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Diversity and Distribution of Phytoplankton in the Singkil Peat Swamp Water, Aceh Province, Indonesia

Dea Savira[1], Nanda Muhammad Razi[2], Khalidin Khalidin[1], Febry Darmawan[3], Mahfud Mahfud[1], Firdus Firdus[4], Zainal A. Muchlisin[5*]

[1] Master Program in Integrated Coastal Resource Management, Institute of Graduate Studies, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia
[2] Doctoral Program of Mathematics and Applied Sciences, Institute of Graduate Studies, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia
[3] Department of Marine Science, Faculty of Marine and Fisheries, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia
[4] Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia
[5] Department of Aquaculture, Faculty of Marine and Fisheries, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia

Corresponding Author Email: muchlisinza@usk.ac.id

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ABSTRACT

The Singkil peat swamp (SPS) is threatened by land conversion into oil palm plantations and settlements, thus posing a significant threat to aquatic biodiversity, including phytoplankton as a primary producer in the aquatic food chain, and yhytoplankton is commonly used as one of the bioindicators for monitoring aquatic health. Therefore, this research aimed to analyze the diversity and distribution of phytoplankton in Singkil peat swamp water as a basic data for monitoring aquatic condition of SPS in the future. The analysis was conducted at 11 sampling locations, which were determined purposively. Phytoplankton samples were collected using plankton net no. 25 by filtering 100 liters of surface water to a depth of 30 cm, while water samples were obtained between 10.00 AM to 15.00 PM. The filtered samples were put into a bottle and added with six drops of 4% Lugol solution. The results showed that there were 32 species of phytoplankton belonging to 8 classes, namely Bacillariophyceae, Cyanophyceae, Chlorophyceae, Cryptophyceae, Euglenoidea, Trebouxiophyceae, Ulvophyceae, and Zygnematophyceae. The highest abundance of phytoplankton was found in Seunabok Pusaka with a density of 2,480 cells/L, and *Cyclotella* sp. was identified as the most frequently occurring species. The average diversity index obtained was 1.50, falling into the medium category, while the average dominance index of 0.32 in the low category showed no dominant species. Furthermore, the average phytoplankton species richness index was in the low category. The Seuneubok and Impadang had a high similarity in community structure compared to other locations. The majority of phytoplankton showed a uniform distribution pattern, although three species had a group distribution pattern. A total of six bioindicator species were found namely *Nitzchia*, *Oscillatoria*, *Euglena*, *Leptocylindrus*, *Phacus*, and *Chlorella*. Seunabok Pusaka AFD 4 (St. 2) showed a higher number of bioindicator species, indicating that the location had been polluted.

1. INTRODUCTION

Indonesia is rich in peat swamp, covering an area of 20 million hectares, and ranks fourth globally after Canada, Russia, and America [1]. Peat swamps are one type of wetland that is formed from the accumulation of organic materials, especially plants that are not completely decomposed. Peat swamp is a freshwater or estuarine ecosystem that can be used for agriculture, horticulture, and fisheries [2]. Previous research has shown that natural peat land is capable of absorbing approximately 30% of carbon [3], serving as water catchment areas that control flooding and provide habitat for aquatic biota including fish, gastropods, bivalves, crustaceans, and insects [4, 5]. Among several provinces in Indonesia, Aceh is characterized by natural peat swamp resources, namely Tripa and Singkil peat swamp. Specifically, the Singkil peat swamp is located in three districts and city, including Aceh Singkil, South Aceh District, and Subussalam city covering an area of 81,802.22 hectares [6]. According to Onrizal [7], several species have been identified in Tripa peat swamp, including 157 birds, 20 mammals, and 15 herpetofauna [7]. However, the exploration of aquatic biota in Rawa Singkil is limited, where only one report identified 39 fish species in 26 families and 31 genera [8].

The presence of aquatic biota is significantly influenced by the availability of phytoplankton in water, which serves as the primary producer in the aquatic food chains, and as a bioindicator to assess the health of waters [9, 10]. Phytoplankton play an essential role as producers for the existence of other organisms, particularly heterotrophic groups including fish larvae, crabs, shrimp, mollusks, zooplankton, and others [11-13]. The abundance of phytoplankton describes the level of productivity and fertility of the waters [14-16], which influences the survival as well as growth of fish and other aquatic biota [17].

Currently, Rawa Singkil area is under threat due to massive deforestation and land conversion into oil palm plantations, and settlements [18]. The activities of oil palm plantations in peat swamp areas affect the aquatic environment, leading to the entry of fertilizer and pesticide residues into water. This phenomenon causes eutrophication, which triggers the mass growth of phytoplankton species (blooming) and reduces the diversity of other aquatic organisms [19-21]. The potential for toxic phytoplankton blooms can also occur, which is dangerous for aquatic organisms and humans [22, 23]. This condition causes disruption of the food chain in water, thereby reducing fishery productivity. Recent research in Rawa Singkil peat swamps is limited to vegetation diversity and terrestrial animals [7, 24, 25]. However, there are two reports on the diversity and distribution of macrozoobenthos as well as fish. Khalidin et al. [26] reported the existence of 21 species of macrozoobenthos comprising three classes, namely Gastropoda, Bivalvia, and Malacostraca. Razi et al. [8] also identified 39 species of fish belonging to 26 families and 31 genera, but there are no reports on the diversity of phytoplankton in peat swamp water. Therefore, this research aimed to analyze the diversity and distribution of phytoplankton in Singkil peat swamp water, Aceh province, Indonesia.

