0.85	0.67	0.47	0.48	0.47	0.37	0.51
	Z. Dominance	0.34	0.22	0.29	0.34	0.39	0.27	0.41	0.33	0.36
	Saprobic	1.5	1.5714	1.5	1.5	1	1.6	1.67	1.67	1.67
Q2 2021	P. Diversity	1.452	1.546	1.475	0.99	1.208	1.119	1.678	1.44	1.66
	Z. Diversity	0	0	0	0	0	0	0	0	0
	P. Dominance	0.902	0.961	0.916	0.405	0.345	0.399	0.204	0.256	0.206
	Z. Dominance	0	0	0	0	0	0	0	0	0
	Saprobic	1	1	1	1	1	1	1	1	1
Q3 2021	P. Diversity	1.846	1.55	3	1.789	1.036	0.687	1.806	1.48	0.687
	Z. Diversity	0.664	0.237	0	0.503	0.218	0	0.727	0.35	0.48
	P. Dominance	0.173	0.24	0.96	0.19	0.371	0.506	0.182	0.244	0.50
	Z. Dominance	0.107	0.011	0	0.027	0.008	0	0.12	0.07	0.02
	Saprobic	1	1	1	1	1	1	1	1	1
Q4 2021	P. Diversity	1.98	1.43	0.68	1.94	1.03	1.03	1.75	1.52	1.06
	Z. Diversity	0.518	0.278	0.224	0.631	0.218	0.218	0.501	0.230	0.360
	P. Dominance	0.154	0.265	0.506	0.16	0.371	0.371	0.142	0.222	0.358
	Z. Dominance	0.031	0.02	0.012	0.08	0.008	0.003	0.029	0.01	0.197
	Saprobic	1	1	1	1	1	1	1	1	1

Note: Z: Zooplankton; P: Phytoplankton

supported some evidence of the role of physical forces in distributing Zooplankton passively in the water column (Holy & Sari, 2020)

In Fig. 6 the rainfall obtained from Q1 2019 to Q4 2021 tends to fluctuate. Based on the monthly rainfall chart, the highest point was in March 2020 (459.04 mm/month), while the lowest monthly rainfall was in August 2019 (106 mm/month). The average regional rainfall was 328 mm/month±102.28 mm/month. Fluctuating rainfall graphs was potentially caused by place and time (Maqbool et al., 2020). The locations that get high sunlight intensity can increased evaporation. Water particles after high evaporation was collected in the atmosphere in high numbers (Corbari et al., 2016). In addition, high sunlight intensity was reduced the melting time of ice particles in the atmosphere into rainwater (Corbari et al., 2016). In March, the position of

