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Aquatic Fertility Assessment Based on Nutrient Levels and Phytoplankton Density in the Wulan Delta Demak

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A B S T R A C T

Research on the effect of nitrate and phosphate content on phytoplankton and chlorophyll-a abundance in the Wulan Demak Delta waters was conducted in November 2019. This study aims to determine the abundance of phytoplankton in the Wulan Delta Waters of Demak Regency, to find out the chlorophyll-a, nitrate and phosphate content, as well as to determine the effect of nitrate and phosphate content on phytoplankton and chlorophyll-a abundance in Wulan Demak Delta waters. Sampling locations were carried out based on the purposive sampling method at eight stations. Phytoplankton sampling using passive sampling. The results showed that the abundance of phytoplankton ranged from 1.074 to 2.595 cells/L. While the results of nitrate concentrations of 0.3447 - 0.8766 mg/L and phosphate concentrations of 0.0129-0.0515 mg/L. The results of chlorophyll-a concentration in Wulan Delta waters ranged from 0.127 to 0.881 mg /L. The presence of nitrate and phosphate nutrients is closely related to the abundance of phytoplankton and chlorophyll a content. So it can be used as an indicator of the fertility of a body of water. The relationship between nitrate and phosphate content on phytoplankton abundance is 70.2%. The relationship of nitrate and phosphate content to chlorophyll-a is 73.5%. Based on the results of nitrate, phosphate and chlorophyll-a concentrations, it can be concluded that the Wulan Demak Delta waters are included in the eutrophic waters category.

Keywords: Phytoplankton, Nitrate, Phosphate, Fertility, Wulan Delta

Introduction

The Wulan Demak Delta is a delta formed by sedimentation originating from nutrients carried by the Wulan River. The Wulan River is a branch of the confluence of the Lusi River and the Serang River, which flows into Wedung District. This river carries sediment material from the mainland to the estuary and then settles to form a delta that widens every year (Hastuti et al., 2018). Waste material from domestic, industrial, agricultural and livestock activities can produce nutrient content in the water. In addition to originating from land material, nutrients also come from the water through the processes of decomposition of plants and the remains of dead aquatic organisms (Mustofa, 2015).

The content of nutrients in waters has an important influence and is needed for the development of aquatic organisms. Nutrients in the aquatic environment that are the focus of attention are nitrate and phosphate. Because these two elements play an important role in the growth of organisms, especially phytoplankton or algae, which can later be used as indicators of water quality and fertility (Utami et al., 2016). Nutrients needed for phytoplankton growth are often limiting factors. Increasing nutrients such as nitrate and phosphate in waters causes an increase in the phytoplankton population. Conversely, if there is a decrease in nutrients in waters, it causes a decrease in the phytoplankton population (Isnaini et al., 2014).

Human activities carried out along the Delta Wulan Waters include industrial, domestic, agricultural, floating net cage cultivation, pond cultivation and ship transportation routes. The many activities can cause problems as well as benefits for the surrounding community. If too much waste enters the waters, it can cause changes in water quality and problems in the waters. On the other hand, if the waste enters the waters does not exceed the quality standards, it can cause its own benefits for the environment and the surrounding community.

Research Method

The material used in the research conducted in the waters of Delta Wulan, Demak Regency, was water samples obtained from sampling conducted in the waters of the River, Estuary and Sea of Delta Wulan, Demak. This research was conducted on November 19, 2019. The water quality parameters measured included physical parameters (brightness, depth, water temperature and current speed) and chemical parameters (nitrate, phosphate, pH and salinity content). Analysis of phytoplankton abundance and measurement of chlorophyll-a concentration were conducted at the Laboratory of Fish Resources and Environmental Management, Department of Aquatic Resources, Faculty of Fisheries and Marine Sciences, Diponegoro University, Semarang. While measurements of nitrate and phosphate concentrations were conducted at the Semarang Testing and Equipment Centre Laboratory.