2. MATERIALS AND METHODS

2.1 Time and site

The research was carried out from June to August 2023 in peat swamp water of Rawa Singkil, Aceh province, Indonesia, as shown in Figure 1. Phytoplankton identification was conducted at the Marine Biology Laboratory, Faculty of Marine and Fisheries, Universitas Syiah Kuala, Banda Aceh. A total of 11 sampling locations were determined purposively, based on considerations for ease of access and the safety of the research team. The water areas were divided into two categories, namely water influenced by tides (red dots on the map) in nine locations and unaffected areas (green dots on the map) in two locations, as shown in Figure 1. Subsequently, three sampling points were determined at every water condition, as presented in Table 1.

2.2 Preservation and identification process

Phytoplankton samples were obtained using a plankton net no. 25. Subsequently, water samples were taken between 10:00 and 15:00WIB, with three repetitions conducted at every sampling point. A total of 100L of surface water were filtered, and the water samples were put into a bottle, added with six drops of 4% Lugol solution, and mixed homogeneously. The samples were stored in an ice box at 4°C and transported to the laboratory at the Faculty of Marine Affairs and Fisheries, Syiah Kuala University, Banda Aceh, for further analysis.

The dissolved oxygen (DO), water temperature, salinity, and pH were recorded in situ during the sampling. The DO was measured using a DO metre (DO-9100 Dissolved Oxygen Analyzer, China), temperature using a glass thermometre (ASTM 12C, etc.), salinity using a salinity metre (Atago MASTER, China), and pH using a pH metre (Atago DPH-2 ATC, China).

The samples were observed and identified using a binocular microscope (Carl Zeiss Primo Star, Germany) with 400x magnification. Before observation, samples in the bottle were inverted to achieve a homogeneous mixture. This was followed by the collecting of 0.05ml of water, which was dropped on a glass object, and observed using the census method. Subsequently, phytoplankton samples were counted and recorded based on APHA, followed by species identification through morphological characteristics and color. The identfication of the taxonomic status was carried out according to Tomas [27], Hasle et al. [28], Verlencar [29], and the online site platform (https://www.marinespecies.org/).

Table 1. The GPS coordinates and descriptions of sampling locations

Station	Descriptions
1	This is a small river located in the area of the ASN plantation company that has black and freshwater, where some parts are overgrown with aquatic vegetation.
2	This location is a river within the area of the ASN plantation company, which has medium water flow, black, and freshwater characteristics, along with a rocky bottom.
3	This location is a river estuary that is influenced by tides, characterized by pine trees and mangrove associations. Additionally, there are traditional fish landing sites near the sampling location and residential areas.
4	The river mouth has black water characteristics, which are influenced by tides, along with palm plantations and mangrove associations around the location.
5	The river estuary is influenced by tides and has the characteristics of brackish and blackish water. During sampling, the water was at high tide, and some parts had mangrove plants grow. Additionally, there is a traditional fish landing site near the sampling location.
6	This location is a freshwater river mouth that has black water. The area is covered by sand dunes and overgrown with mangrove plants.
7	This is a freshwater river mouth with black water characteristics, comprising sand dunes and mangroves.
8	The river mouth was covered by sand dunes during sampling, but the water was brackish and brownish.
9	This location is an estuary area that is influenced by tides and covered with mangroves. Furthermore, there is a raft crossing the river Kuala Baru connecting the South Aceh area to Singkil Regency.
10	This river is a tributary of the Alas River, characterized by brownish-yellow and freshwater, with mangrove and nipah vegetation.
11	This location is part of the lower stream of the Alas River, characterized by fast currents, and brownish water. The river is influenced by tides, but the water is still fresh, with fish landing ports at the sampling location.

