Relationship Between Total Suspended Solid (TSS) and Phytoplankton Abundance in the Waters of Rupat Strait, Riau Province

Alqoriffah Hasanah[1], Irvina Nurrachmi[1], Syafruddin Nasution[1]

[1]Department of Marine Science, Faculty of Fisheries and Marine, Universitas Riau, Pekanbaru 28293 Indonesia
* alqoriffah.hasanah2019@student.unri.ac.id

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Abstract

This study was conducted in March 2023 in the waters of the Rupat Strait, Riau Province. This study aimed to determine the total suspended solid (TSS) concentration, the type and abundance of phytoplankton, and the relationship between TSS concentration and phytoplankton in the Rupat Strait waters. The method used was a survey method; the location of the study was determined by purposive sampling; there were 4 sampling stations consisting of 3 sampling points. The results showed that the highest average TSS was at Station 4 (98.33 mg/L), and the lowest was at Station 1 (85 mg/L). There were 14 types of phytoplankton found, namely *Nitzschia* sp, *Synedra ulna*, *Isthmia obliquita*, *Rhabdonema adriticum*, *Grammatophora* sp, *Guinardia striata*, *Rhizosolenia alata*, *Cyclotella atomus*, *Oscillatoria* sp, *Lyngbya* sp, *Tolypothrix* sp, *Pleurotaenium* sp, *Closterium* sp, *Gonatozygon* sp with the most dominant species being *Isthmia obliquata*, *Synedra ulna*, *Grammatophora* sp. The highest abundance was in the Darul Aman area (5004.207 ind/L), and the lowest was in the Bandar Bakau area (2573.592 ind/l). The relationship between TSS and phytoplankton abundance shows a strong and negative relationship, meaning that the higher the TSS, the lower the abundance of phytoplankton in the waters of Rupat Strait.

1. Introduction

The waters of the Rupat Strait are a small strait in the Malacca Strait and geographically located between the coast of Dumai City and Rupat Island, Bengkalis Regency, Riau Province, which has a length of ± 72.4 km and a width of 3.8-8 km. These waters are influenced by the movement of water originating from the Indian Ocean through the Malacca Strait and the movement of currents emanating from the South China Sea through the Bengkalis Strait, as well as the influence of fresh water from the Siak River (Sarianto et al., 2019).

Dumai City is located on the eastern coast of Sumatra Island. Dumai region is between 10°1.23".37'-101°.8".13' east longitude and 1° .23".23' - 1° 24".23' north latitude. Dumai City is influenced by the marine climate, with an average temperature of 21° - 35°C. Also, a state-owned company (BUMN) is engaged in the port, namely PT. Pelindo makes the waters of the Rupat Strait a sea transportation area with shipping ships from within and outside the country.

Disposal of household waste and port and industrial activities will impact the environment. One of the changes that will occur is an increase in water turbidity and the concentration of total suspended solids (TSS). Suspended substances in the water include fine sand, clay, and natural mud, which are inorganic or organic materials that float in the water (Alaerts, 1984).

Waters with high TSS concentrations will reduce the quality of these waters (Parwati et al., 2011). Phytoplankton plays an important role in aquatic ecosystems because it contains chlorophyll pigments that allow it to photosynthesize. Phytoplankton will be utilized by trophic-level consumers in the waters, such as invertebrates, fish and marine mammals (Asriyana et al., 2012). The higher value of suspended solids in a body of water

The total suspended solid concentration in a water body can affect the presence of phytoplankton, especially in phytoplankton abundance. However, information on the effect of TSS concentration on the presence and abundance of phytoplankton in the waters of Rupat Strait has not been well-informed. It is necessary to conduct this research to provide scientific clarity on the relationship between total suspended solid (TSS) concentration and phytoplankton species and abundance.

