

Spatial distribution of Chl-a and Nutrient In Tengah Island

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SPATIAL DISTRIBUTION OF CHLOROPHYLL-A AND NUTRIENTS IN THE TENGAH ISLAND, KARIMUNJAWA INDONESIA

DISTRIBUSI SPASIAL KLOROFIL-A DAN NUTRIEN DI PULAU TENGAH, KARIMUNJAWA INDONESIA

ABSTRACT: Tengah Island is located in the middle between Sintok Island and Cilik Island in Karimunjawa, Jepara Regency, Central Java. Tengah Island is one of the zones for the use of marine tourism, which has a very high density of coral reefs, that attracts tourists for snorkelling and diving. Coral reefs require chlorophyll-a as a photosynthetic pigment by zooxanthellae. The chlorophyll-a concentration is influenced by many factors including nutrients and environmental parameters. This study aims to see the distribution of chlorophyll-a in Tengah Island and its relationship to nutrients including ammonium, phosphate and nitrate as well as environmental parameters, namely salinity, pH, DO, temperature and brightness. Data processing uses Principal Component Analysis (PCA). The results showed that chlorophyll-a had a close relationship with ammonium ($r=0.826$) and brightness ($r=0.492$). The highest chlorophyll-a was obtained at station 1 of $1,063 \mu\text{g/l}$, which is jetty area and the closest to the mainland. This finding is supported by ammonium sourced from domestic waste and microbial activity and chlorophyll-a requires good brightness for the photosynthesis process.

Keywords: chlorophyll-a, nutrients, PCA Analysis, Tengah Island, water quality

ABSTRAK: Pulau Tengah terletak di tengah antara Pulau Sintok dan Pulau Cilik di Karimunjawa, Kabupaten Jepara Jawa Tengah. Pulau Tengah merupakan salah satu zona pemanfaatan wisata bahari, yang memiliki kerapatan terumbu karang yang sangat tinggi, yang menjadi daya pikat wisatawan untuk snorkling dan menyelam. Terumbu karang membutuhkan klorofil-a sebagai pigmen fotosintesis oleh zooxanthellae. Konsentrasi klorofil-a dipengaruhi banyak faktor diantaranya yaitu nutrisi dan parameter lingkungan. Penelitian ini bertujuan untuk melihat sebaran klorofil-a di Pulau Tengah dan keterkaitannya dengan nutrisi meliputi amonium, fosfat dan nitrat serta parameter lingkungan yaitu salinitas, pH, DO, suhu dan kecerahan. Pengolahan data menggunakan Analisis Komponen (PCA). Hasil penelitian menunjukkan klorofil-a memiliki keterkaitan yang erat dengan amonium ($r=0,826$) dan kecerahan ($r=0,492$). Klorofil-a tertinggi diperoleh di stasiun 1 sebesar $1,063 \mu\text{g/l}$ yang merupakan area dermaga dan terdekat dengan daratan. Temuan ini didukung bahwa amonium bersumber dari limbah domestik dan aktifitas mikroba serta klorofil-a membutuhkan kecerahan yang baik untuk proses fotosintensis.

Kata Kunci: analisa PCA, klorofil-a, kualitas perairan, nutrisi, Pulau Tengah

INTRODUCTION

Pulau Tengah is located on the east side of the Karimunjawa National Park (TNKJ), which is bordered by Karimunjawa Island on the west side, the high seas on the east side, Sintok Island on the north side, and Cilik Island on the south side (Figure 1). Tengah Island is part in the marine utilization zone located in TNKJ, with the attractiveness offered is the beauty of coral reefs with high coral density and variety of coral species (Wungo *et al.*, 2020). To support marine tourism in Tengah Island, there is a jetty and tourist resort with complete facilities (Uwardiono, 2011).

Chlorophyll-a (chl-a) is a green pigment found in plants that allows these plants to carry out photosynthesis with the help of sunlight to produce organic compounds from simple molecules. Consequently, chl-a is used as a measure of phytoplankton biomass in the waters. Moreover, chl-a is also used as an indicator of the level of water fertility, water quality, an indicator of nutrient availability (Trevor *et al.*, 1998). Coral reefs are animals of polyp species that have mutualism symbiosis with algae, in this case zooxanthellae which contain chlorophyll-a and -c pigments. The content of chl-a in these zooxanthellae actually carries out the photosynthesis process, which is very much needed for its survival (Sayekti *et al.*, 2017).

