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Spatial Distribution of Phytoplankton in Jatigede Reservoir, West Java, Indonesia

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Authors' contributions

This work was carried out in collaboration among all authors. Author RNH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ZH and HH managed the analyses of the study. Authors IN and AS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Jatigede Reservoir has water input from the Cimanuk River. This river has gone through several anthropogenic activities that can affect its waters. Changes in conditions can occur due to changes in ecosystems carried out by several ecological aspects, one of which is the distribution of biota structures. The purpose of this study is to map the distribution of phytoplankton through spatial distribution both horizontally and vertically at the Jatigede Reservoir, West Java. The study began in July 2019 until September 2019. This research uses survey method. Sampling was carried out at 4 stations on the surface, half of the compensation depth, and compensation depth. The water parameters analyzed are transparency, temperature, depth, current, pH, CO_2, BOD, DO, NO_3-, PO_4^{3-}, NH_3, fitoplankton abundance, diversity index and dominance index. The results showed that 49 genera from 11 classes and 5 phyla were identified. Diversity index during the study reached between 0.904-2.062 and the dominance index was in the range of 0.267-0.681. The highest phytoplankton composition at each station and depth was found in the Bacillariophyceae class as much as 59.65% with an average abundance of 5523 ind/L.11 phytoplankton classes found during the study were identified at all observation stations, except in the eustigmatophyceae and mediophyceae classes.

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1. INTRODUCTION

One aspect that affects the aquatic ecosystem is the structure of a biota or organism that lives in a waters. One of the biota community structures that affects the dynamics of ecosystems in waters is plankton as a biological parameter of a waters. As a biological parameter, plankton especially phytoplankton, which have an important role in the food chain in aquatic ecosystems, are often used as indicators of stability, fertility and water quality [1]. Phytoplankton also have a role as an oxygen suppliers through the process of photosynthesis [2].

Distinctive biota distribution pattern, suitable to the habitat where the biota is located [3]. Jatigede Reservoir has main water input coming from the Cimanuk River. The input water from the Cimanuk River to the Jatigede Reservoir can affect the quality of its waters. The increase ofhuman population settlements, industrial activities, and agricultural activities around the river flow can affect conditions in these waters [4].

Changes in water conditions can occur due to the dynamics of ecosystems that are influenced by several ecological aspects of its waters. This ecological aspects include morphology, physical-chemical parameters of water, biota community structure, and trophic status [5]. Therefore, it is necessary to know the spatial distribution of phytoplankton both horizontally and vertically as biological parameters of the waters to determine the status of the structure of the aquatic ecosystem as a basicstudies for further utilization.

2. METHODOLOGY

2.1 Study Area

This research was conducted at Jatigede Reservoir, Sumedang Regency, West Java Province, Indonesia. The study was carried out during July 2019 until September 2019 which is the dry season in Indonesia. Observation and sampling stations (Fig. 1) were carried out using the purposive sampling method which was divided into four stations.The observation station for sampling is chosen based on the zone and input of water flowing through the Jatigede Reservoir dam, including:

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Station 1: Located at the reservoir inlet with a geographical location of 6°55'58.8"S-108° 05'20.3" E which receives water input dominated by the Cimanuk River and is a riverine zone.

Station 2: Located at transition zone with a geographical location of 6°54'40.1"S-108°05'46.4" E which is a transitional body of water from the Cimanuk river water input towards the center of the water body.

Station 3: Located in the middle of the body of the Jatigede Reservoir with a geographical location of 6°53'06.8"S- 108°06'11.3" E which receives water input from the Cimanuk river and also other tributaries such as the Cinambo River, Cibayawak River, CihonjeRiver, Cicacaban River, and Cimuja River.

Station 4: Located at Reservoir Outlet with a geographical location of 6°51'32.6"S-108° 05'49.0"E which is the lacustrine zone where the outflow of Jatigede Reservoir water flows from various water inputs at the previous station.