2. Methodology

2.1. Time, Place, and Materials

This research was conducted in March 2023. Sampling was carried out in the waters of the Rupat Strait, with 4 station points (Figure 1), namely Station I, located in Darul Aman Village; Station II, located at Tanjung Kapal Roro Port, station III, located at TPI Dumai Port, and station IV located at Bandar Bakau Mangrove Tourism. Total Suspended Solid (TSS) concentration analysis was conducted at the Marine Chemistry Laboratory, and phytoplankton abundance analysis was conducted at the Marine Biology Laboratory of the Department of Marine Science, Faculty of Fisheries and Marine Sciences, Universitas Riau.

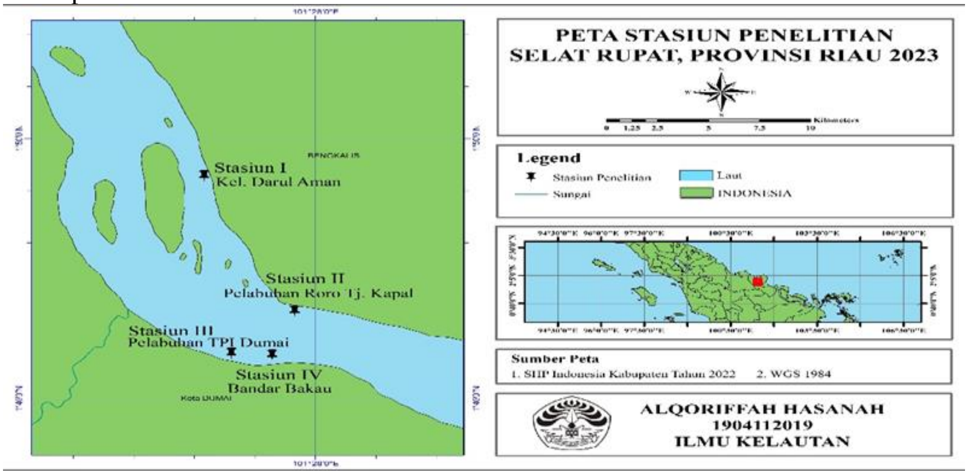

Figure 1. Research Location Map

2.2. Method

The methods used are survey methods and laboratory analysis. The research was conducted directly on the object under study without giving special treatment to the object under study. The sampling method used in determining the research station is purposive. Sampling was carried out at four stations, each with three sampling points. The distance of each sampling point is 100 meters taken horizontally from the edge of the beach when it recedes.

2.3. Procedure

Total suspended solids (TSS) analysis samples were taken using a 200 mL Van Dorn Bottle water sample. Furthermore, gravimetric analysis is carried out by separating large particles that float using filter paper Whatman no.42 with 2,5 µm and vacuum pump and then in the oven with a temperature of 105°C for 45 minutes, the weight of filter paper is then calculated in the calculation of TSS (SNI 06-6989-3, 2004) using the following formula:

$$\text{TSS (mg/L)} = \frac{(A - B)x\ 1000}{V}$$

Description:

A = Weight of filter paper + dry residue (mg)
B = Weight of filter paper (mg)
V = Volume of test sample (mL)

Water samples for phytoplankton abundance analysis using plankton net no. 25 with mesh size 55 µm and 10 L bucket volume for 10 times filtering. Water samples for phytoplankton identification were put into plastic bottles (125 mL capacity) and given 3 drops of 3% Lugol solution, and then the bottles were labelled. Sampling was carried out at 10:00 am - 2:00 pm. Phytoplankton samples were identified using a microscope Olympus CX23 and glass objects using literature from Davis (1955) and Yamaji (1979). The preserved phytoplankton samples were then observed in the laboratory.

Temperature was measured using a thermometer. Salinity measurements were made using a hand refractometer. Acidity was measured at each sampling location point using a pH meter and dipping it into the water. Turbidity is measured using a turbidimeter in the laboratory.