The concentration of chl-a in the waters are influenced by many factors, such as nutrient inputs namely ammonia, phosphate and nitrate (Inayati & Farid, 2020; Qiu *et al.*, 2021) and environmental parameters specifically as salinity, pH, Dissolved Oxygen (DO), temperature and brightness (Zulhaniarta *et al.*, 2015; Moira *et al.*, 2020). In case the input of nutrients exceeds the equilibrium condition, it will have a serious impact on the occurrence of eutrophication which causes algae blooms, which disrupts marine aesthetics, decreases DO which affects the survival of coral reefs. The dependence of coral reefs on chl-a is very substantial, therefore, the aims of this research is to determine the spatial distribution of chl-a in the Tengah Island, Karimunjawa and its relationship with nutrients (ammonium, phosphate and nitrate) and environmental parameters (salinity, pH, DO, brightness and temperature).

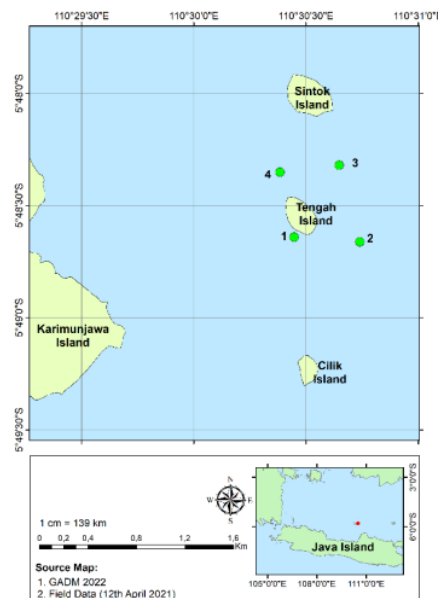


Figure 1. Research Area

METHODS AND MATERIAL

There are 4 observation stations randomly taken around the Tengah Island at 12th April 2021. For each station, field data was taken of 2L surface water samples using a Nansen bottle further processed in the laboratory. Chl-a data processing, using the APHA standard (2005), then for nutrient processing for ammonia using SNI 06-6989.30 (2005), nitrate using APHA 4500-No.3-B (2017), and phosphate using APHA 4500-P-B, C (2017). As for the environmental parameters such as salinity using

a refractor, pH using a pH-meter, brightness using a seichi disk, DO and sea surface temperature using a Water Quality Checker.

3 Analysis of relationship of chl-a to nutrients and environmental parameters using the Pearson's and Principal Component Analysis (PCA) approach. This PCA method is to simplify data to a new coordinate system that has a maximum variance, without significantly reducing the characteristics of the data (Firliana *et al.*, 2015). The advantage of this method is to minimize multicollinearity problems without having to exclude the independent variables involved in collinear relationships. In addition, using the PCA method can determine the dominant factors that affect a parameter (Rahmawati, 2014).

RESULTS

The spatial distribution of chl-a, nutrients and environmental parameters in Pulau Tengah detailly is shown in Table 1. The range of chl-a concentrations is 1.1063-0.772 $\mu\text{g/L}$ with an average of 0.861 $\mu\text{g/L}$. The highest chl-a is found at Station 1 which is the jetty area and the closest to the mainland. In general, although in Pulau Tengah there are jetty and tourist resorts, the concentration of chl-a is not in a eutrophic condition, ie below the chl-a range is 1.16–1.84 g/L (Ignatiades *et al.*, 1992).

The results of the concentration range for nutrients specifically ammonia, nitrate and phosphate, namely 0.088-0.111 ppm, 0.005-0.010 ppm, and 0.001 ppm. In general, the smallest value is found for phosphate in Pulau Tengah, this is due to the existing sources of phosphate do not come from domestic and industrial waste, but from natural sources, namely diffusion from sediment (Widiaratih *et al.*, 2022). Ammonia concentration shows the same pattern as chl-a, which is highest discovered at Station 1, which is the jetty area and the closest point to the land. This found is strengthened by the input of domestic waste, and microbial activity in Tengah Island sourced from tourist resorts and jetty. However, the ammonia concentration achieved is still below the sea water quality standard < 0.3 mg/L (KepmenLH 51/2004). Furthermore, the concentration of nitrate obtained is smaller than ammonia, it corresponds to the Nitrogen Cycle with the phase sequence transformation of ammonium-nitrite-nitrate (Patey *et al.*, 2008). This is reinforced by the results of high ammonium concentrations, because the transformation process from the nitrogen cycle has not occurred, so that any nitrite or ammonium in the sea will be transformed into the final form of nitrate which causes the nitrate concentration found is to be lower than ammonium (Meirinawati & Fitriya, 2018).