2.2 Sampling and Measurement

Water and phytoplankton sampling were carried out with a seven-day period of five times samplings. Water and phytoplankton samples taken at the four stations were carried out on the surface, half of compensation depth, and compensation depth. Phytoplankton samples are taken by filtering 10 liters of water using a plankton net with mesh size of 20 μm. Filtered water sample were put into a 50 ml bottle sample and preserved using Lugol 1% until it turns yellow-brown in color. Phytoplankton found were identified up to the genus level.Phytoplankton are calculated by census method and identified using plankton identification books. There are Sachlan [6], Prescott (1978), Bold and Wynne (1985), and Bellinger and Sigee (2010). The water parameters measured include transparency, water depth, temperature, current, pH, CO_2, BOD, DO, NO_3, PO_4 and NH_3.

2.3 Sample Analysis

Phytoplankton data analysis was performed in a comparative descriptive method with the following observational parameters.

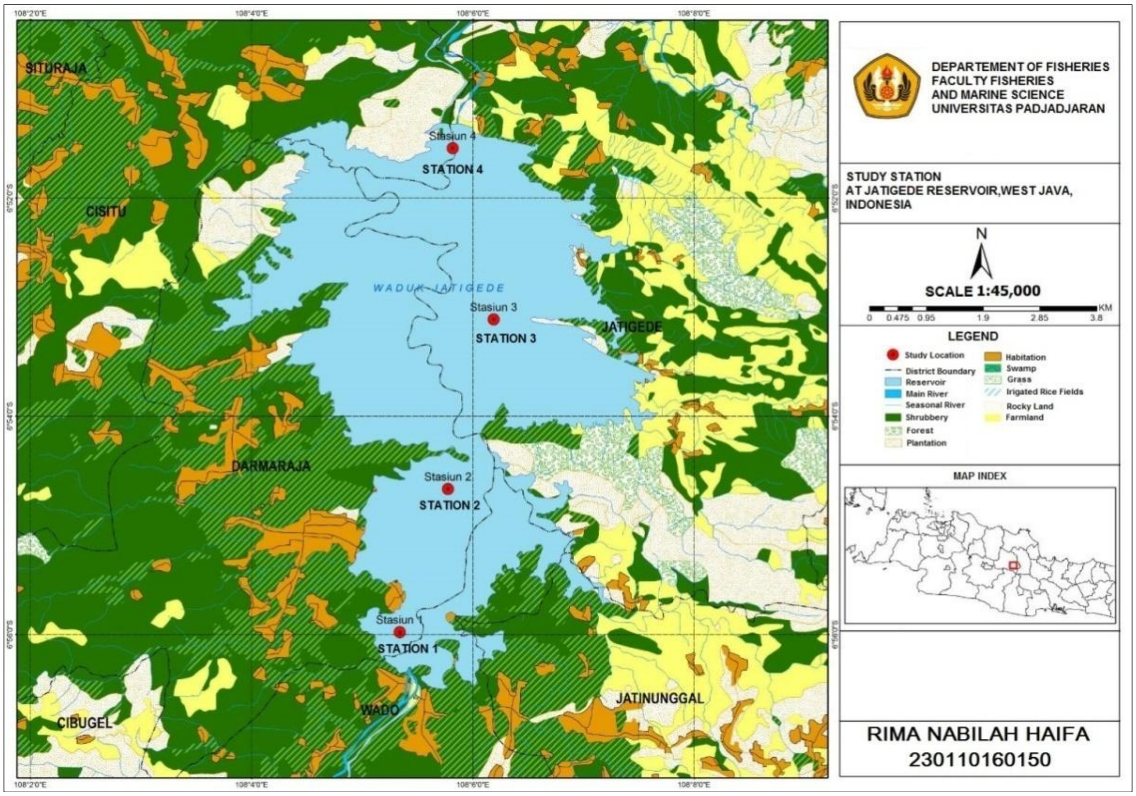

Fig. 1. Map of study location

2.3.1 Phytoplankton abundance

Phytoplankton abundance is the number of phytoplankton individuals per unit volume. Plankton abundance quantitatively is based on abundance expressed in individuals/Liters. Plankton abundance is calculated according to the following formula [6].