Water brightness is measured using a Secchi disk. To calculate the brightness, you can use the formula:

$$\text{Brightness (cm)} = \frac{\text{lost distance+Visible distance}}{2}$$

Current velocity was measured using a current drought. A stopwatch was used for time calculation. The current velocity value was calculated using the formula:

$$\text{Velocity} = \frac{\text{Distance (m)}}{\text{time (s)}}$$

Phytoplankton abundance was quantitatively expressed in the number of cells/ml. The number of phytoplankton that has been obtained from each station is then calculated using the Lackey Drop Macrotransec Counting (LDMC) method from APHA (1992) as follows:

Number of Ind/L= T/Lx V0/V1 x 1/P x 1/W x N

Description:

N	=	Number of phytoplankton individuals found per preparation
T	=	glass cover area (22 x 22 mm²)
L	=	microscope field of view (1.306 mm²)
V0	=	the volume of sample water in the sample bottle (125 mL)
V1	=	the volume of sample water under the cover glass (0.06 mL)
P	=	number of field of view observed (12 field of view)
W	=	volume of filtered water (100 L)

Relationship analysis was used to see the relationship between total suspended solids and phytoplankton abundance. Statistically, the commonly used relationship is as follows (Tanjung, 2014):

$$Y = a + bx$$

Description:

Y	=	Phytoplankton abundance (ind/mL)
a and b	=	Constants
x	=	Total Suspended Solids Concentration (mg/L)

The coefficient of determination (R2) is used to determine the effect of Total Suspended Solid on phytoplankton abundance expressed in the correlation coefficient (r). To assess the closeness of the relationship, the correlation coefficient (r) is used where the value of r is between 0-1. According to Tanjung (2014), the closeness of the value is:

Table 1. Correlation Index Value Relationship

Coefficient Interval	Relationship Level
0,00 - 0,25	Weak Relationship
0,26 - 0,50	Medium Relationship
0,51 - 0,75	Strong Relationship
0,76 - 1,00	Very strong relationship

3. Result and Discussion

Water Quality Parameters

Water quality parameters are always used in the fertility level approach and as supporting data to determine the general variation of the parameters studied at each station. Based on the research, the results of water quality measurements in the waters of Rupat Strait, Riau Province, can be seen in Table 2.

Based on Table 2, the average range of water quality parameters at each station can be seen. The highest current velocity is found at station III with a value of 0.08 m/s and stations II and IV with 0.06 m/s. The high current velocity at this station is influenced by current movements originating from shipping activities from ships that cross the waters of the Rupat Strait (Reandy et al., 2014). While at station I, it has a weak current of 0.04 m/s.

The brightness of each station has a varied value ranging from 69.33 - 90 cm; the brightness of these waters is classified as low for marine biota but still supports the life of aquatic organisms (Tambaru, 2014). The highest brightness value is found at station II, with a value of 90 cm, which is the area around the Tanjung Kapal Roro Port Area, while the lowest brightness value is found at station III, which is in the area around TPI Dumai, with a value of 65.90 cm.

The salinity of the Rupat Strait waters ranges from 19.67 to 26 ppt, which is the salinity of brackish water (Fardiansyah, 2011). The highest salinity was at Station I, 26 ppt, and the lowest was at Station II, with a value of 19.67 ppt. The highest turbidity is found at station IV, which is 17.14 NTU, while the lowest turbidity, with a value of 8.20 NTU, is found at station I.

In the Rupat Strait waters, the water's turbidity is strongly influenced by the contribution of suspension from the river carried by the current along the coast (longshore current). In addition, it is influenced by wave stirring of coastal sediments because the waters of the Rupat Strait are estuary waters where several rivers empty out, such as the Dumai River and the Mosque River.

The water temperature of the Rupat Strait ranges from 28.67 - 29.33 °C. The temperature of the Rupat Strait waters ranges from 28.67 - 29.33°C. This temperature condition is good for marine biota (Tambaru, 2014). The highest temperature is at Stations II and IV, 29.33°C, and the lowest is at Station 1, at 28.67 °C. The degree of acidity (pH) in the waters of Rupat Strait ranges from 6.73 - 7.83. According to Rahman et al. (2016), the ideal pH for phytoplankton survival ranges from 6.5 - 8, with the highest pH at Station I, 7.83, and the lowest at Station IV, 6.73. The pH condition of Rupat Strait is still at the optimum value for phytoplankton growth.