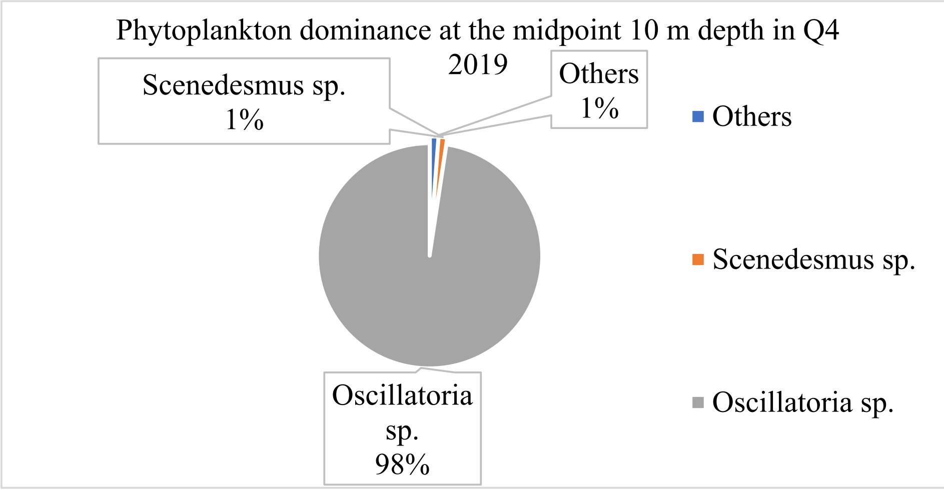

Fig. 4. Phytoplankton dominance at the midpoint 10 m depth in Q4 2019

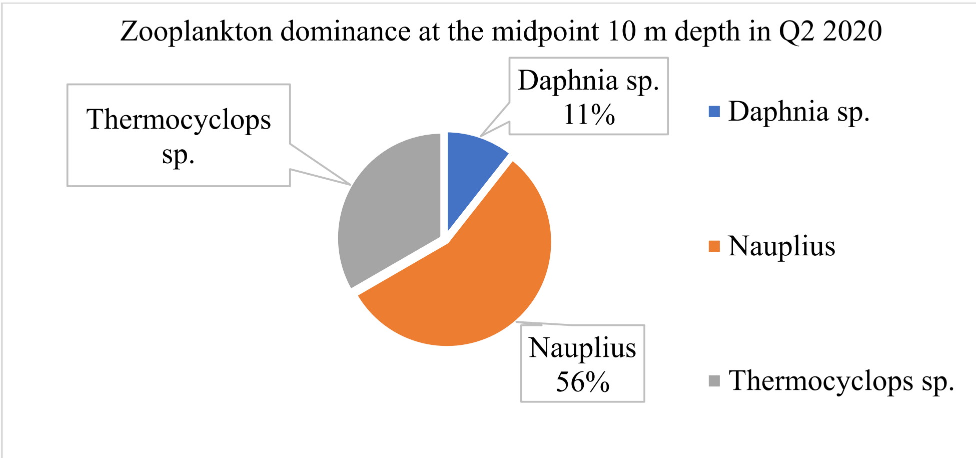

Fig. 5. Zooplankton dominance at the midpoint 10 m depth in Q2 2020

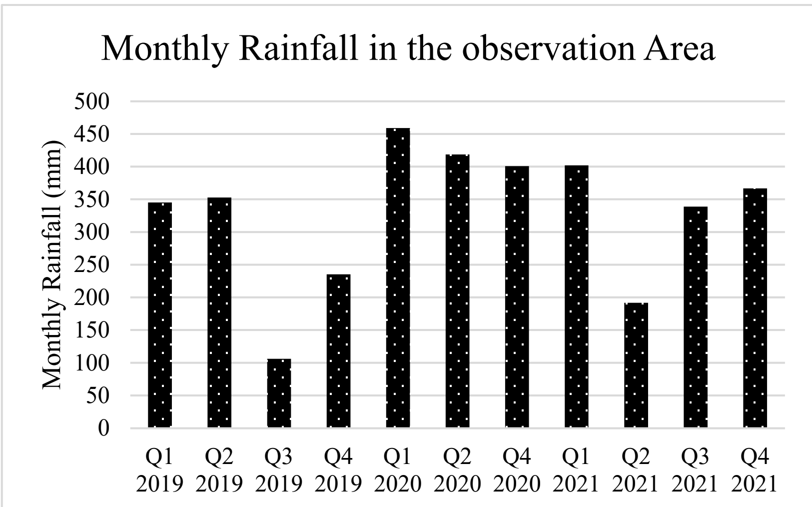

Fig. 6. Monthly Rainfall in the observation Area

the earth's orbit to the sun was close, but the earth rotates with an inclination of 23.45o. Based on this condition the earth's temperature in the tropics was not at its peak (Peng et al., 2021). The temperature of the earth's surface in March in the tropics carried the continuity of a good rainfall cycle (Peng et al., 2021). In addition, in March the west monsoon blows was increased the chances of high rainfall [81]. This statement was shown by Fig. 6 in March Q1 had high rainfall for 3 years. Factors that could affected the distribution of rain include geography and topography (Peng et al., 2021).

In this study, the species that had the highest number of individuals was Oscillatoria sp. and Nauplius. One of the factors that can potentially increase the number of individuals was rainfall (Peng et al., 2021). High rainfall was a medium for transporting plankton into the lake (Corbari et al., 2016). Based on this events, the value of rainfall in the study area was potentially affected the number of individuals.

The results of relation value between rainfall and the number of Oscillatoria sp. was showed 66% very low relationship value. That can be indicated that there are other factors that affected the number of Oscillatoria sp. on the lake. Researchers indicated that the factor of sunlight intensity could have a high effect on the number of Oscillatoria sp. The correlation value was showed positive so that the higher rainfall value, the higher number of Oscillatoria sp. on the lake.

The results of relationship between rainfall and the number of individual Nauplius was showed that 55% have a very low relationship. Therefore, it can be indicated that there are other factors that have a strong correlation with the number of individual Nauplius species in the lake. Researchers indicated lake water temperature was a factor that influenced to the number of Nauplis. The correlation value was showed positive so that the higher the rainfall value, the higher the number of Nauplius in the lake.

Maximum correlation value of rainfall to Oscillatoria sp. and Nauplius were found at an inlet point with a depth of 10 m. In this area, the correlation of rainfall to Oscillatoria sp. by 0.6 or a very strong relationship. The highest relationship between rainfall and Nauplius was 0.47 or enough. This condition was caused by the inlet point being the first area to receive rainwater and there is no vegetation cover (Santoso, 2021). In this situation, the lake received rainwater in large quantities and the rainwater dilution occurred earlier than the midpoint and outlet. This situation was caused sufficient organic matter for photosynthesis and food sources for zooplankton (Santoso, 2021). The minimum point of the correlation value was at the midpoint of 10 m depth. In this situation, the correlation value between rainfall to Oscillatoria sp. was 0.06. beside that, the correlation rainfall between Nauplius was 0.24. This was because at a depth of 10 m, rainwater did not properly dilute lake water. In this situation water dilution proportional to water depth (Santoso, 2021).