$$N = n \times (Vr / Vo) \times (1 / Vs)$$

Information:

N = Abundance (ind / L)
N = Number of phytoplankton observed
Vr = Filtered phytoplankton volume (ml)
Vo = Volume of water at Sedgewick Rafter Chamber (SRC)
Vs = The volume of filtered water

2.3.2 Diversity index

To find out genus/species diversity, diversity index calculated using the Shannon-Wienner diversity index with the following formula [2]:

$$H' = - \sum [Pi \ln Pi]$$

Information:

H ' = Diversity
Pi = ni / N
Ni = Number of individuals in one genus/species
N = The total number of individuals of all genus/species

The classification of conditions for the biota community based on the value of H 'is:

H '<1 = Low diversity (unstable)
1 <H '<3 = Medium diversity (Medium stability)
H '> 3 = High diversity (High stability)

2.3.3 Dominance index

Dominance index is used to determine the extent of dominance of a species or genus in other groups. The calculation method used is the Simpson dominance index formula [2].

$$D = \sum [(Pi)]^2$$

Information:

D = Dominance
Pi = ni / N

Ni = Number of individuals in one type
N = Total number of individuals of all types

The domiation index criteria are:

0 <C ≤ 0.5 = no genus or species dominates;
0.5 <C <1 = there is a dominant type

3. RESULTS AND DISCUSSION

3.1 Physical and Chemical Parameters of Water

Physical and chemical parameters of the waters during the study can be seen in Table 1. Transparency of light greatly determines the presence of phytoplankton. The higher the transparency of light, the easier the light to enter the water and vice versa the lower will inhibit the process of photosynthesis of phytoplankton [7]. The lowest average transparency was at station 1,27,60±7,80 cm and the highest average transparency was at station 4 which was 93,10±18,49 cm. Station 1 is a reservoir inlet that has a main water input directly from the Cimanuk River and is still in the riverine zone so it has a low transparency value. The high value of light transparency at station 4 is caused by the water condition which is clearer and far from anthropogenic activity.

Based on research data, it can be seen that the surface depth has an average temperature range of 27,02±1,06-27,48±1,06°C. Then, a decrease in temperature at a depth of 0.5 compensation occurs with an average temperature range of 27,02±0,53-27,38±0,53°C and a decrease in temperature continues with increasing depth where the temperature range at the depth of compensation is 26,58±0,36-27,06±0,51°C. The deeper the depth the lower the temperature of the waters. This is consistent with the statement which reveals that one of the factors that influence temperature is the transparency of light. This is because light has a direct effect on temperature, which means that high light intensity will produce heat which will further increase the temperature [8].

Station 2 has the lowest average current speed of 0,136±0,092 m/s, while the highest average current speed is at station 3 with a value of 0,216±0,148 m/s. The average flow in the waters of the Jatigede Reservoir is still categorized as slow flow. There are five categories of currents, namely very slow currents (less than 0,10 m/s), slow (0,10-0,25 m/s), moderate (0,25-0,50 m/s), fast (0,50-1 m/s) and very fast (more than 1 m/s) [9].

The pH observed during the study was classified as sufficient pH for the life of phytoplankton. This is indicated in the average pH range of 7,96±0,64-8.30±0,29 at surface depth, 8,03±0,38-8,40±0,59 at half depth compensation, and 7,69±0,78 to 8,30±0,11 at the depth of compensation. High or low pH values of water depend on several factors, namely, the condition of gases in water such as CO_2, concentrations of carbonate and bicarbonate salts, and the process of decomposition of organic matter at the bottom of the waters [10].