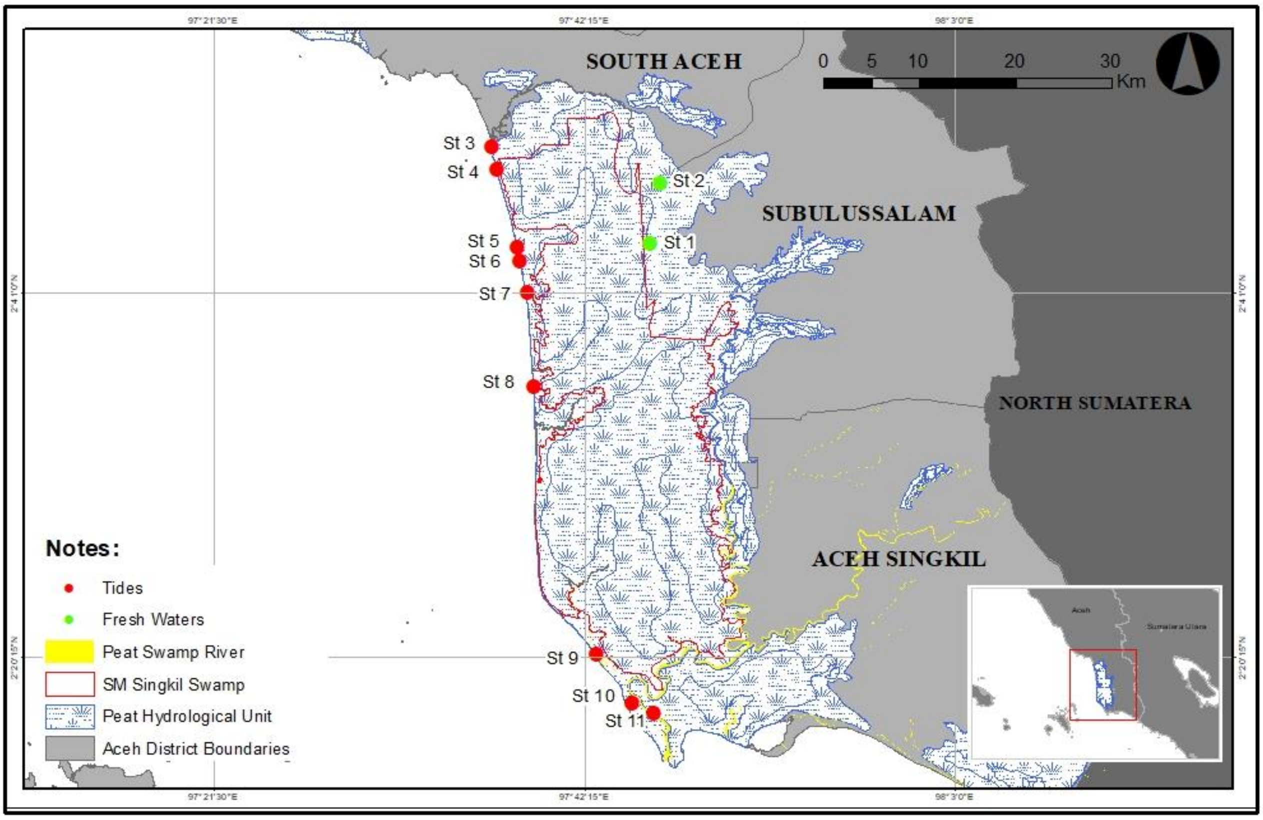

Figure 1. The map of the Singkil peat swamp area showing the sampling locations
Note: Red dots are locations that are influenced by tides, and green dots are sampling locations that are not influenced by tides.

2.3 Measured parameters

Abundance

Phytoplankton abundance was calculated using a formula based on APHA [30], as follows:

$$N=n\times\frac{1}{Vd}\times\frac{Vt}{Vs}$$

where, N= abundance (cell/L), n= total individual, Vt= total volume of filtered water (mL), Vd= total volume of water (L), Vs= total volume of water sample in the glass object (mL).

Frequency of occurrence

According to Krebs [31], frequency of occurrence (%) is expressed as (Total number of sampling locations of species found/ Total number of sampling locations) × 100. The results are categorized into various groups, including 0-25%: very rare presence, 25-50%: rare presence, 50-75%: moderate presence, and 75-100%: absolute presence.

Diversity index

The Shannon-Wiener diversity index was calculated based on Odum [32] as follows:

$$H' = -\sum_{i=1}^{s} \text{Pi Log2 Pi}$$

where, H': Shannon-Wiener, Log2=3.3219xlog Pi, Pi=ni/N, N= total individuals in all species, ni= Total individual belonging to the ith species. The Shannon-Wiener diversity index is categorized as follows: $H' < 1$ indicates low diversity, suggesting an unstable community. Additionally, $1 < H' \leq 3$ represents moderate, which indicates stability, and $H' \geq 3$ shows high diversity and stable community.

Simpson's dominance index

The dominance index ranges from 0 to 1, where a value closer to zero suggests the absence of dominant species and vice versa. In this research, Simpson's dominance index formula was used for analysis based on Somerfield et al. [33], as follows:

$$C = \sum_{i=1}^{s} \left(\frac{ni}{N}\right)^2$$

where, C is the dominance index, ni is the total individual of ith species, and N is the total individual of all species. The index is categorized based on values, where $C \leq 0.50$ indicates the absence of dominant species, $C \geq 0.50$ and ≤ 0.75 shows the presence of a dominant species at a moderate level, while $C \geq 0.75$ represents a high level of dominant species.

Species richness index

The Margalef's species richness index was calculated based on Magurran [34] using the following formula:

$$D=(S-1)/\ln N$$

where, D is the Margalef's species richness, S is the total species at ith location, and N is the total individual of all species at ith location. The Margalef's species richness index is divided into various categories, namely $D<2.5$: low, $2.5>D>4$: moderate, and $D>4.0$: high.

Similarity index

The similarity index was calculated based on Brower et al. [35] as follows:

$$SI\ (\%) = \frac{2C}{A + B} \times 100$$

where, SI is the similarity index, A is the total species at location-a, B is the total species at location-b, and C is the total species at locations a and b. Based on Odum and Barret [32], the similarity index is categorized as SI 75%-100%, very similar, SI 50%-75%, similar, SI 25%-50%, not similar, IS<25%, very not similar. The level of similarity in community structure between locations was analyzed using Paleontological Statistics Software (PAST 4.13) and represented in a dendrogram graphic.

Distribution pattern

The Morisita index (Id) was used to analyze the distribution pattern of phytoplankton using the proposed formula by Brower et al. [35] as follows:

$$Id = n\frac{\Sigma X^2 - N}{N(N - 1)}$$

where, Id is Morisita index, n is total plot, N is total individual, X^2 = total species in every plot, and frequency of incidence in each plot. Based on categorization, Id = 1 represents random, Id < 1 shows uniform, and Id > 1 indicates group distribution pattern.

Main water quality parameters

The main water quality parameters measured included surface water temperature, salinity, dissolved oxygen, and pH. The measurements were carried out in situ with three replications and the results were compared with standards of water quality based on Indonesian Government Regulation (PP) No. 22, 2021.

2.4 Data analysis

The data were presented in tables and figures, followed by descriptive analysis by comparing the results with related research or references and obtaining conclusions.