In Table 3, the saprobic value showed a stable pattern. Saprobic time series characteristics were not shown in different patterns at three sampling points and depths. The saprobic index was calculated around 1-2. The highest index was observed in Q1 2019 (2), followed by Q2 2019 (2) and Q4 2020 (1.67). The water quality at all sampling points in the research area was predicted to be in the very lightly polluted category. Based on the classification of the saprobic index, the very lightly polluted class is the best water quality class or oligo/mesosaprobic. Very lightly polluted indicated that the observation area can accommodate producers in the form of phytoplankton which are sensitive to polluted water (Sari et al., 2018). This situation shows that the research area was ready to accommodate a larger number of producers (Qiong Zhang & Rosalind E.M.R., 2020). Very lightly polluted categories can be identified by the fact that there are organic and inorganic materials in the lake (Resiana et al., 2021). This condition can be estimated that inorganic materials was lower than organic materials because there is a genus that can utilize organic matter for its survival, namely Cyanophyceae, besides that there is a genus that cannot survive high inorganic materials, namely Crustacea.

In the research area, there was no activity and pollutants coming from humans. Thus, organic and inorganic matter come from runoff water pouring into the lake. Runoff water comes from rainwater combined with surrounding catchment areas of post-mining areas and forest habitats. The soil in the observation area has the potential to contain soil types that were easily eroded by water, contain organic and inorganic materials. Some minerals dissolved from drainage could potentially impact the saprobic value as well (Sari et al., 2018). The entry of organic and inorganic materials can change the quality of lake water so that it can keep up the activity and growth of phytoplankton (Qiong Zhang & Rosalind E.M.R., 2020). However, the macronutrients that enter the lake too high can cause algae blooms. At the research location the values of diversity and dominance fell into the low to medium category. This condition proves that there was no algae blooming and there is a balance between nutrients and the total of individual plankton.

According to statistical data processing, there is no difference in the average saprobic index values at the three depths at the inlet, middle, and outlet points (p-value <0.05). The saprobic index was not detected in the depth variation. This situation was caused by some factors such as meteorological factors supporting the process of adequately diluting lake water so that lake water's physical and chemical qualities are evenly distributed (Blanchette & Lund, 2016).

The saprobic index classification shows that Oscillatoria sp. belongs to the β-Mesosaprobic group. The high abundance of Oscillatoria sp. was indicated prolific water in the Post-mining Lake in Paringin District (Li et al., 2021). Oscillatoria sp. was created chlorophyll-a (Bon et al., 2021). Chlorophyll-a was formed from the mixing reaction of chlorophyll with ATP-activated tRNA, magnesium, and nitrogen (Equation 4.3) (Bon et al., 2021).

$$C_{55}H_{72}O_5 + 4N + Mg \rightarrow C_{55}H_{72}O_5N_4Mg \tag{4}$$

The chlorophyll-a absorbed blue and red photons at λ 673 nm from sunlight (Hefni et al., 2016). After that, Oscillatoria sp. was absorbing water and carbon dioxide to produce glucose (Equation 4.4) (Bon et al., 2021).

$$12\ H_2O + 6\ CO_2 \rightarrow C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O \tag{5}$$

Glucose can be converted into proteins, fats, nucleic acids and other organic molecules (Bon et al., 2021). The results of converting glucose can be utilized by Oscillatoria sp. for cell growth. The death of Oscillatoria sp. can dropped organic elements in the water so that it becomes a raw material for the production of chlorophyll in other. Hence, the life cycle of Oscillatoria sp. can be a basic ingredient in the production of another type of chlorophyll and the production of organic matter in waters (Li et al., 2021).

In Fig. 7 Oscillatoria sp. was became a species that rose significantly in Q4 2019. This condition was potentially to be affected by the optimum pH value (Zuorro et al., 2021). The best pH to built Chlorophyll-a in lake waters was 7.9-8 (Rahmah et al., 2022). Optimum pH changes can bound Mg elements and then produce chlorophyll-a with color pigments that do not change (Adebayo-Tayo et al., 2019). Stable pigments indicated the best photon absorption ability for photosynthesis (Rahmah et al., 2022). In addition, a neutral pH could optimize nutrient solutions to be diluted using transport tissues throughout the body (Adebayo-Tayo et al., 2019).

There was a reduced in the number of Oscillatoria sp. individuals at the midpoint shown in Q1 2020 (See Fig 7). Decline the density of Oscillatoria sp. was influenced by the low adaptability to the huge TSS (Bhuyar et al., 2020). A large TSS value marked there was an inflation of particulates in the water. The high number of particulates in the water could cover the surface of the water so that the water becomes turbid (Maqbool et al., 2020). Covering the water surface by a high number of particulates effected sunlight to be reflected by the particles (Verma & Srivastava, 2016). This situation causes the population of Oscillatoria sp. do not get