Waste from land, anthopogenic activities, shipping activities, and supply from mangrove ecosystems, waves, and currents influence the concentration of suspended solids. The average measurement of suspended solid concentration in the waters of Rupat Strait is presented in Table 3

Table 2. Measurement Results of Rupat Strait Water Quality

No.	Parameters	Unit	Station			
			I	II	III	IV
1.	Velocity	m/set	0,04	0,06	0,08	0,06
2.	Brightness	cm	81,67	90	65,90	69,33
3.	Salinity	ppt	26	19,67	22,33	22
4.	Turbidity	NTU	8,20	13,87	15,90	17,14
5.	Temperature	°C	28,67	29,33	29	29,33
6.	pH	-	7,83	7,13	7,17	6,73

Table 3. Average TSS Concentration at Each Station

Station	Average TSS Concentration (mg/L)	Standard Deviation
I	85	2,64575
II	93,67	3,05505
III	95,67	2,08167
IV	98,33	3,51188

The lowest average TSS concentration is at station I, with an 85 mg/L value. This station is a Darul Aman area with mangrove ecosystem areas and oil palm plantations owned by residents. This condition does not influence TSS concentration or turbidity, such as the current speed, which is only 0.04 m/s. The presence of anthropogenic waste also does not have a significant effect because this area has a low population density; this condition is supported by land dominated by community-owned oil palm plantations and mangrove ecosystems. This condition follows the statement of Wardheni et al. (2014) that current velocity can be used to estimate the amount of energy acting on the bottom of the water that can move sediment from one place to another.

At station II, namely the Tanjung Kapal Roro Port area, the TSS concentration is 93.67 mg/l. The high concentration of TSS at this station is thought to be due to sea transportation activities and other port activities such as loading and unloading of ships (containers, liquid bulk, dry bulk, general cargo, Roro) or fishermen activities causing an increase in TSS and turbidity. The physical parameters of the waters, namely the current velocity at this station, have a value of 0.06 m/s and the measurement of the turbidity level using a turbidimeter tool is 13.87 NTU.

The TSS concentration at station III averages 95.67 mg/L at the TPI Dumai Port. Waste disposal results in the industry will usually be disposed of in the waters. Despite having a Waste Water Disposal Installation (WWTP), many industrial activities do not pay attention to good procedures in the disposal of industrial waste. This will increase the level of pollution and TSS value in the waters. The physical parameters of the waters, namely the current speed at this station, have a value of 0.08 m/sec and a turbidity level of 15.90 NTU.

At Station IV Bandar Bakau Mangrove Area, the TSS concentration level is the highest, averaging 98.33 mg/L. The presence of the Dumai River estuary supports this condition. This is supported by the statement of Surbakti (2012) that currents also play a role in the distribution of material in the estuary area (estuary meeting between ocean currents and currents from rivers), according to the results of research by Jewlaika et al. (2014) where the more turbid a body of water is, the higher the value of total suspended solids and the lower the brightness of a body of water. The increase in suspended solids concentration is proportional to the increase in turbidity concentration and inversely proportional to brightness. High concentrations of suspended solids greatly reduce the penetration of sunlight into the ocean (Connell & Miller, 1995), so the heat received by surface seawater is not effective enough for photosynthesis. However, it seems that the concentration of suspended solids in these waters has not hindered the transfer of energy from the sun to the sea surface so that the solar energy received by seawater can still carry out photosynthesis.

Phytoplankton Species

Based on the results of phytoplankton analysis at each station, phytoplankton found in the waters of Rupat Strait consists of 5 classes with varying numbers of orders. The classification of phytoplankton can be seen in Table 4.