3. RESULTS

3.1 Species composition, abundance, and frequency of occurrence

A total of 32 species belonging to 8 classes of phytoplankton were recorded during the research, including Bacillariophyceae, Cyanophyceae, Chlorophyceae, Cryptophyceae, Euglenoidea, Trebouxiophyceae, Ulvophyceae, and Zygnematophyceae. Based on the results in Figure 2, Bacillariophyceae was identified as the most numerous species, accounting for 64%. As shown in Table 2, the abundance of phytoplankton in Singkil peat swamp water ranged from 300 cells/L to 2,840 cells/L, where the highest was found in Seunabok Pusaka AFD 4 (St. 2). This suggested the classification of Singkil peat swamp as mesotrophic water or moderate fertility, with *Euglena* sp. as the most commonly found species.

The frequency of occurrence analysis showed that *Cyclotella* sp. was found in nine locations, with a percentage of 81.82%. Additionally, there were 4 species with a moderate level of occurrence, namely, *Synedra* sp., *Euglena* sp., *Melosira* sp., and *Pinnularia* sp. The results in Table 3 showed 4 species with rare occurrence, namely, *Ulotrix* sp., *Nitzchia* sp., *Navicula* sp., and *Fragilaria* sp., as well as other 16 species with very rare occurrence.

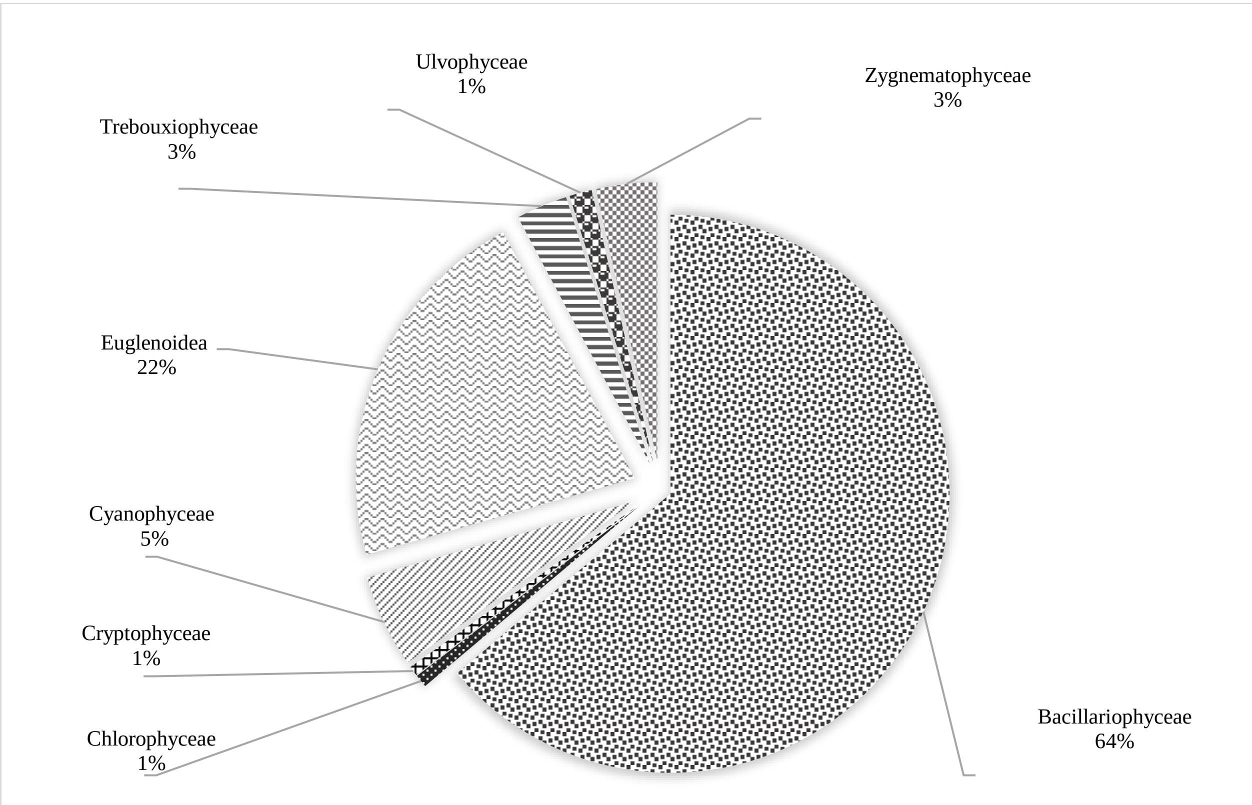

Figure 2. Composition of classes based on species number of phytoplankton in the Singkil peat swamp

Table 2. The abundance of phytoplankton in the Singkil peat swamp waters based on sampling locations