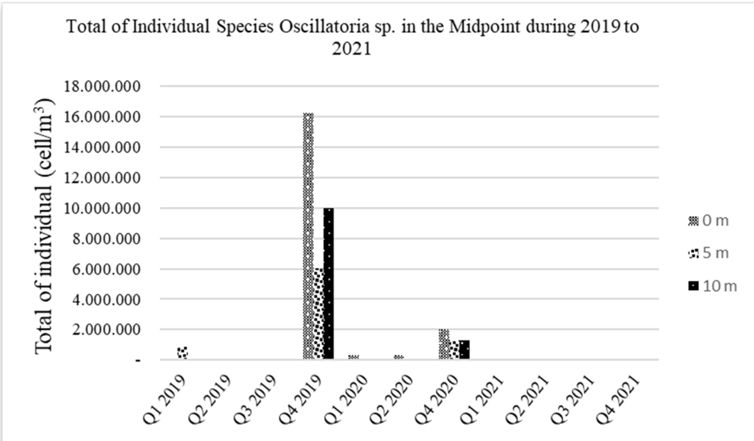

Fig. 7 Total of Individual Species Oscillatoria sp. in the inlet point

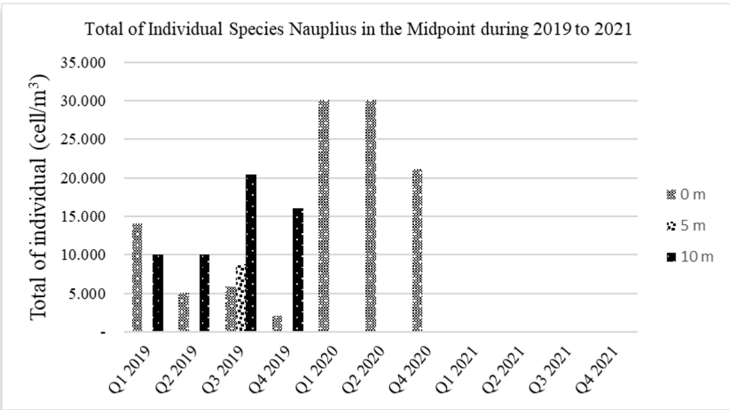

Fig. 8 Total of Individual Species Nauplius sp. in the midpoint

sunlight evenly (Maqbool et al., 2020). The population of Oscillatoria sp. become malnourished and then die (Verma & Srivastava, 2016). Therefore, the number of individual Oscillatoria sp. potentially had a stronger relationship to sunlight intensity than rainfall. The water has a high chance of getting turbid when there was an eroded land. Erosion on land can occurred in the areas that have mollisol soil. Mollisol soil had a low density (Dwi Agung Pramono, 2016). Mollisol soil can be found in South Kalimantan Province, Balangan Regency, Paringin District so that the study area has the potentially to have mollisol soil (Fiantis, 2017).

In the midpoint Q1 2020 there was a rose of Nauplius individuals (See Fig. 8). The huge number of Nauplius individuals was effected by the optimal water temperature value for carrying out the hatching function (Dunstan et al., 2011). Optimal temperature was optimized cell performance and then increased the speed of cell cleavage (Hamre et al., 2013). Rapid cell cleavage has an impact on massive cell growth(Berger, 1989). In addition to high cell growth, the optimal temperature could not damage the shell significantly so that the shell cracking or molting period lasts a long time (Katircioğlu et al., 2008). High cell growth accompanied by a long molt period resulted in the quality of Nauplius individuals that can hunt well (Ricardo Jiménez Montealegre et al., 1995). This situation can improve the quality of life of Nauplius. A good quality of life for Nauplius could boosted the number of reproductive activities, then increasing the number of individuals (Tri Aditya et al., 2019). The number of individual Nauplius potentially had a stronger relationship to lake water temperature than rainfall.

The dominance values of phytoplankton were dropped in Q3 2019, Q1 2020 and Q4 2021 (See Table 3). This situation was caused by environmental factors around the lake which have been well isolated so that no pollutants and human activities enter the lake (Ross & Arnott, 2022). In addition, there was no intentional addition of predators into the lake so that the balance of the ecosystem towards predators and producers runs in balance (Tjahjono A & Hartanto, 2020). All of these factors could support the growth of the number of species in equal (Suryani, 2018).

In Q1 2021, the dominance value of zooplankton was continued to decline. This situation was caused by high species dominance leading to high densities in Q4 2020 (Vaschetto et al., 2021). High density causes the availability of nutrients to be increasingly limited. The dominated species was migrated to reduce density (Holy & Sari, 2020) Migration of zooplankton was built the balance of zooplankton species so that there is no tight competition for nutrients in the study area (Maqbool et al., 2020). The balance of the number of individual species in the observation area could maintain a good and sustainable food chain cycle (Gal et al., 2016). The observation area was ready to accommodating a more complex food chain (Holy & Sari, 2020).

The diversity value of phytoplankton was continued to enlarge Based in Q3 2021. It was categorized as a moderate diversity. Diversity values from medium to high can be indicated the water has physical and chemical quality that can support the asexual reproduction of phytoplankton (Adebayo-Tayo et al., 2019). This situation was indicated in Q3 2021 has a pH value of 7.9 – 8, this value is optimal for the reproduction of aquatic biota. In the observation area, the phytoplankton species was found to have characteristics in the form of multicellular filaments. This species reproduces by binary fission and fragmentation (Sahidin et al., 2019). The process of dividing the cell nucleus into new individuals was required a stable cycle of chemical energy transfer throughout all cells within individual phytoplankton (Sun et al., 2020). Therefore, the optimal H^+ concentration was an important role in maintaining the cycle of chemical energy exchange by ATP in cells (Escalas et al., 2019).