Table 4. Classification of Phytoplankton Species in Rupat Strait Waters

Class	Ordo	Family	Species
Bacillariophyceae	Bacillariales	Bacillariaceae	*Nitzschia* sp
	Centrales	Rhizosoleniaceae	*Isthmia obliquata*
	Rhabdonematales	Rhabdonemataceae	*Rhabdonema adriticum*
	Pennales	Tabellariaceae	*Grammatophora* sp
		Fragilariaceae	*Synedra ulna*
	Rhizosoleniales	Rhizosoleniaceae	*Guinardia striata*
			Rhizosolenia alata
Chlorophyceae	Chlorococcales	Desmidiaceae	*Closterium* sp
	Zygnematales	Mesotaeniaceae	*Gonatozygon* sp
Mediaphyceae	Stephanodiscale	Stephanodiscaceae	*Cyclotella atomus*
Conjugatophyceae	Desmidiales	Desmidiaceae	*Pleurotaenium* sp
Cyanophyceae	Oscillatoriales	Oscillatoriaceae	*Oscillatoria* sp
			Lyngbya sp
	Nostocales	Tolypothrichaceae	*Tolypothrix* sp

Table 4 shows that the Bacillariophyceae belong to 5 orders, Chlorophyceae and Cyanophyceae with 2 orders. Conjugatophyceae and Mediaphyceae each 1 order. While the species found amounted to 14 species which include Nitzschia sp, *Synedra ulna*, *Isthmia obliquata*, *Rhabdonema adriticum*, *Grammatophora* sp, *Guinardia striata*, *Rhizosolenia alata*, *Cyclotella atomus*, *Oscillatoria sp*, *Lyngbya* sp, *Tolypothrix sp*, *Pleurotaenium* sp, *Closterium sp*, *Gonatozygon* sp (Table 5).

Of the 5 phytoplankton classes found, the most phytoplankton species came from the *Bacillariophiceae* class. The suspected Bacillariophyceae class can better adapt to existing environmental conditions; this class is cosmopolitan and has high tolerance and adaptability. This is presumably because the waters of the Rupat Strait contain many nutrients carried over from household activities, plantations, and the mangrove ecosystem. In addition, diatoms have a higher reproductive ability than other phytoplankton divisions, which causes a large abundance. The large number of phytoplankton species from the Bacillariophyceae class is also due to their ability to reproduce up to 3 x 24 hours (Witariningsih, 2020). According to Alianto et al. (2018), the Bacillariophyceae class is abundant because it is the main member of phytoplankton found in all parts of marine waters, both estuarine waters, beaches, straits to the open sea.

The identification of phytoplankton species showed that the most phytoplankton species were found at station I, with 12 phytoplankton species. Station III has the least phytoplankton, which is only 8 phytoplankton species.

Table 5. Distribution of Phytoplankton Species

No.	Class	Species	Station			
			I	II	III	IV
1	Bacillariophyceae	*Nitzschia* sp	+	+	-	+
2		*Isthmia obliquata*	+	+	+	+
3		*Rhabdonema adriaticum*	-	+	-	+
4		*Grammatophora sp*	+	+	+	+
5		*Synedra ulna*	+	+	+	+
6		*Guinardia striata*	+	-	-	+
7		*Rhizosolenia alata*	+	+	-	-
8	Cyanophyceae	*Closterium* sp	+	+	+	-
9		*Gonatozygon* sp	+	+	-	-
10	Mediaphyceae	*Cyclotella atomus*	+	+	-	-
11	Conjugatophyceae	*Pleurotaenium* sp	+	-	+	+
12	Cyanophyceae	*Oscillatoria sp*	+	-	+	+
13		*Lyngbya* sp	+	+	+	-
14		*Tolypothrix* sp	-	-	+	+
		Number of species	12	10	8	10

Isthmia obliquata was found to dominate the waters because this type of phytoplankton habitat is nutrient-rich mangrove waters and can adapt very quickly to changes in habitat conditions. *I.obliquata* also has a role as a transfer of pollutants in the food chain and absorbing pollutants. These microorganisms are classified as prokaryotic organisms because they do not have cell structures such as nuclei and chloroplasts (Queiroz et al., 2020) but can develop rapidly in coastal waters (Palupi et al., 2022).