No.	Species	South Aceh District								Aceh Singkil District			ni	Abundance (cells/L)
		1	2	3	4	5	6	7	8	9	10	11		
1	*Asterionella*	-	-	-	-	-	-	-	-	-	2	1	3	60
2	*Bacillaria* sp.	-	3	-	-	-	-	-	-	-	-	-	3	60
3	*Chaetoceros lorenzianus*	-	-	-	-	-	2	-	-	-	-	-	2	40
4	*Chaetoceros* sp.	1	-	-	-	-	-	-	-	-	-	2	3	60
5	*Cyclotella* sp.	5	22	-	2	32	3	15	5	9	-	4	97	1940
6	*Eucampia zodiachus*	4	-	-	-	-	-	-	-	-	-	-	4	80
7	*Fragilaria* sp.	1	4	-	-	-	-	-	-	-	-	1	6	120
8	*Leptocylindrus minimus*	-	-	14	-	-	-	-	-	-	-	-	14	280
9	*Licmophora* sp.	-	-	-	-	-	-	2	-	-	-	-	2	40
10	*Melosira* sp.	-	2	6	2	-	1	-	5	2	-	5	23	460
11	*Navicula laterostrata*	-	5	-	-	-	-	-	-	-	-	-	5	100
12	*Navicula* sp.	-	17	-	-	-	-	-	-	-	9	7	33	660
13	*Nitzchia acicularis*	-	-	-	-	-	-	-	-	-	-	4	4	80
14	*Nitzchia* sp.	6	5	-	-	-	-	7	-	-	-	-	18	360
15	*Pinnularia* sp.	2	1	-	-	-	-	10	5	-	9	46	73	1460
16	*Surirella* sp.	-	-	-	-	-	-	-	-	-	4	5	9	180
17	*Synedra* sp.	3	1	-	5	2	1	7	3	-	-	5	27	540
18	*Synedra ulna*	-	6	-	-	-	8	-	-	-	-	-	14	280
19	*Thalasiothrix* sp.	3	-	-	-	-	-	-	-	-	-	-	3	60
20	*Ceratium* sp.	-	2	-	-	-	-	-	-	-	-	-	2	40
21	*Chalothrix* sp.	-	-	-	-	-	-	11	-	-	-	-	11	220
22	*Microcoleus vaginatus*	-	-	-	-	-	-	9	-	-	-	-	9	180
23	*Oscillatoria* sp.	-	-	-	-	-	-	-	-	-	-	7	7	140
24	*Palmella* sp.	-	-	-	-	-	-	-	-	-	-	4	4	80
25	*Cryptomonas* sp.	-	3	-	-	-	-	-	-	-	-	-	3	60
26	*Euglena* sp.	4	28	-	13	-	-	10	9	8	17	12	101	2020
27	*Phacus crassus*	-	12	-	-	-	-	-	-	-	3	-	15	300
28	*Chlorella* sp.	-	3	-	-	-	-	-	-	7	-	-	10	200
29	*Oocystis* sp.	-	6	-	-	-	-	-	-	-	-	-	6	120
30	*Cosmarium* sp.	6	-	-	-	-	-	-	-	-	10	-	16	320
31	*Hyalotheca undulata*	-	3	-	-	-	-	-	-	-	-	-	3	60
32	*Ulothix* sp.	2	1	-	-	-	-	-	-	-	4	-	7	140
	Total	37	124	20	22	34	15	71	27	26	26	103	537	10.74
	Abundance (cell/L)	740	2480	400	440	680	300	1420	540	520	520	2060	10740	

Table 3. Frequency of occurancy of phytoplankton in the Singkil peat swamp waters based on sampling locations

No.	Species	South Aceh District								Aceh Singkil District			FO %	Status
		1	2	3	4	5	6	7	8	9	10	11		
1	*Asterionella*	-	-	-	-	-	-	-	-	-	2	1	18.18	VRO
2	*Bacillaria* sp.	-	3	-	-	-	-	-	-	-	-	-	9.09	VRO
3	*Ceratium* sp.	-	2	-	-	-	-	-	-	-	-	-	9.09	VRO
4	*Chaetoceros lorenzianus*	-	-	-	-	-	2	-	-	-	-	-	9.09	VRO
5	*Chaetoceros* sp.	1	-	-	-	-	-	-	-	-	-	2	18.18	VRO
6	*Chalothrix* sp.	-	-	-	-	-	-	11	-	-	-	-	9.09	VRO
7	*Chlorella* sp.	-	3	-	-	-	-	-	-	7	-	-	18.18	VRO
8	*Cosmarium* sp.	6	-	-	-	-	-	-	-	-	10	-	18.18	VRO
9	*Cryptomonas* sp.	-	3	-	-	-	-	-	-	-	-	-	9.09	VRO
10	*Cyclotella* sp.	5	22	-	2	32	3	15	5	9	-	4	81.82	VOO
11	*Eucampia zodiachus*	4	-	-	-	-	-	-	-	-	-	-	9.09	VRO
12	*Euglena* sp.	4	28	-	13	-	-	10	9	8	17	12	72.73	MO
13	*Fragilaria* sp.	1	4	-	-	-	-	-	-	-	-	1	27.27	RO
14	*Hyalotheca undulata*	-	3	-	-	-	-	-	-	-	-	-	9.09	VRO
15	*Leptocylindrus minimus*	-	-	14	-	-	-	-	-	-	-	-	9.09	VRO
16	*Licmophora* sp.	-	-	-	-	-	-	2	-	-	-	-	9.09	VRO
17	*Melosira* sp.	-	2	6	2	-	1	-	5	2	-	5	63.64	MO
18	*Microcoleus vaginatus*	-	-	-	-	-	-	9	-	-	-	-	9.09	VRO
19	*Navicula laterostrata*	-	5	-	-	-	-	-	-	-	-	-	9.09	VRO
20	*Navicula* sp.	-	17	-	-	-	-	-	-	-	9	7	27.27	RO
21	*Nitzchia acicularis*	-	-	-	-	-	-	-	-	-	-	4	9.09	VRO
22	*Nitzchia* sp.	6	5	-	-	-	-	7	-	-	-	-	27.27	RO
23	*Oocystis* sp.	-	6	-	-	-	-	-	-	-	-	-	9.09	VRO
24	*Oscillatoria* sp.	-	-	-	-	-	-	-	-	-	-	7	9.09	VRO
25	*Palmella* sp.	-	-	-	-	-	-	-	-	-	-	4	9.09	VRO
26	*Phacus crassus*	-	12	-	-	-	-	-	-	-	3	-	18.18	VRO
27	*Pinnularia* sp.	2	1	-	-	-	-	10	5	-	9	46	54.55	RO