The diversity of zooplankton at all sampling points was raised to become moderate diversity in Q4 2020. The medium diversity of zooplankton was indicated the balanced of plankton ecosystem. This statement was proven that phytoplankton in Q4 2020 was in moderate diversity. The balance of phytoplankton and zooplankton could create a balanced and sustainable food chain cycle (Escalas et al., 2019). Diversity in the moderate category in post-mining lakes occur in Post-mining lake of PT Bukit Asam, the lake was 21 years old and has moderate diversity in zooplankton and phytoplankton (Kodir et al., 2017). Then another study took place in the Post-mining lake of PT. Kasongan Bumi Kencana, the lake was 25 years old has a high diversity of plankton (Putrawiyanta, 2020). This situation showed that the ecosystem activity of aquatic biota in the study area was developed to larger ecosystem gradually (Adebayo-Tayo et al., 2019).

CONCLUSION

The most abundant phytoplankton species in all stations was Oscillatoria sp. (>90%) while Nauplius sp. (>30%) was detected for zooplankton. The number of individual species in the study area had a very weak relation value to rainfall. The highest dominance value of phytoplankton and zooplankton was recorded around the end of 2019 to early 2020 as well as a saprobic index for phytoplankton. Otherwise, diversity was found higher in 2021 rather than other years, notably Q2 2021. After the Q4 2019 period, the diversity value in the research lake improved to moderate diversity. This situation proved there was a recovery of the plankton population in the lake. At the research location the values of diversity and dominance were reached to the medium category. This condition validated that there was no algae blooming and there was a balance between nutrients and the total of individual plankton.

ACKNOWLEDGMENT

The authors sincerely acknowledge PT. Adaro Indonesia Management for providing database and information related to the research.

GRANT SUPPORT DETAILS

The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

REFERENCES

Adebayo-Tayo, B., Salaam, A., & Ajibade, A. (2019). Green synthesis of silver nanoparticle using Oscillatoria sp. extract, its antibacterial, antibiofilm potential and cytotoxicity activity. *Heliyon*, *5*(10). https://doi.org/10.1016/j.heliyon.2019.e02502

Dwirani, F. (2019). Menentukan Stasiun Hujan dan Curah Hujan dengan Metode Polygon Thiessen Daerah Kabupaten Lebak. 2 (2).

Arriaga, D., Nelson, T. C., Risacher, F. F., Morris, P. K., Goad, C., Slater, G. F., & Warren, L. A. (2019). The co-importance of physical mixing and biogeochemical consumption in controlling water cap oxygen levels in Base Mine Lake. *Applied Geochemistry*, *111*. https://doi.org/10.1016/j.apgeochem.2019.104442

Berger, C. (1989). In situ primary production, biomass and light regime in the Wolderwijd, the most stable Oscillatoria agardhii lake in The Netherlands. *Hydrobiologia*, 185, 233–244, https://doi.org/10.1007/BF00036611.

Berger, C., & Bij De Vaate, A. (1983). Limnological studies on the eutrophication of Lake Wolderwijd A shallow hypertrophic Oscillatoria dominated lake in the Netherlands. *Z. Hydrol* 45 (2). https://doi.org/10.1007/BF02538134

Berger, C., & Sweers, H. E. (1988). The IJsselmeer and its phytoplankton—with special attention to the suitability of the lake as a habitat for Oscillatoria agardhii. *Journal of Plankton Research*, *10*(4), 579–599. https://doi.org/10.1093/plankt/10.4.579.

Bhuyar, P., Rahim, M. H. A., Maniam, G. P., Ramaraj, R., & Govindan, N. (2020). Exploration of bioactive compounds and antibacterial activity of marine blue-green microalgae (Oscillatoria sp.) isolated from coastal region of west Malaysia. *SN Applied Sciences*, *2*(11). https://doi.org/10.1007/s42452-020-03698-8

Bianchini, A., & Wood, C. M. (2008). Sodium uptake in different life stages of crustaceans: the water flea Daphnia magna Strauss. *Journal of Experimental Biology*, *211*(4), 539–547. https://doi.org/10.1242/jeb.009175.

Blanchette, M. L., & Lund, M. A. (2016). Pit lakes are a global legacy of mining: an integrated approach to achieving sustainable ecosystems and value for communities. In *Current Opinion in Environmental Sustainability* (Vol. 23, pp. 28–34). Elsevier B.V. https://doi.org/10.1016/j.cosust.2016.11.012.

Bon, I. C., Salvatierra, L. M., Lario, L. D., Morató, J., & Pérez, L. M. (2021). Prospects in cadmium-contaminated water management using free-living cyanobacteria (Oscillatoria sp.). *Water (Switzerland)*, *13*(4). https://doi.org/10.3390/w13040542.