The average range of CO_2concentration observed was 4.19±0-9.22±3.5 mg/l at surface, 4,19±0-7,54±3,5 mg/l at half of compensation depth and 4,19±0-7,54±3,5 mg/l at compensation depth. Can be seen in Table 1, station 1 has the highest CO_2 concentration compared to other observation stations. The high average level of carbondioxide at Station 1 is caused by the water area which is a reservoir inlet where many pollutants from the Cimanuk River that carry carbon dioxide in waters lead to the Jatigede Reservoir inlet.

The lowest average BOD_5level at station 4 was 11,03±6,00 mg/l, while the highest BOD_5 level was at station 1 at 12,65±6,00 mg/l. The high levels of BOD_5 at Station 1 indicate that the content of organic matter dissolved in the waters is classified as high because this station is a reservoir inlet which is the input of Cimanuk River water which contains industrial waste as well as settlements. BOD_5 levels in waters can come from waste or garbage from settlements that are not decomposed by microbial degrading organic matter in the waters [11].

The observed average DO range was 6,54±0,5-7,12±0,8 mg/l at surface, 6,38±1,2-7±0,6 mg/l at half of compensation depth and 6,46±1-7±0,8 mg/l at compensationdepth. The DO concentration decreases along with its depth, this is due to the deeper into the water the less incoming sunlight so that the phytoplankton photosynthesis process is not going well [12].

The average range of nitrates observed were 0,168±0,037-0,238±0,028 mg/l at surface, 0,188±0,046-0,244±0,082 mg/l at half-compensationdepth and 0,183±0,029-0,256±0,103 mg/l at compensation depth. The average range of observed phosphate concentration was 0,148±0,027-0,161±0,031 mg/l at surface, 0,139±0,019-0,175±0.026 mg/l at half compensation depth and 0,15±0,041-0,185 mg/l at compensation depth. The main source of phosphate and nitrate nutrients comes from the waters themselves, namely through the decomposition of weathering or decomposition of plants and the remains of dead organisms [13].

The average range of observed ammonia concentration was 0,0098±0,005-0,039±0,04 mg/l at surface, 0,0103±0,008-0,04±0,031 mg/l at half of compensation depth, and 0,0065±0,005-0,027±0,026 mg/l at compensation depth. The range and average ammonia concentration during the study were still relatively good. The maximum limit of ammonia concentration for aquatic organisms is 0,1 mg/l [14].

3.2 Phytoplankton Community Structure

Stations 1, 2 and 3 during the study, showed that the deeper the depth of the water, the lower the abundance of phytoplankton (Fig. 2). Whereas, station 4 has the highest abundance of phytoplankton at a depth of half compensation of 13181 ind/L and the lowest abundance on the surface with an abundance of 8462 ind/L. The high abundance of phytoplankton at station 4 at a depth of half compensation is due to the condition of the waters at this point which is optimal for the survival of phytoplankton. This condition occurs because the intensity of the incoming light has increased. Increased light intensity and temperature on the surface of the water makes phytoplankton unable to carry out the process of photosynthesis optimally.

Phytoplankton identified during the study were 49 genera from 11 classes and 5 phyla. The five phyla are Cyanophyta, Chlorophyta, Chrysophyta, Pyrrophyta, and Euglenophyta. Phytoplankton from the phyla Chrysophyta are the most common phytoplankton with a percentage of 60% of the total phytoplankton found. Based on Fig. 3, phytoplankton from the Bacillariophyceae class are the most commonly found phytoplankton with a percentage of 59.65% of the total phytoplankton found, in this class identified in the genus Navicula, Neidium, Pinnularia, Gyrosigma, Gomphonema, Nitzchia, Synedra, and Surirella.

Phytoplankton diversity index during the study was in the range of 0,889-2,010 (Fig. 4). Station 1, station 2, and station 3 at all observed depths have a value of 1 <H '<3, this indicates that these stations have a moderate diversity index (moderate stability), while station 4 at a half of compensation depth has diversity index H '<1 which indicates that diversity is low (unstable).