This group of Bacillariophyceae class types can be found in almost every aquatic environment with enough sunlight to maintain activity, and this is supported by the level of brightness that still supports the life of aquatic organisms (Tambaru, 2014). *Synedra ulna* is also known to have the ability to withstand changes in unfavourable environmental conditions. In addition, *Synedra* sp can survive in an environment that is low in nutrients (oligotrifik) and has low nitrogen and phosphate concentrations. *Synedra* sp can accumulate nutrients and store them as food reserves as non-dissolved polymers (Istianah, 2015).

This type of *Grammatophora* sp phytoplankton is a phytoplankton that can live at various depths as long as there is still sufficient sunlight to carry out photosynthesis. The main habitat of *Grammatophora* sp taxa is as epiphytes on marine macroalgae and seagrasses (Supono et al., 2018). According to Imran (2016), the survival ability of this species can adapt to the environment, withstand extreme conditions and have high reproductive power.

Nutrient abundance can affect phytoplankton abundance and vice versa. Phytoplankton can reduce nutrient content in water. The results of total phytoplankton abundance at all stations in the waters of Rupat Strait are presented in Table 6.

Table 6. Average Phytoplankton Abundance

Station	Average Phytoplankton Abundance (ind/l)	Standard Deviation ±
I	5004,207	665,204
II	3074,01	539,727
III	3002,524	982,806
IV	2573,592	214,466

The average phytoplankton abundance data showed that the highest abundance was found at station I, which was 5004.207 ind/l. The high abundance of phytoplankton at Station I is thought to be due to being in the vicinity of mangrove vegetation. According to Nugraheni et al. (2014), mangrove vegetation is a nutrient trap, and deposition increases the concentration of phytoplankton and nutrients on the surface and supports the process of photosynthesis.

The lowest average phytoplankton abundance was found at station IV, which was 2573.590 ind/L. This is thought to be due to the high turbidity level at this station, which reached 17.14 NTU. The high turbidity value also aligns with the TSS concentration value at this station, which is also the highest value of all stations, namely 98.33 mg/L (Table 3). The condition of the area close to the mouth of the Dumai River and the many industrial activities greatly affect the turbidity and TSS concentration.

The average abundance of phytoplankton in the waters of Rupat Strait is 2573.592 - 5004.207 ind/L (Table 6). Following Yulifrizal's statement *in* Rasmiati et al. (2017) that phytoplankton abundance is divided into 3 categories, namely: 1) low phytoplankton abundance < 12500 ind/L, 2) medium phytoplankton abundance 12500 - 17000 ind/l, 3) high phytoplankton abundance > 17000 ind/l. So, based on these criteria, phytoplankton abundance in the waters of Rupat Strait is classified as low.

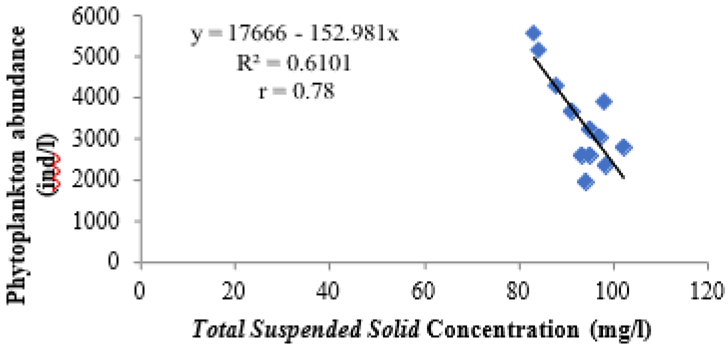

Figure 2. Relationship between *Total Suspended Solid* and Phytoplankton Abundance

The highest TSS concentration is at Station IV, with a value of 98.33 mg/L with a phytoplankton abundance of 2573,592 ind/L. Followed by Station III with TSS of 95.67 mg/L and phytoplankton abundance of 3002.592 ind/L. With a TSS of 93.67 mg/L, Station II obtained a phytoplankton abundance of 3074.01 mg/l. Then, Station I, the location with the smallest TSS concentration level of 85 mg/L, has a phytoplankton abundance of 5004,207 ind/L. So, it can be seen that the higher the TSS concentration, the lower the phytoplankton abundance obtained at the research location.