This research was a descriptive study. The location of water and phytoplankton sampling was determined by purposive sampling; there were 8 stations. The stations I and II are located on the Wulan Baru River near residential areas. The location of Station III is a station located at the mouth of the estuary leading to the sea. Station IV is located south of the Wulan Baru River estuary. The location of Station V is a station located in the sea, which fishermen widely use to catch fish using nets. The locations of stations VI and VII are stations located near the lagoon, and there is floating net cage cultivation. The location of station VIII is at the mouth of the Wulan Lama River estuary, which has experienced shallowing. Phytoplankton sampling uses a passive sampling method that takes 100 litres of water using a 10-litre bucket and filters it using a 25 µm plankton net. Phytoplankton samples were placed in a 50 mL sample bottle and then given 1 mL of 4% Lugol iodine solution. Phytoplankton identification used the Sedgewick Rafter tool. Nitrate, phosphate and chlorophyll-a were sampled using a sample bottle and placed in a coolbox. The location of the sampling study can be seen in Fig. 1.

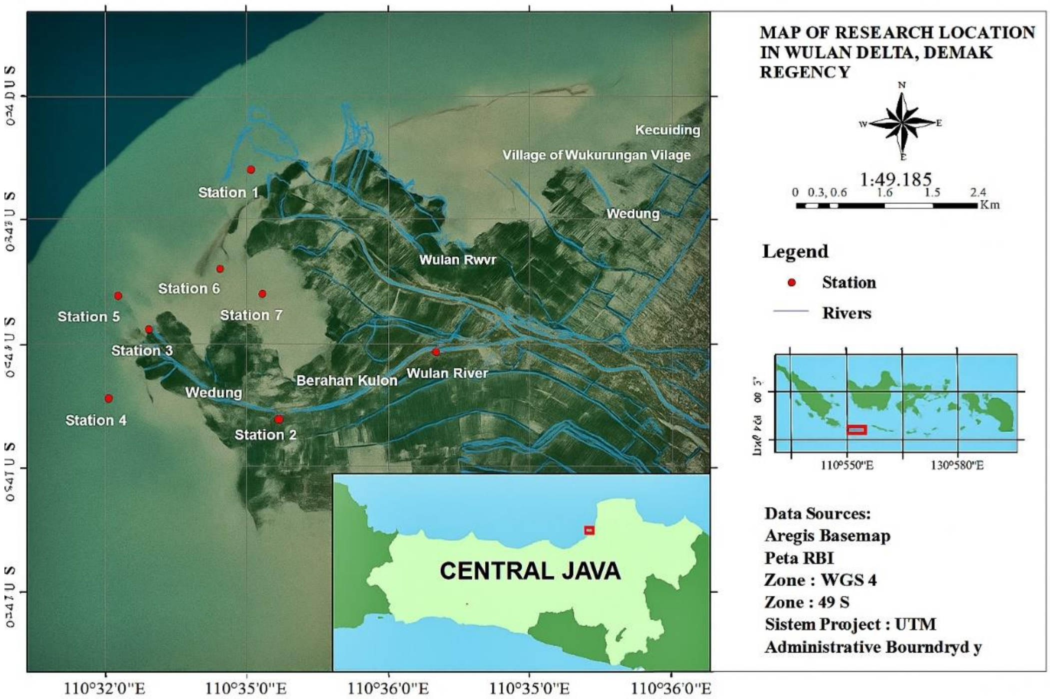

Fig. 1 - Map of Water Sampling Locations in the Wulan Delta Waters.

Data Analysis

a. Phytoplankton Abundance

Calculation of phytoplankton abundance using the APHA formula (2005) in Yulianto et al (2018), namely:

$$\boldsymbol{N = nx\,\frac{(Vt)}{(Vo)}x\frac{Asrc}{Aa}x\frac{1}{Vd}} \qquad (1)$$

Where:

N = Phytoplankton abundance (cells/L)

n = Number of phytoplankton cells observed (cells)

Vt = Volume of phytoplankton sample (mL)

Vo = Observed water volume (at SRC) (mL)

Asrc = Area of Sedgewick Rafter Counting Cell (mm^2)

Aa = Area of observed Sedgewick Rafter Counting plot (mm^2)

Vd = Volume of filtered water sample (liters)

b. Plankton Community Structure

The diversity index (H') is calculated using the formula according to Shannon-Wienner (Syafriani and Apriadi, 2017) as follows:

$H' = -\sum_{i=1}^{S} Pi ln Pi$ (2)

Where:

H' = Diversity Index

S = Number of Species

Pi = Number of individuals of type i divided by the total number of individuals

According to Odum (1993), diversity index values can be classified into three categories, namely as follows:

H' < 2.3026 : Low diversity and low community stability

2.3026 < H' < 6.9078 : Moderate diversity and moderate community stability

H' > 6.9078 : High diversity and high community stability

The uniformity index (e) is calculated using the Shannon-Evenness formula. (Syafriani and Apriadi, 2017) as follows :

$e = \frac{H'}{Ln\ S}$ (3)

Where:

e = uniformity index

H' = diversity index

S = number of types

According to Odum (1993), the range for uniformity index values is as follows:

e = 0 : the distribution of individuals between species is uneven or there is a certain group of species that dominates;

e = 1 : the distribution of individuals between species is even.

Dominance Index (D) is calculated using the formula according to Simpson's (Syafriani and Apriadi, 2017) as follows:

$D = \sum(\frac{ni}{N})^2$ (4)

Where:

D = dominance index

ni = number of individuals of type i

N = total number of individuals

According to Odum (1993), the D value ranges from 0-1, if the D value is close to 0 there are almost no individuals who dominate and it is usually followed by the large e value (approaching 1), whereas if the D value approaches 1, it means that a certain type is dominant with a smaller e value or approaching 0.

c. Plankton Community Structure

The level of relationship between nitrate and phosphate concentrations on phytoplankton and chlorophyll-a abundance was calculated using multiple regression tests. Nitrate and phosphate concentrations as independent variables (X_1 and X_2) and diatom and chlorophyll-a abundance as dependent variables (Y), while determining the magnitude of the influence of nitrate and phosphate on phytoplankton abundance using partial regression analysis.

Result and Discussion

a. Plankton Community Structure

The types of phytoplankton obtained through observations of water samples from the Wulan Delta Waters that have been observed are: *Bacillariophyceae* (16 genera) and Dinophyceae (2 genera). Table 1 shows the types of phytoplankton found in the Delta Wulan Demak Waters. The genera found in the class *Bacillariophyceae* namely *Skeletonema* sp, *Guinardia* sp, *Nitzschia* sp, *Navicula* sp, *Pleurosigma* sp, *Leptocylindrica* sp, *Coscinodiscus* sp, *Gyrosigma* sp, *Neocalyptrella* sp, *Chaetoceros* sp, *Thalassionema* sp, *Odontella* sp, *Pseudo-nitzschia* sp, *Hemialus* sp, *Entomonesis* sp. and *Triceratium* sp, while the genus found in the class *Dinophyceae,* namely *Ceratium* sp and *Peridinium* sp. The abundance of phytoplankton at 8 research stations was found with a total abundance of 1,074 – 2,595 cells/L. The distribution of phytoplankton abundance was highest at station 1, which was 2,595 cells/L, while the lowest phytoplankton abundance was at station 4, which was 1,074 cells/L.

The high abundance of phytoplankton at station 1 is because station 1 is located in a river area close to settlements. Waters close to land receive direct nutrient input from land in the form of nitrate and phosphate, while the low abundance at station 4 is because the station is far from the coastal area, where nutrient sources are abundant (Paiki and Kalor, 2017). In addition, the low abundance at station 4 is because the current speed at the station is relatively high, where the high current affects the distribution of phytoplankton in the waters (Suwartimah et al., 2011). Phytoplankton have limited mobility, so they cannot move, affecting their water distribution (Syahbaniati and Sunardi, 2019).

Table 1 - Phytoplankton Abundance at Research Locations (cells/L).