The dominance index during the study was in the range of 0,267 to 0,681. Station 4 has a dominance value of 0,5 <C ≤ 1 with a range of 0,536-0,681 (Fig. 4). The depth of half compensation at this station has the highest value of dominance. This shows that at station 4 there are species or genera that dominate. The high dominance value is due to the low diversity index at station 4, especially at the depth of half compensation which has the lowest diversity value so that it has the highest dominance value.

3.3 Phytoplankton Mapping

Phytoplankton mapping during the study can be seen in Fig. 5 with the abundance of each class shown in Table 2. The Bacillariophyceae class shown in yellow in the bar diagram section has the highest abundance compared to other phytoplankton classes in all stations and observed depth. The Bacillariophyceae class has the highest average abundance with an average abundance of 5523 ind/L. The genus that dominates from the Bacillariophyceae class is the genus Nitzschia. Bacillariophyceae is the most tolerant type of phytoplankton and is able to adapt well to its aquatic environment, besides that Bacillariophyceae has greater reproductive ability compared to other groups of phytoplankton [15]. The existence of dominance shows the existence of competition or competition in the use of resources and environmental conditions that are not balanced or depressed [16]. This is confirmed again by the statement that the dominant type is the type of organism that is most able to compete with other types in utilizing limited resources, such as water and nutrients [17].

11 phytoplankton classes found during the study were identified at all observation stations, except in the Eustigmatophyceae and Mediophyceae classes. The Eustigmatophyceae class is the least found phytoplankton class. The genus found in this class is Chlorobotrys which is only found at station 2 at half of compensation depth of 1 ind/L; station 3 at a surface depth of 1 ind/L; and Station 4, which is the Jatigede Reservoir Outlet at surface depths and compensation depths respectively of 3 and 2 ind/L. In addition, Phytoplankton from the Mediophyceae class that only identified the genus Cyclotella were not found at station 3 at the surface.