28	*Surirella* sp.	-	-	-	-	-	-	-	-	-	4	5	18.18	VRO
29	*Synedra* sp.	3	1	-	5	2	1	7	3	-	-	5	72.73	MO
30	*Synedra ulna*	-	6	-	-	-	8	-	-	-	-	-	18.18	VRO
31	*Thalasiothrix* sp.	3	-	-	-	-	-	-	-	-	-	-	9.09	VRO
32	*Ulothix sp.*	2	1	-	-	-	-	-	-	-	4	-	27.27	RO

Note: 1 = Seunabok Jaya AFD 5, 2 = Seunabok Pusaka AFD 4, 3= Kuala Trumon, 4= Alur Seuneubok, 5= Ie Meudama, 6 = TPI Teupin Tinggi, 7= Teupin Tinggi, 8 = Impadang, 9= Kuala Baru, 10 = Jembatan Kembar, 11 = Kilangan Village Harbor. VRO= Very rare occurance, VOO= Very often occurance, MO= Moderate occurance, RO= Rare occurance

Table 4. Ecological indices of Singkil peat swamps waters, Aceh province, Indonesia

No.	Location	Diversity Index (H')		Dominance Index (D)		Sepcies Richness (d)	
		Value	Category	Value	Category	Value	Category
1	Seunabok Jaya AFD 5	2.26	Moderate	0.11	Low	2.77	Moderate
2	Seunabok Pusaka AFD 4	2.41	Moderate	0.12	Low	3.53	Moderate
3	Kuala Trumon	0.61	Moderate	0.58	Moderate	0.33	Low
4	Alur Seuneubok	1.08	Moderate	0.42	Low	0.97	Low
5	Ie Meudama	0.22	Low	0.89	High	0.28	Low
6	TPI Teupin Tinggi	1.29	Moderate	0.35	Low	1.48	Low
7	Teupin Tinggi	1.99	Moderate	0.14	Low	1.64	Low
8	Impadang	1.55	Moderate	0.23	Low	1.21	Low
9	Kuala Baru	1.28	Moderate	0.29	Low	0.92	Low
10	Jembatan Kembar	1.88	Moderate	0.18	Low	1.72	Low
11	Kilangan Village Harbor	1.96	Moderate	0.23	Low	2.59	Moderate
	Min.	0.22		0.11		0.28	
	Max.	2.41		0.89		3.53	
	Average	1.50	Moderate	0.32	Low	1.62	Low

3.2 Community structure

The results showed that phytoplankton diversity index ranged from 0.22 to 2.41, with an average value of 1.50 in the medium category, as shown in Table 4. The dominance index ranged from 0.11 to 0.89, with an average of 0.32, belonging to the low category or absence of dominant species The species richness index varied from 0.28 to 3.53, where Seunabok Pusaka AFD 4 (St. 2) served as location within high category. However, the average species richness of Singkil peat swamp water was 1.62, which belonged to the low category, as shown in Table 4.

3.3 Distribution patterns

The results showed that several locations had high similarities in community structure, including Alur Seuneubok (St. 4) and Impadang (St. 8), with a similarity level of 89%. As shown in Figure 3, the similarity level between Alur Seuneubok (St. 4) and Kuala Trumon (St. 3) was found to be 75%. Morisita index (Id) analysis showed that approximately all phytoplankton showed a uniform distribution pattern, where *Cosmarium* sp., *Cyclotella* sp., and *Navicula* sp. were clustered, as presented in Table 5.

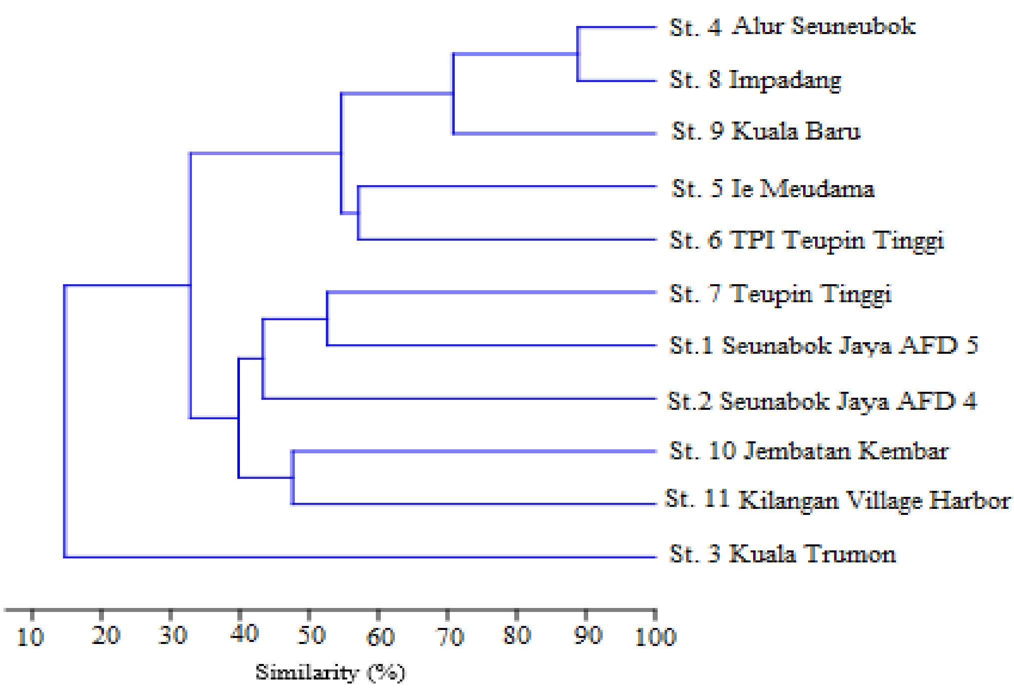

Figure 3. Dendogram of similarity index of phytoplankton community structure of Singkil peat swamp, Aceh province, Indonesia