No.		Station							
		1	2	3	4	5	6	7	8
	Bacillariophyceae								
1	*Skeletonema* sp.	2172	1922	678	284	317	-	434	-
2	*Guinardia* sp.	184	122	122	178	250	89	172	134
3	*Nitzcshia* sp.	134	78	134	128	106	322	311	734
4	*Navicula* sp.	78	89	211	78	139	450	389	511
5	*Pleurosigma* sp.	-	-	84	89	89	122	56	184
6	*Leptocylindrica* sp.	-	-	134	-	-	-	-	-
7	*Coscinodiscus* sp.	-	-	84	78	61	84	72	-
8	*Gyrosigma* sp.	-	-	128	-	111	300	172	217
9	*Neocalyptrella* sp.	-	-	-	45	45	78	128	78
10	*Chaetoceros* sp.	-	-	239	195	145	-	-	-
11	*Thalassophobia* sp.	-	-	-	-	67	67	84	-
12	*Odontella* sp.	-	-	-	-	50	-	-	-
13	*Pseudo-nitzschia* sp.	-	-	-	-	89	139	139	250
14	*Hemialus* sp.	-	-	-	-	56	61	45	-
15	*Entomonesis* sp.	-	-	-	-	-	72	72	111
16	*Peridinium* sp.	28	-	-	-	-	-	-	-
	Dinophyceae								
17	*Ceratium* sp.	-	45	-	-	34	45	78	-
18	*Triceratium* sp.	-	34	28	-	-	-	-	-
Amount		2595	2289	1840	1074	1556	1828	2150	2217

b. Plankton Community Structure

1. Diversity Index

The results of the diversity index values presented in Table 2 from eight research stations ranged from 0.590-2.338. The highest diversity index value was at station 5, which was 2.338, while the lowest diversity index was at station 1, which was 0.590. Based on the diversity index classification, only one station had a moderate diversity index, which was station 5, while the other stations had a low diversity index. Waters that have a diversity index of (0 <H' <2.3), which indicates the distribution of the number of individuals of each type of phytoplankton is moderate, the stability of the phytoplankton community in these waters is moderate (Wiyarsih et al., 2019).

2. Uniformity Index

The results of the uniformity index presented in Table 2 at the research location ranged from 0.371 to 0.739. The highest uniformity index value was at station 4, which was 0.739, while the lowest diversity index was at station 2, which was 0.371. Based on the uniformity index classification, six stations that had a high uniformity index were stations 3, 4, 5, 6, 7 and 8, while the other two stations had a low uniformity index. The uniformity index is used to determine whether the distribution of species is even or not. If the uniformity index value is high, then the phytoplankton in the environment is of a uniform type or not too different. In addition, the uniformity between species is relatively even and the differences are not so striking. Conversely, at station 2 the uniformity index was low because the uniformity value was close to 0. This indicates that at that station the types of phytoplankton were not individual, each species was very different (Raunsay and Koirewoa, 2016).

3. Dominance Index

The results of the dominance index presented in Table 2 at the research location ranged from 0.111 - 0.739. The highest dominance index value was at station 2, which was 0.739, while the lowest diversity index was at station 5, which was 0.111. Based on the classification of the dominance index, two stations had dominant genera, namely stations 1 and 2, while the other six stations did not have dominant genera. The type of phytoplankton that dominated at station 2 was from the genus *Skeletonema* sp. The genus *Skeletonema* sp can live in euryhaline waters so that it can live in the sea, coast and river estuaries (Supriyantini, 2013).

Table 2 - Plankton Community Structure.

Station	Diversity Index (H')	Uniformity Index (e)	Dominance Index (D)
1	0.643	0.400	0.709
2	0.683	0.381	0.711
3	1,972	0.856	0.190
4	1,932	0.929	0.163
5	2,392	0.906	0.106
6	2,199	0.885	0.140
7	2,310	0.900	0.121
8	1,821	0.876	0.199

c. Concentration of Nitrate, Phosphate and Chlorophyll-a

The nitrate concentration at the water sampling location in the Delta Wulan Waters showed a range between 0.3447-0.8766 mg/L. Based on these results, the highest nitrate concentration was at station 1, which was 0.8766 mg/L. While the lowest nitrate concentration was at station 4, which was 0.3447 mg/L. Station 1 is a location close to residential areas. While Station 4 is a station far from the coastal area. The high nitrate levels in areas near residential areas are because the main source of nitrogen in water is domestic waste, industrial waste, agricultural activities and fisheries cultivation (Patricia et al., 2018). The distribution of nitrate concentration values at the research location can be seen in Figure 2.