Chaktraborty, S., Karmaker, D., Rahman, Md. A., Bali, S. C., Das, S. K., & Hossen, R. (2021). Impacts of pH and salinity on community composition, growth and cell morphology of three freshwater phytoplankton. *Plant Science Today*, *8*(3). https://doi.org/10.14719/pst.2021.8.3.1190.

Corbari, C., Lassini, F., & Mancini, M. (2016). Effect of intense short rainfall events on coastal water quality parameters from remote sensing data. *Continental Shelf Research*, *123*, 18–28. https://doi.org/10.1016/j.csr.2016.04.009.

Davis, A., Nasser, F., Lead, J. R., & Shi, Z. (2020). Development and application of a ratiometric nanosensor for measuring pH inside the gastrointestinal tract of zooplankton. *Environmental Science: Nano*, *7*(6), 1652–1660. https://doi.org/10.1039/C9EN01300H.

Driscoll, H. E., Vincent, J. J., English, E. L., & Dolci, E. D. (2016). Metagenomic investigation of the microbial diversity in a chrysotile asbestos mine pit pond, Lowell, Vermont, USA. *Genomics Data*, *10*, 158–164. https://doi.org/10.1016/j.gdata.2016.11.004.

Dunstan, A. J., Ward, P. D., & Marshall, N. J. (2011). Vertical distribution and migration patterns of Nautilus pompilius. *PLoS ONE*, *6*(2). https://doi.org/10.1371/journal.pone.0016311.

Dwi Agung Pramono. (2016). Distribution of Soil Types in the Karang Mumus River Sub-region Using Geographical Information Systems. *Jurnal Teknologi Informasi Universitas Lambung Mangkurat (JTIULM)*, *1*(2), 60–72. https://doi.org/10.20527/jtiulm.v1i2.9.

Effendi, H., Kawaroe, M., Lestari, D. F., Mursalin, & Permadi, T. (2016). Distribution of Phytoplankton Diversity and Abundance in Mahakam Delta, East Kalimantan. *Procedia Environmental Sciences*, *33*, 496–504. https://doi.org/10.1016/j.proenv.2016.03.102.

Escalas, A., Catherine, A., Maloufi, S., Cellamare, M., Hamlaoui, S., Yéprémian, C., Louvard, C., Troussellier, M., & Bernard, C. (2019). Drivers and ecological consequences of dominance in periurban phytoplankton communities using networks approaches. *Water Research*, *163*, 114893. https://doi.org/10.1016/j.watres.2019.114893.

Ezza Qodriatullah Ajr, & Fitri Dwirani. (2019). Setting Rain and Rainfall Stations with the Thiessen Polygon Method in Lebak Regency. *JURNALIS*, *2*(2), 139–142.

Fengjie L, Martha G, Qiao-Guo, T, K. Z., Qiong Z, Pascal S, Alessandro T, Yanjun Z, Dominik W, Eric P.A, & Yuri K. (2022). Phycosphere pH of unicellular nano- and micro- phytoplankton cells and consequences for iron speciation. *Journal of Multidisciplinary Microcial Ecology*, *16*(1), 2329–2336.

Fiantis, D. (2017). *Morfologi dan Klasifikasi Tanah*. Universitas Andalas.

Gal, L., Grippa, M., Hiernaux, P., Peugeot, C., Mougin, E., & Kergoat, L. (2016). Changes in lakes water volume and runoff over ungauged Sahelian watersheds. *Journal of Hydrology*, *540*, 1176–1188. https://doi.org/10.1016/j.jhydrol.2016.07.035.

Garcia, T. M., Santos, N. M. O., Campos, C. C., Costa, G. A. S., Belmonte, G., Rossi, S., & Soares, M. O. (2021). Plankton net mesh size influences the resultant diversity and abundance estimates of copepods in tropical oligotrophic ecosystems. *Estuarine, Coastal and Shelf Science*, *249*. https://doi.org/10.1016/j.ecss.2020.107083.

Hamre, L. A., Eichner, C., Caipang, C. M. A., Dalvin, S. T., Bron, J. E., Nilsen, F., Boxshall, G., & Skern-Mauritzen, R. (2013). The Salmon Louse Lepeophtheirus salmonis (Copepoda: Caligidae) Life Cycle Has Only Two Chalimus Stages. *PLoS ONE*, *8*(9). https://doi.org/10.1371/journal.pone.0073539.

Hermansyah, H., Lulu, Y., Eddy, I., & Marsi, M. (2022). Analysis of the characteristics of ex-mining soil after 5 years and 10 years of revegetation. *Media Konservasi*, *26*(3), 239–247. https://doi.org/10.29244/medkon.26.3.239-247.

Hidayat, A. R., Ramadhan, R. A. M., & Nasrudin, N. (2022). Insect Diversity and Domination on Rice Field in Mangkubumi, Indihiang, And Cibereum District, Tasikmalaya City. *Journal of Applied Agricultural Sciences*, *4*(2), 48–56. https://doi.org/10.36423/agroscript.v4i2.986.