Table 5. Distribution patterns of the phytoplankton in the Singkil peat swamps water of Aceh province, Indonesia

No.	Species	Distribution Pattern	Category
1	*Asterionella* sp.	-14	Uniform
2	*Bacillaria* sp.	-12	Uniform
3	*Ceratium* sp.	-27	Uniform
4	*Chaetoceros lorenzianus*	-27	Uniform
5	*Chaetoceros* sp.	-14	Uniform
6	*Chalothrix* sp.	0	Uniform
7	*Chlorella* sp.	-1.73	Uniform
8	*Cosmarium* sp.	1.5	Group
9	*Cryptomonas* sp.	-12	Uniform
10	*Cyclotella* sp.	2.96	Group
11	*Eucampia zodiachus*	-7	Uniform
12	*Euglena* sp.	0.15	Uniform
13	*Fragilaria* sp.	-4.8	Uniform
14	*Hyalotheca undulata*	-12	Uniform
15	*Leptocylindrus minimus*	0.69	Uniform
16	*Licmophora* sp.	-27	Uniform
17	*Melosira* sp.	-0.91	Uniform
18	*Microcoleus vaginatus*	-0.75	Uniform
19	*Navicula laterostrata*	-4.5	Uniform
20	*Navicula* sp.	1.09	Group
21	*Nitzchia acicularis*	-4.25	Uniform
22	*Nitzchia* sp.	0.75	Uniform
23	*Oocystis* sp.	-3	Uniform
24	*Oscillatoria* sp.	-2	Uniform
25	*Palmella* sp.	-7	Uniform
26	*Phacus crassus*	-0.17	Uniform
27	*Pinnularia* sp.	0.86	Uniform
28	*Surirella* sp.	-2,41	Uniform
29	*Synedra* sp.	-0.74	Uniform
30	*Synedra ulna*	-0.89	Uniform
31	*Thalasiothrix* sp.	-12	Uniform
32	*Ulothix* sp.	-4	Uniform

Table 6. The main water quality parameter in Singkil peat swamp waters of Aceh province, Indonesia

Station	District	Location	Temp. (°C)	DO (mg/L)	pH	Salinity(ppt)
1	Trumon	Seunabok Jaya AFD 5	31	4.4	6.5	0
2	Trumon	Seunabok Pusaka AFD 4	31.5	4.3	6.7	0
3	Trumon	Kuala Trumon	29	5.6	7.5	9
4	Trumon	Alur Seuneubok	28.9	3.5	6.5	2
5	Trumon	Ie Meudama	28.9	4.1	6.8	0
6	Trumon	TPI Teupin Tinggi	28.6	3.9	4.6	0
7	Trumon	Teupin Tinggi	28.2	4.4	6.9	0
8	Trumon	Impadang	28.6	5.1	6.7	2
9	Kuala Baru	Kuala Baru	28.9	5.9	6.8	2
10	Kuala Baru	Jembatan Kembar	33.5	6.8	8.7	22
11	Singkil	Kilangan Village Harbor	33.7	5.6	8.6	0
		Average	29.9	4.9	6.9	3.4
Quality standard of waters based on Indonesian Regulation No. 22, 2021			Dev. 3	3.00	6.9	-

3.4 Main water quality parameters

The research showed that temperature ranged from 28.2 to 33.7°C, the highest and lowest value recorded in Kilangan Village Harbor (St. 11) and Teupin Tinggi (St. 7), respectively. The dissolved oxygen (DO) varied from 3.5 to 6.8 mg/L, with the highest value obtained at Jembatan Kembar (St. 10), while the lowest was found at TPI Teupin Tinggi (St. 6) and Seuneubok Alur (St. 6). Furthermore, pH ranged from 4.6 to 8.7, with the highest ad lowest value obtained at the Jembatan Kembar (St. 10) and TPI Teupin Tinggi (St. 6), respectively. The salinity varied from 0 ppt to 22 ppt, where Jembatan Kembar (St. 10) had the highest value of 22 ppt. Based on the classification, the salinity level between 2-9 ppt was classified as brackish for Kuala Trumon (St. 3), Alur Seuneubok (St. 4), Impadang (St. 8), and Kuala Baru (St. 9). Meanwhile, the other six locations were classified as freshwater, as shown in Table 6.

4. DISCUSSION

The research showed that Bacillariophyceae had the highest number of species, accounting for 62%, due to the adaptability of the class to environmental variations [36, 37]. Apart from the Singkil peat swamp, the Bacillariophyceae were also dominantly found in the Russian Yugra peat swamp [38] and the Ogan Komering Ilir peat swamp, South Sumatra [39]. According to Heraamza et al. [40] and Saxena et al. [41], Bacillariophyceae, which are mostly from the diatom group, are cosmopolitan phytoplankton capable of surviving in extreme or polluted waters. Meanwhile, phytoplankton, with a low proportion, such as Cryptophyceae, Ulvophyceae, and Chlorophyceae have slow growth and a long life cycle [42]. Chlorophyceae are solitary, and their growth is largely determined by the amount of nutrients in the water [43, 44].