Table 1. Water quality at sampling station

Parameters	Depth		Station			
			1	2	3	4
Transparency (cm)		R	19,5-38,5	25-79	63-116,5	72-113
		A	27,6±7,8	54,7±21,22	88,7±19,15	93,1±18,49
Water Depth (m)			2,89	4,88	31,94	53
Temperature (°c)	S	R	26,9-28,3	27-28,1	26,4-28,9	26,4-28,4
		A	27,48±0,54	27,46±0,5	27,02±1,06	27,26±0,73
	0,5	R	26,7-28	26,7-27,8	26,4-27,5	26,4-28
	C	A	27,38±0,53	27,32±0,45	27,02±0,53	27,04±0,59
	C	R	26,4-27,8	26,4-27,6	26,2-27,1	26,3-27,6
		A	26,96±0,59	27,06±0,51	26,58±0,36	26,72±0,6
Current (m/s)		R	0,14-0,16	0,05-0,25	0,06-0,43	0,04-0,20
		A	0,152±0,008	0,136±0,092	0,216±0,148	0,142±0,069
pH	S	R	7,04-8,77	7,94-8,74	7,88-8,57	7,79-8,46
		A	7,96±0,64	8,26±0,3	8,194±0,25	8,30±0,29
	0,5	R	7,57-8,7	7,73-8,65	7,9-9,38	7,81-8,76
	C	A	8,15±0,44	8,03±0,38	8,40±0,59	8,40±0,36
	C	R	7,04-8,62	6,5-8,67	8,18-8,44	7,78-8,51
		A	7,84±0,58	7,69±0,78	8,30±0,11	8,17±0,28
Carbon Dioxide (mg/L)	S	R	4,19-12,57	4,19-4,19	4,19-8,38	4,19-4,19
		A	9,22±3,5	4,19±0	5,03±1,87	4,19±0
	0,5	R	4,19-12,57	4,19-4,19	4,19-4,19	4,19-4,19
	C	A	7,54±3,5	4,19±0	4,19±0	4,19±0
	C	R	4,19-12,57	4,19-4,19	4,19-8,38	4,19-4,19
		A	7,54±3,5	4,19±0	5,03±1,87	4,19±0
BOD (mg/L)		R	4,86-21,08	6,48-24,32	6,48-17,84	3,24-17,84
		A	12,65±6,00	12±7,12	12,32±4,95	11,03±6,00
DO (mg/L)	S	R	6,2-7,9	5,4-8	5,8-7,9	6,1-7,3
		A	6,94±0,8	6,78±1,1	7,12±0,8	6,54±0,5
	0,5	R	6,5-7,9	4,8-7,9	6,2-7,5	6,5-7,7
	C	A	7±0,6	6,38±1,2	6,76±0,5	7±0,5
	C	R	6-7,9	5,5-8,2	6-7,9	6,1-8
		A	7±0,8	6,46±1	6,84±0,8	7±0,8
Nitrate (mg/L)	S	R	0,209-0,279	0,16-0,314	0,133-0,222	0,121-0,2
		A	0,238±0,028	0,232±0,066	0,187±0,034	0,168±0,037
	0,5	R	0,148-0,357	0,126-0,286	0,116-0,259	0,13-0,237
	C	A	0,244±0,082	0,222±0,061	0,199±0,051	0,188±0,046
	C	R	0,15-0,37	0,162-0,321	0,159-0,251	0,152-0,221
		A	0,256±0,103	0,236±0,064	0,191±0,036	0,183±0,029
Phosphate (mg/L)	S	R	0,128-0,211	0,114-0,169	0,127-0,182	0,115-0,183
		A	0,161±0,031	0,148±0,02	0,156±0,023	0,148±0,027
	0,5	R	0,146-0,215	0,104-0,214	0,123-0,17	0,131-0,16
	C	A	0,174±0,026	0,152±0,04	0,139±0,019	0,141±0,012
	C	R	0,14-0,267	0,134-0,183	0,113-0,219	0,111-0,193
		A	0,185±0,049	0,152±0,019	0,15±0,041	0,142±0,033
Ammonia (mg/L)	S	R	0,007-0,101	0,0047-0,042	0,004-0,02	0,003-0,016
		A	0,039±0,04	0,0139±0,016	0,011±0,006	0,0098±0,005
	0,5	R	0,009-0,09	0,005-0,053	0,002-0,023	0,004-0,021
	C	A	0,04±0,031	0,0184±0,02	0,0132±0,009	0,0103±0,008
	C	R	0,002-0,067	0,003-0,049	0,002-0,019	0,0023-0,013
		A	0,027±0,026	0,0136±0,02	0,0113±0,008	0,0065±0,005