The phosphate concentration at the water sampling location in the Delta Wulan Demak Waters ranges between 0.0129-0.0515 mg/L. Based on these results, the highest phosphate concentration was at station 8, which was 0.0515 mg/L. While the lowest phosphate concentration was at station 5, which was 0.0129 mg/L. Station 8 is a station located at the Wulan Lama River Estuary. Station 5 is a station located in the sea, far from the coast. Based on this location, Station 5 has a low phosphate concentration because it is located far from the phosphate source, which is far from the coast. In addition, the current around station 5 is a current from the open sea that carries a small source of phosphate. So that the phosphate that isin marine waters comes from marine biota that have died and are decomposed by decomposer organisms (Rigitta et al., 2015). The distribution of phosphate concentration values at the research location can be seen in Figure 2.

The concentration of chlorophyll a obtained at the sampling location in the Delta Wulan Waters ranged from 0.127 - 0.881 mg / L. The highest concentration of chlorophyll a was at station 1, which was 0.881 mg / L. While the lowest concentration of chlorophyll-a was at station 4, which was 0.127 mg / L. The location of Station 1 is in a river close to settlements. The high concentration of chlorophyll a is related to the high levels of nutrients, namely nitrate and phosphate. According to Zulhaniarta et al., (2015), the high concentration of chlorophyll-a is generally found in coastal waters that have abundant nutrients. Nutrients originating from land through river runoff cause an abundance of phytoplankton. So that chlorophyll-a is also abundant with the abundance of phytoplankton. Conversely, the concentration of chlorophyll-a tends to be lower in offshore waters because it is far from nutrient sources. The distribution of chlorophyll-a concentration values at the research location can be seen in Figure 2.

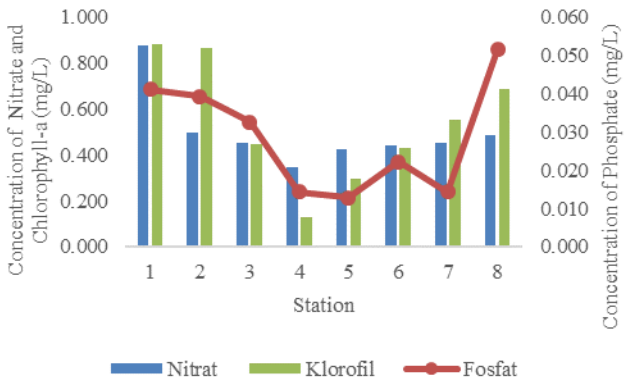

Fig. 2 - Distribution of Nitrate, Phosphate and Chlorophyll-a Concentrations.

d. The Effect of Nitrate and Phosphate on Phytoplankton Abundance and Chlorophyll-a

Linear Equations to analyze the effect of nitrate and phosphate concentrations on the abundance of phytoplankton are $Y = a + bX_1 + bX_2$. The analysis results were obtained through multiple analyses presented in Figure 3.

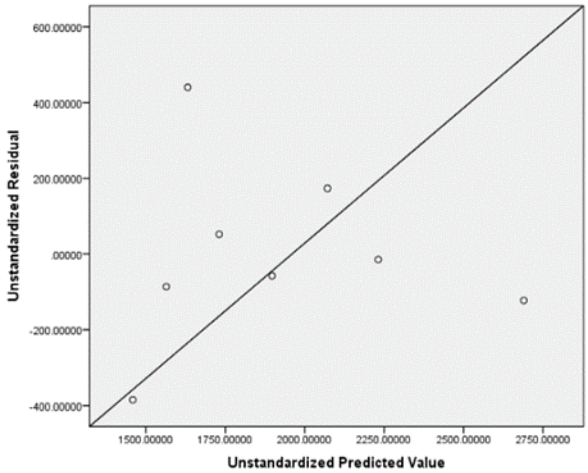

Fig. 3 - Results of Multiple Regression Test of Nitrate and Phosphate Concentrations on Phytoplankton Abundance.

Based on the multiple correlation analysis results shown in the table, the correlation coefficient (r) value is 0.38, which means that the relationship between nitrate and phosphate and diatom abundance is categorised as strongly related. The determination coefficient (R^2) value is 0.702. This value shows that nitrate and phosphate concentrations influence 70.2% of diatom abundance. Other factors, such as physical and chemical factors in the water influence the remaining 29.8%. Increasing nutrients in the waters is followed by an increase in the abundance of phytoplankton. Proving that phytoplankton utilise these nutrients to grow and develop. This shows the water's high nutrients, followed by the abundance of phytoplankton. These nutrients are utilized by phytoplankton as raw materials for making organic materials that are primary food sources. Phytoplankton are primary producers in the food chain because they can make their own food through photosynthesis (Tungka et al., 2016).