Table 1. Concentration of chl-a, nutrient and environment parameters in Tengah Island, TNKJ

Location	Salinity (‰)	PH	DO (mg/L)	Brightn ess (%)	Temperat ure (°C)	Chloro phyll-a ($\mu\text{g/L}$)	Ammoniu m (ppm)	Nitrate (ppm)	Phosphat e (ppm)
Tengah 1	27	7.63	5.82	100	30.7	1.063	0.111	0.005	0.001
Tengah 2	27	7.86	5.42	98	30.6	0.780	0.099	0.010	0.001
Tengah 3	27	7.53	5.32	99	29.7	0.829	0.088	0.005	0.001
Tengah 4	30	7.59	6.55	100	30.9	0.772	0.092	0.005	0.001

The results of the environmental parameter values generally show that Tengah Island is still in preferable condition and supports to coral reef ecosystems. The results of the range of values for salinity, pH, DO, Brightness, temperature is 27-30‰, 7.53-7.86, 5.32-6.55 mg/L, 98-100%. According to Ompi *et al.* (2019), a suitable salinity range for coral reefs is 30-35‰. Tengah Island has a salinity range of 27-30‰, and only station 4 has ideal conditions for coral reefs. Furthermore, according to Juliani and Rahmatsyah (2011), the pH value of sea water quality standards for marine tourism is around 7-8.5, and the pH value in Tengah Island is still in the range of 7.53-7.86, so it is appropriate for coral reefs. For DO value, according to Sumarno and Muryanto (2014), that coral can grow in DO conditions with levels above 3.5 mg/L, while in Tengah Island it has a DO range of 5.32-6.55 mg/L, so it is in convenience with coral reef habitats. The brightness is also very influential on the growth of coral reefs because there are zooxanthellae that need sunlight to carry out the photosynthesis process (Sayekti *et al.*, 2017), and in general in Tengah Island has a very great brightness.

Table 2. Correlation of chl-a, nutrient and environment parameters in Tengah Island, TNKJ

Variables	Salinity (‰)	PH	DO (mg/L)	Brightness (%)	Temperature (°C)	Chlorophyll-a (µg/L)	Ammonium (ppm)	Nitrate (ppm)	Phosphate (ppm)
Salinity (‰)	1	0.289	0.922	0.522	0.533	-0.434	-0.348	-0.280	-0.495
PH	-0.289	1	-0.279	-0.706	0.388	-0.198	0.332	0.965	0.327
DO (mg/L)	0.922	0.279	1	0.731	0.727	-0.073	0.026	-0.372	-0.787
Brightness (%)	0.522	0.706	0.731	1	0.344	0.492	0.244	-0.846	-0.900
Temperature (°C)	0.533	0.388	0.727	0.344	1	0.103	0.521	0.207	-0.688
Chlorophyll-a (µg/L)	-0.434	0.198	-0.073	0.492	0.103	1	0.826	-0.410	-0.558
Ammonium (ppm)	-0.348	0.332	0.026	0.244	0.521	0.826	1	0.082	-0.548
Nitrate (ppm)	-0.280	0.965	-0.372	-0.846	0.207	-0.410	0.082	1	0.540
Phosphate (ppm)	-0.495	0.327	-0.787	-0.900	-0.688	-0.558	-0.548	0.540	1

Values in bold are different from 0 with a significance level $\alpha=0,05$

Correlation results using Pearson's approach for chl-a, nutrients and environmental parameters are shown in Table 2. In general, chl-a has a close relationship with ammonium ($r=0.826$). This has a pattern that the higher the chl-a, the higher the ammonia concentration found, this is in line with Riley and Chester 1971; Chen 2007 which states that high ammonium is needed for metabolic processes, physiological processes and biochemical reactions by marine organisms. Furthermore, chl-a has a moderate but opposite relationship with nitrate ($r=-0.410$) and phosphate ($r=-0.558$).

Correlation for chl-a with environmental parameters obtained a moderate and positive relationship with brightness, this is because chl-a requires sunlight to carry out the photosynthesis process (Fauziah *et al.*, 2019). Moreover, there is a significant correlation between nitrate and pH ($r=0.965$) with ($\alpha<0.05$). This result is supported by the higher of pH value, the higher the amount of nitrate in the waters. This situation is in line with the research of Widiarati *et al.*, 2022 on Seruni Island, which showed the same pattern, when during the day the photosynthesis process runs optimally by marine biota that contains chl-a, because there is sufficient solar intensity to produce O_2 which then has an effect on increasing the pH. This condition has the impact of decreasing the DO value which is then used by marine biota to carry out the transformation phase of the nitrogen cycle from ammonia-nitrite and nitrate, so that the amount of nitrate increases with increasing pH.

The spatial distribution pattern of chl-a and ammonium in Tengah Island are shown in Figures 2&3. In general, station 1 has maximum values for chl-a and ammonium, this is due to its position on the jetty and closest to the mainland which is a source of pollutants (domestic waste, industry, etc). The result corresponding from Bonnin *et al.*, 2008, that sources of ammonia source from microbial activity, ammonia industry, coal processing and waste treatment such as domestic waste, agricultural waste, and waste from factories, especially nitrogen fertilizer factories.