The highest abundance of phytoplankton was found in Seunabok Pusaka AFD 4 (St. 2), with Euglena sp. being the most abundant. Meanwhile, the lowest abundance was found at the TPI Teupin Tinggi (St. 6), characterized by blackish brown waters, with numerous aquatic plants that prevent the penetration of sunlight, photosynthesis process, and growth of phytoplankton [45]. The low abundance of phytoplankton was attributed to currents and tides [46]. In comparison with other locations, the highest abundance of Euglena sp. was found in Seunabok Pusaka AFD 4 (St. 2). Regarding phytoplankton and water status, Seunabok Pusaka AFD 4 (St. 2) and Kilangan Village Harbor (St. 11) were classified as mesotrophic or medium fertility levels, while nine locations were classified as oligotrophic water with low fertility. Although some areas in Singkil peat swamp water had been converted into oil palm plantations, there was no indication of eutrophication at the sampling locations. This phenomenon occurred because plantations in the area had an extensive scale, resulting in minimal fertilizer residue runoff into water.

The results showed that several species of bioindicator phytoplankton occurred in Rawa Singkil water, namely, *Nitzschia* was found at Seunabok Jaya AFD 5 (St. 1), Seunabok Pusaka AFD 4 (St. 2), Teupin High (St. 7), and Kilangan Village Harbor (St. 11). *Chlorella* was found at Seunabok Pusaka AFD 4 (St. 2) and Kuala Baru (St. 9), while *Oscillatoria* was identified at Kilangan Village Harbor (St. 11). Furthermore, *Leptocylindrus* was found on Kuala Trumon (St. 3), *Euglena* was discovered at all stations except Kuala Trumon (St. 3), Ie Meudama (St. 5), and TPI Teupin Tinggi (St. 6). Other species, specifically *Phacus* was found at Seunabok Pusaka AFD 4 (St. 2) and Jembatan Kembar (St. 10). According to Sidomukti and Wardhana [47], the presence of two or more aquatic bioindicators, including phytoplankton, serves as an indication of water pollution. Therefore, the presence of bioindicator species at six locations showed significant disturbances in water body. At Seunebok Pustaka AFD 4 (St. 2), four bioindicator species were found, suggesting pollution.

The research showed that *Cyclotella* sp. of the Bacillariophyceae class had a very high frequency of occurrence. This class of phytoplankton was also dominated peat swamp water of the Ambawang River, Kubu Raya Regency, West Kalimantan Province, Indonesia [48], and the Obolo River Estuary, Niger Delta [49]. Most species from the Bacillariophyceae class have a wide distribution, thriving in various types of habitats, including freshwater, seas, and estuaries [50]. The results showed that almost all phytoplankton had a uniform distribution pattern, although three species showed group distribution namely *Cosmarium* sp., *Cyclotella* sp., and *Navicula* sp. Grouping patterns occur due to variations in habitat, such as hydrographic conditions and tidals [51]. Additionally, the distribution of phytoplankton depends on the movement of water currents [52], temperature, sunlight, dissolved oxygen (DO), pH, and turbidity [53].

The average index diversity of phytoplankton in Singkil peat swamp water was classified as a moderate category. This served as an initial indication that the water was under threat from ecological perturbation due to the high level of exploitation and land conversion to oil palm plantation. Therefore, it is necessary to immediately take preventive action by developing regulations to prevent the conversion of peat swamps to plantations and maintaining the function of this ecosystem as water catchment and flood control. The use of chemicals, such as excessive use of fertilizers and pesticides, on oil palm plantations on peatlands also needs to be regulated. The average value of phytoplankton dominance index was in the low category, indicating the absence of dominant species. Based on the similarity index, Alur Seuneubok (St. 4) and Impadang (St. 8) had a high level of similarity in community structure, reaching 89%. The results showed that the composition and abundance of each species between the two locations were relatively the same due to the habitat and water quality. Stations 4 and 8 are both river estuaries with brackish water salinity, characterized by relatively the same pH and temperature. However, the physical-chemical quality values in Rawa Singkil water are still within the standards of Indonesian Government Regulations No. 22, 2021.

5. CONCLUSION

In conclusion, this research identified 32 species of phytoplankton, which were divided into eight classes, namely Bacillariophyceae, Cyanophyceae, Chlorophyceae, Cryptophyceae, Euglenoidea, Trebouxiophyceae, Ulvophyceae, and Zygnematophyceae. The highest abundance of phytoplankton was found in Seunabok Pusaka AFD 4 (St. 2), with *Cyclotella* sp. being the most frequently occurring species. The average diversity index of 1.50 was classified into medium category, while a value of 0.32 indicated the low category, suggesting no dominant species. However, six bioindicator species, namely *Nitzchia*, *Oscillatoria, Euglena*, *Leptocylindrus, Phacus*, and *Chlorella*, were found, where Seunabok Pusaka AFD 4 (St. 2) had the highest species. The results also showed that the average species richness index was classified into the low category. Additionally, Seuneubok (St. 4) and Impadang (St. 8) had a high similarity index compared to other locations. The distribution pattern of phytoplankton was generally classified as uniform, while *Navicula* sp., *Cyclotella* sp., and *Cosmarium* sp. had a group distribution pattern. These findings are the initial indication of disturbances in the water quality of the Singkil peat swamp.

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