Linear Equation to analyse the effect of nitrate and phosphate concentration on chlorophyll-a is Y = a + bX1 + bX2. The analysis results were obtained through multiple analyses presented in Figure 3.

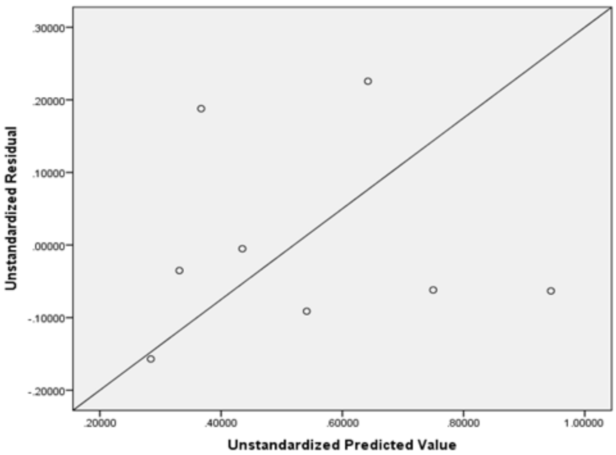

Fig. 4 - Results of Multiple Regression Test of Nitrate and Phosphate Concentrations on Chlorophyll-a.

The abundance of nutrients in waters can cause an abundance of chlorophyll-a. This is evidenced by the relationship between nitrate and phosphate to chlorophyll-a, which obtained a correlation of 73.5%. Nutrients such as nitrate and phosphate are abundant in waters close to settlements because the source of nutrients in the waters comes from human activities. This is reinforced by Muhibbudin et al., (2018) that the chlorophyll-a content in waters near land is more concentrated. While the chlorophyll-a content is getting closer to the sea, the concentration is getting lower.

The effect of nutrients on chlorophyll-a concentration is directly proportional. Nutrients in the water are utilized by phytoplankton to grow and develop. In addition, phytoplankton that act as primary producers in making their food through the process of photosynthesis require nutrients and chlorophyll-a. Phytoplankton are known as plants that have chlorophyll-a pigments so that they are able to photosynthesis. The high or low supply of nutrients into a body of water can affect the concentration of chlorophyll-a. This is because nutrients cause the fertility of a body of water, which will ultimately be beneficial for phytoplankton to photosynthesis (Sihombing et al., 2013).

The concentration of nitrate, phosphate and chlorophyll-a can be used as a reference to determine the fertility status of waters. Based on the concentration of nitrate, phosphate and chlorophyll-a, the Delta Wulan Waters are included in the eutrophic category. The large amount of organic material input from human waste activities carried into the waters will disrupt texisting waters. The high organic matter content can cause eutrophication (Alfionita et al., 2019). Eutrophication is a high level of fertility in waters. Eutrophication occurs due to the continuous increase in nutrients in high concentrations which will eventually cause the waters to be fertile and can have negative impacts (Garno, 2012).

Conclusions

Based on the research results, the greatest abundance of phytoplankton was found in the class *Bacillariophyceae*, which is 88.9%, while from class *Dinophyceae* which is 11.1%. The highest abundance is found at station 1, which is 2,595 cells/L, while the lowest phytoplankton abundance is at station 4, which is 1,074 cells/L. The most dominant phytoplankton is *Skeletonema* sp. The nitrate concentration in the Delta Wulan Waters ranges from 0.3447-0.8766 mg/L, while the phosphate concentration ranges from 0.0129-0.0515 mg/L. Chlorophyll-a concentration in the Delta Wulan Waters Demak ranges from 0.127 – 0.882 mg/L. Based on these results, the Delta Wulan Waters are eutrophic. The effect of nitrate and phosphate content on the abundance of Diatoms is strongly related, which is 74.2%. Meanwhile, the nitrate and phosphate content also have a relationship with chlorophyll-a, which is 73.5%.

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