Holy, N. H., & Sari, L. A. (2020). The effect of catfish and chicken cultivation waste to Daphnia sp. culture. *IOP Conference Series: Earth and Environmental Science*, *441*(1), 012057. https://doi.org/10.1088/1755-1315/441/1/012057.

Huang, Y., Campana, O., & Wlodkowic, D. (2017). A Millifluidic System for Analysis of Daphnia magna Locomotory Responses to Water-born Toxicants. *Scientific Reports*, *7*(1). https://doi.org/10.1038/s41598-017-17892-z.

Infante, A., & Abella, S. E. B. (1985). Inhibition of Daphnia by Oscillatoria in Lake Washington. *Limnology and Oceanography*, *30*(5), 1046–1052. https://doi.org/10.4319/lo.1985.30.5.1046.

Islam, Md & Azadi, M. & Nasiruddin, Munira & Sarker, Muhammad. (2022). Plankton Species Composition, Abundance And Diversity Indices In Three Ponds of Chittagong University Campus, Bangladesh. 9. 1-14.

Kadir, M. A., Damar, A., & Krisanti, M. (2015). Spatial and Temporal Dynamics of Zooplankton Community Structure in Jakarta Bay. *Jurnal Ilmu Pertanian Indonesia*, *20*(3), 247–256. https://doi.org/10.18343/jipi.20.3.247

Katircioğlu, H., Aslim, B., Rehber Türker, A., Atici, T., & Beyatli, Y. (2008). Removal of cadmium(II) ion from aqueous system by dry biomass, immobilized live and heat-inactivated Oscillatoria sp. H1 isolated from freshwater (Mogan Lake). *Bioresource Technology*, *99*(10), 4185–4191. https://doi.org/10.1016/j.biortech.2007.08.068

Kodir, A., Hartono, D. M., Haeruman, H., & Mansur, I. (2017). Integrated post mining landscape for sustainable land use: A case study in South Sumatera, Indonesia. *Sustainable Environment Research*, *27*(4), 203–213. https://doi.org/10.1016/j.serj.2017.03.003

Li, H., Gu, X., Chen, H., Mao, Z., Zeng, Q., Yang, H., & Kan, K. (2021). Comparative toxicological effects of planktonic Microcystis and benthic Oscillatoria on zebrafish embryonic development: Implications for cyanobacteria risk assessment. *Environmental Pollution*, *274*. https://doi.org/10.1016/j.envpol.2020.115852

Mamodu, A., Ojonimi, I. T., Apollos, S. S., Jacinta, O.-C. N., Salome, W. H., & Enesi, A. A. (2018). Analyzing the environmental impacts and potential health challenges resulting from artisanal gold mining in Shango area of Minna, North-Central, Nigeria. *Journal of Degraded and Mining Lands Management*, *5*(2), 1055–1063. https://doi.org/10.15243/jdmlm.2018.052.1055

Maqbool, M., Bhatti, H. N., Sadaf, S., Mana AL-Anazy, M., & Iqbal, M. (2020). Biocomposite of polyaniline and sodium alginate with Oscillatoria biomass: a potential adsorbent for the removal of basic blue 41. *Journal of Materials Research and Technology*, *9*(6), 14729–14741. https://doi.org/10.1016/j.jmrt.2020.10.017

Marlenny S, & Firsty R, P. (2018). Comparison of Diversity Index and Dominant Index of Phytoplankton at Ciliwung River Jakarta. *Journal of Biological Diversity*, *11*(1), 75–79.

Mdumela, M. N., & Sengani, F. (2021). Analysis of the potential of acid mine drainage generation from the neutralized coal mining tailings. *Journal of Degraded and Mining Lands Management*, *8*(4), 2925–2930. https://doi.org/10.15243/jdmlm.2021.084.2925

Peng, Z., Zhang, Y., Zhu, J., Hu, W., Liu, G., Zhang, H., & Gao, R. (2021). Large lake sluice operations during an extreme rainfall season greatly affect circulation and water quality dynamics of a shallow eutrophic lake. *Science of the Total Environment*, *781*. https://doi.org/10.1016/j.scitotenv.2021.146756

Putrawiyanta, I. P. (2020). Use of Void as a Post-Mining Lake at PT Kasongan Bumi Kencana Katingan Regency Central Kalimantan Province. *PROMINE*, *8*(1), 8–13. https://doi.org/10.33019/promine.v8i1.1801

Qiong Zhang, & Rosalind E.M.R. (2020). Interactions of thallium with marine phytoplankton. *Journal of Geochimica et Cosmochimica Acta*, *276*(1), 1–13.