R: Range, A: Average, S: Surface, C: Compensation

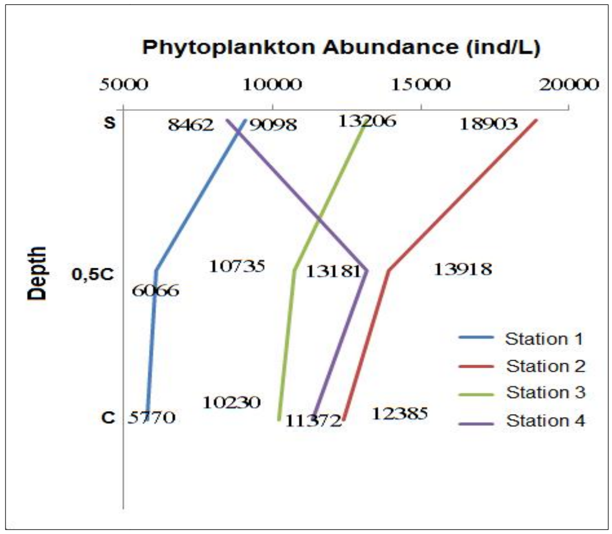

Fig. 2. Phytoplankton abundance during study

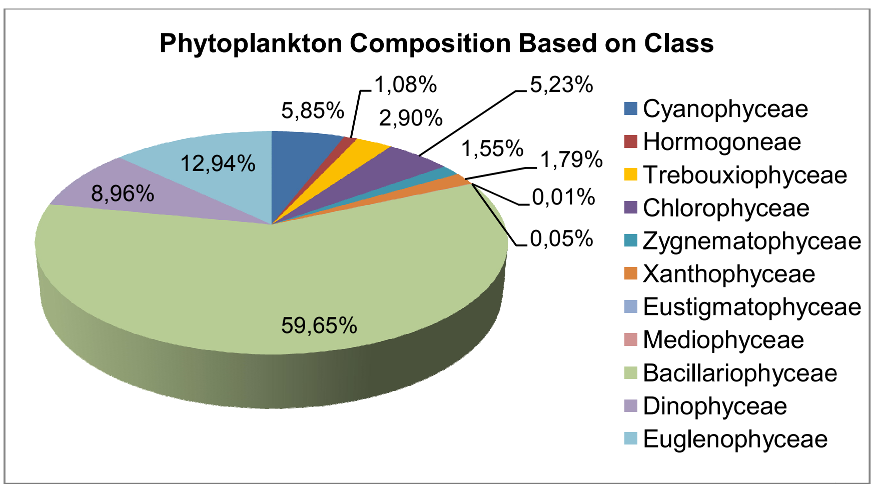

Fig. 3. Phytoplankton composition based on class during study

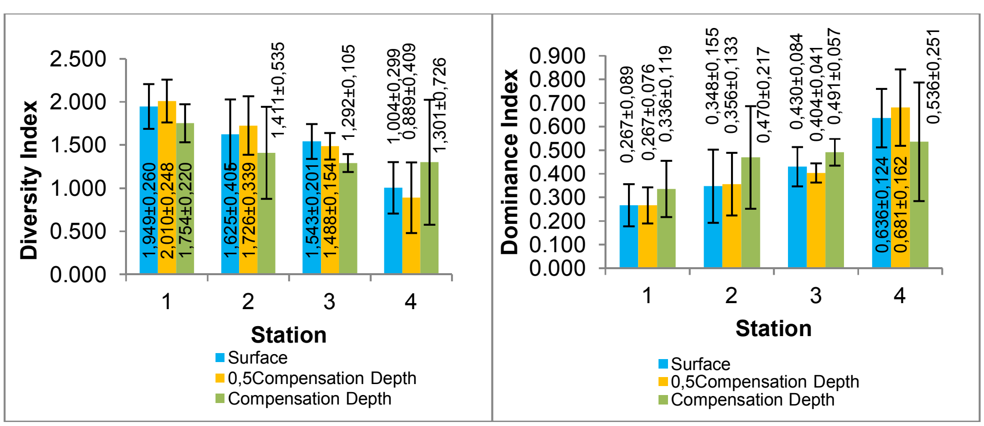

Fig. 4. Phytoplankton diversity and dominance index during study

Table 2. Average of phytoplankton abundance based on class

Class	Station												Average (ind/L)
	1			2			3			4			
	S	0,5C	C	S	0,5C	C	S	0,5C	C	S	0,5C	C	
Cyanophyceae	709	597	408	513	720	397	825	807	653	181	308	388	542
Hormogoneae	92	55	73	139	82	66	117	111	66	107	180	109	100
Trebouxiophyceae	238	210	150	538	573	332	416	183	218	102	148	117	269
Chlorophyceae	442	428	375	1012	1073	584	533	293	278	218	248	321	484
Zygnematophyceae	64	65	48	156	116	67	242	173	159	201	170	258	143
Xanthophyceae	222	150	183	273	274	268	148	72	103	84	101	111	166
Eustigmatophyceae	0	0	0	0	1	0	1	0	0	3	0	2	0
Mediophyceae	6	14	6	3	4	3	0	5	1	3	8	3	5
Bacillariophyceae	2666	2460	3267	6061	4620	5397	7831	5697	6273	5550	9168	7283	5523
Dinophyceae	1866	423	109	1738	1448	307	602	1406	674	311	382	688	829
Euglenophyceae	1278	653	189	5321	2687	2902	291	201	98	293	272	198	1199
Total	7582	5055	4808	15753	11598	10321	11005	8946	8525	7052	10984	9477	