Based on the simple regression test, the relationship between Total Suspended Solid and phytoplankton abundance at each station is shown by the mathematical equation Y = 17666 - 152.981x. The constant b is negative, meaning there is a negative relationship between phytoplankton abundance and TSS concentration; the higher the TSS, the lower the phytoplankton abundance. This is reinforced by the coefficient of determination (R^2) = 0.6101, meaning that 61.01% of phytoplankton abundance is influenced by TSS concentration, and the remaining 38.99% is influenced by other environmental factors, such as physical factors (temperature, salinity, and current speed), water chemistry (pH), and biology (mangroves). Research conducted by Suhendar et al. (2020) stated that the factors that influence the value of phytoplankton abundance are not only physical parameters of water; the high and low biological parameters and factors limiting the presence of phytoplankton such as the availability of nutrients are also factors that determine the presence of phytoplankton in a body of water. Water quality parameters also play an important role in the relationship between TSS and phytoplankton abundance.

The low phytoplankton abundance followed the high TSS at station IV. This is also supported by brightness, salinity and turbidity, which are very different from the other 3 stations. So, other water quality parameters influence as much as 38.99% of phytoplankton abundance in these waters. The low abundance value was caused by the current velocity factor obtained during the study between 0.04- 0.08 m/sec. Current speed affects phytoplankton abundance. This is supported by Lasri et al. (2013), who stated that current speed is an important parameter concerning the presence of phytoplankton. Strong currents can affect the distribution of phytoplankton in a body of water, indirectly affecting the abundance of phytoplankton. Likewise, station I is a station that has a very low TSS level with the highest phytoplankton abundance.

Correlation values are useful for finding the relationship between two quantitative variables. The relationship between the two variables can occur because of a causal relationship or by chance alone. The correlation value in the relationship between TSS and phytoplankton abundance in the waters of Rupat Strait is r = 0.78. The value of r when compared with the statement of Tanjung (2014), which means the relationship between TSS and phytoplankton abundance in the waters of Rupat Strait is strong, which means that the concentration of TSS affects the abundance of phytoplankton in the seas of Rupat Strait. The results of this study are similar to research conducted by Wisha et al. (2016), which states that the value of phytoplankton abundance is inversely proportional when compared to the concentration of suspended solid content. This also means that the distribution of TSS concentrations influences the abundance of phytoplankton because the higher the concentration of TSS and turbidity will cause a block to the entry of sunlight into the waters and ultimately can interfere with the photosynthesis process by phytoplankton.

4. Conclusion

Based on the results of the study, it can be concluded that the Total Suspended Solid content is 85 -98.33 mg/l, with the highest TSS content in the Bandar Bakau area at 98.33 mg/l, while the lowest is in the Darul Aman area, Magruf Umbul Rejo Tourism with a value of 85 mg/l. Phytoplankton species in the waters of Rupat Strait during the study were found to be 14 species dominated by the Bacillariophyceae class with the highest phytoplankton abundance in the Darul Aman Village area of Magruf Umbul Rejo Tourism at 5004.207 ind/l, and the lowest was in the Bandar Bakau tourist area at 2573.592 ind/l. Changes strongly influence high and low abundance in environmental parameters. The relationship between TSS content and phytoplankton abundance in Rupat Strait waters has a strong relationship, where with increasing total suspended solids content, phytoplankton abundance will decrease.

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