Rahmah, N., Zulfikar, A., & Apriadi, T. (2022). bundance of Phytoplankton dan Its Relation with Some Water Environmental Parameters in Sei CarangEstuaryTanjungpinang City. *Journal of Marine Research*, *11*(2), 189–200. https://doi.org/10.14710/jmr.v11i2.32945

Ramadhan, N. F., Gunawan, T., & Adji, T. N. (2020). Environmental damage assessment due to traditional mining on local scale in the Wungkal Hills, Yogyakarta-Indonesia. *Journal of Degraded and Mining Lands Management*, *7*(2), 1995–2000. https://doi.org/10.15243/jdmlm.2020.072.1995

Resiana, T., Apriadi, T., & Muzammil, W. (2021). Epilytic Periphyton as a Bioindicator of Senggarang River Water Quality on Bintan Island, Riau Archipelago. *Jurnal LIMNOTEK Perairan Darat Tropis Di Indonesia*, *28*(1), 39–50. https://doi.org/10.14203/limnotek.v28i1.357

Ricardo Jiménez Montealegre, Johan Verreth, Kees Steenbergen, Jan Moed, & Marcel Machiel. (1995). A dynamic simulation model for the blooming of Oscillatoria agardhii in a monomictic lake. *Ecological Modelling*, 17–24.

Risacher, F. F., Morris, P. K., Arriaga, D., Goad, C., Nelson, T. C., Slater, G. F., & Warren, L. A. (2018). The interplay of methane and ammonia as key oxygen consuming constituents in early stage development of Base Mine Lake, the first demonstration oil sands pit lake. *Applied Geochemistry*, *93*, 49–59. https://doi.org/10.1016/j.apgeochem.2018.03.013

Ross, A. J., & Arnott, S. E. (2022). Similar zooplankton responses to low pH and calcium may impair long-term recovery from acidification. *Ecological Applications*, *32*(3). https://doi.org/10.1002/eap.2512

Sahidin, A., Nurruhwati, I., Riyantini, I., & Triandi, M. (2019). Structure of Plankton Communities in Cijulang River Pangandaran District, West Java Province, Indonesia. *World News of Natural Sciences*, *23*, 128–141. www.worldnewsnaturalsciences.com

Santoso, A. (2021). Glycobiology, glycans and glycoprotein with its applications in health. *BERITA BIOLOGI*, *20*(1), 1–12. https://doi.org/10.14203/beritabiologi.v20i1.3991

Sari, L. A., Satyantini, W. H., Manan, A., Pursetyo, K. T., & Dewi, N. N. (2018). The identification of plankton tropical status in the Wonokromo, Dadapan and Juanda extreme water estuary. *IOP Conference Series: Earth and Environmental Science*, *137*(1). https://doi.org/10.1088/1755-1315/137/1/012029

Sena Pradipta. (2017). *Study of Post-Mining Surface Water Management in Part of Paringin non- active mining area ar PT. Adaro Indonesia*. Institut Teknologi Bandung.

Subowo G. (2011). Environment Friendly Open Pit Mining Systems and Reclamation Post-Mining Efforts to Improve the Quality of Land Resources and Soil Biodiversity. *Jurnal Sumberdaya Lahan*, *5*(2), 83–94.

Sun, X., Kong, M., Alkhazragi, O., Shen, C., Ooi, E.-N., Zhang, X., Buttner, U., Ng, T. K., & Ooi, B. S. (2020). Non-line-of-sight methodology for high-speed wireless optical communication in highly turbid water. *Optics Communications*, 125264. https://doi.org/10.1016/j.optcom.2020.125264

Suryani, S. A. M. P. (2018). Pollution with saprobic index and nutrition value coefficient of fish. *International Journal of Life Sciences (IJLS)*. https://doi.org/10.29332/ijls.v2n2.134

Tjahjono A, & Hartanto. (2020). Plankton indexes and heavy metal pollution in Kendal coastal waters, Indonesia. *Politeknik Transportasi Sungai*, *13*(3), 46–63.

Tri Aditya, M., Sulistyana Bargawa, W., Agung Cahyadi, T., Rindu Widara, M., Teknik Pertambangan, M., & Veteran Yogyakarta, U. (2019). Pemanfaatan Pit Lake Sebagai Program Pasca Tambang. *Seminar Nasional Sains Dan Teknologi Terapan VII 2019*, 551–556.

Vaschetto, P., Regaldo, L., Polla, W., Andrade, V., Gervasio, S., & Gagneten, A. M. (2021). Plankton Community Responses to Anthropogenic Pollution in an Argentinian Urban Reserve. *Water, Air, & Soil Pollution*, *232*(10), 427. https://doi.org/10.1007/s11270-021-05380-0

Verma, B. S., & Srivastava, S. K. (2016). *Nature Environment and Pollution Technology An International Quarterly Scientific Journal Study of Factors Affecting Phytoplankton Primary Productivity in a Pond of Patna, Bihar, India*. *15*, 291–296. www.neptjournal.com

Zuorro, A., Leal-Jerez, A. G., Morales-Rivas, L. K., Mogollón-Londoño, S. O., Sanchez-Galvis, E. M., García-Martínez, J. B., & Barajas-Solano, A. F. (2021). Enhancement of Phycobiliprotein Accumulation in Thermotolerant Oscillatoria sp. Through Media Optimization. *ACS Omega*, *6*(16), 10527–10536. https://doi.org/10.1021/acsomega.0c04665