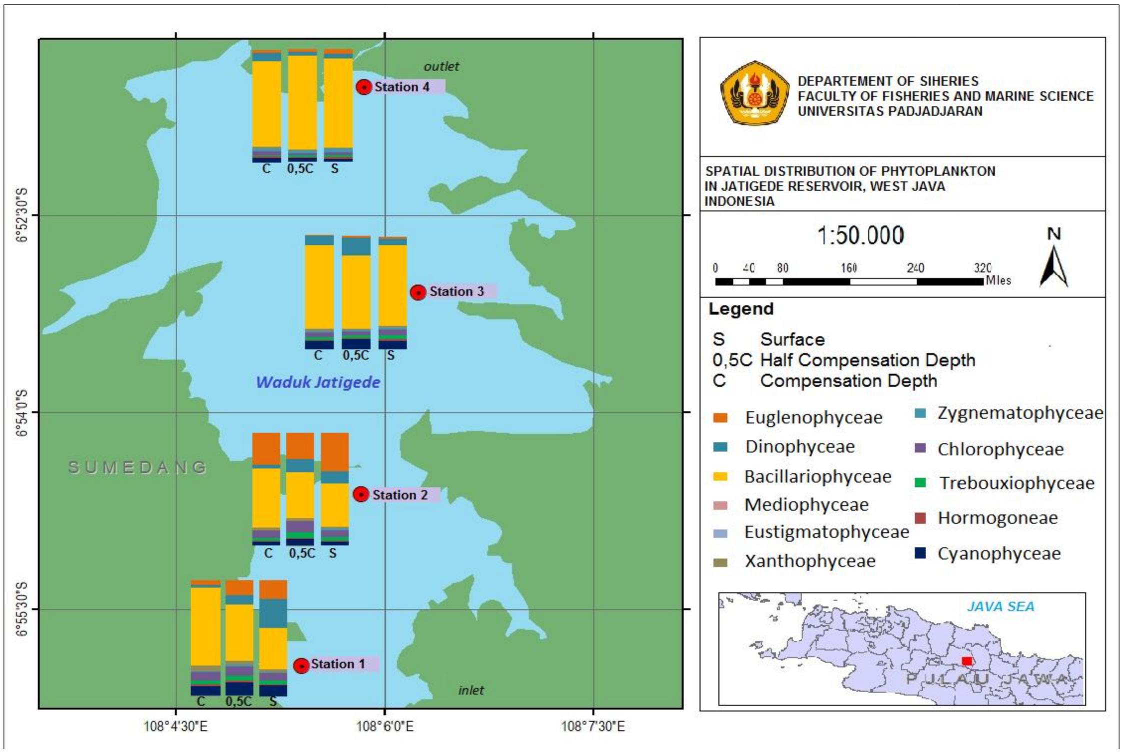

Fig. 5. Phytoplankton mapping in study station based on class

4. CONCLUSION

Phytoplankton identified during the study were 49 genera from 11 classes and 5 phyla. Diversity index and index of dominance during research respectively ranged from 0,04 to 2,062 and 0,267 to 0,681. The bacillariophyceae class has the highest abundance compared to other phytoplankton classes in all stations and the observed depth with an average abundance of 5523 ind/L. 11 phytoplankton classes found during the study were identified at all observation stations, except in the eustigmatophyceae and mediophyceae classes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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