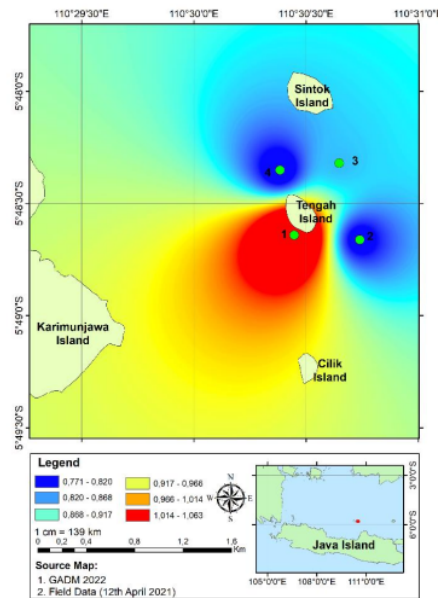


Figure 2. Distribution of chl-a ($\mu\text{g/L}$) from surface water in Tengah Island, TNKJ

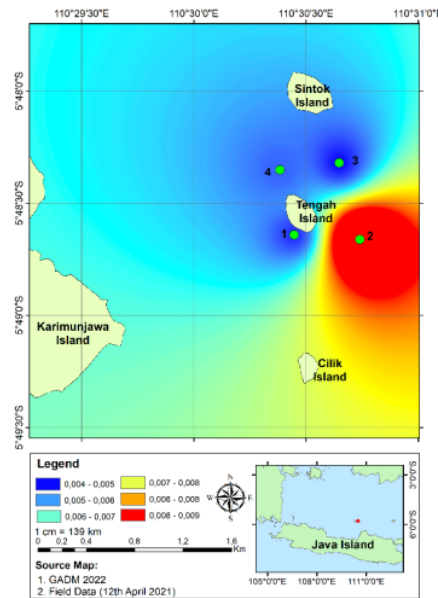


Figure 3. Distribution spatial of ammonium (ppm) from surface water in Tengah Island, TNKJ

The spatial pattern of phosphate is shown in Figure 4. In general, stations 2 & 3 have maximum values for Phosphate. The concentration of phosphate was found to be the lowest value among other chemical compounds. According to Patty *et al.*, (2015) natural phosphate sources come from weathering of mineral rocks and decomposition of organic matter and diffusion processes originating from sediments. This is supported by Station 3 located between the Sintok Island and the Tengah Island, which is dominated by coral and sand.

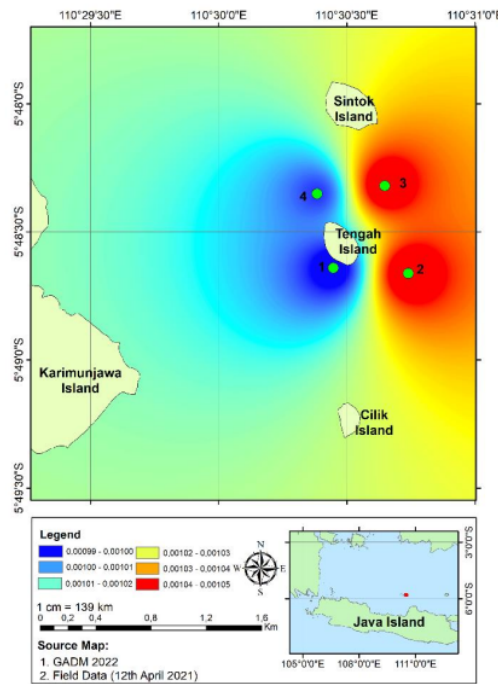


Figure 4. Distribution spatial of phosphate from surface water in Tengah Island, TNKJ

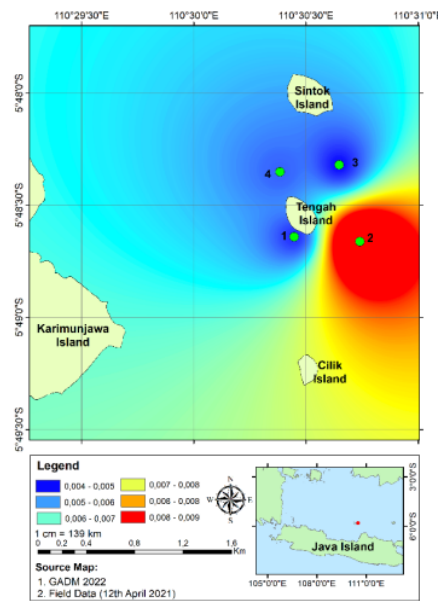


Figure 5. Distribution spatial of nitrate from surface water in Tengah Island, TNKJ

Furthermore, the spatial distribution pattern of nitrate in Tengah Island is shown in Figure 5. In general station 2 has a maximum value for nitrate. Chl-a requires nitrate compounds to be broken down

to produce nitrogen (Hutagalung and Rozak, 1997). Moreover, nitrate is an essential nutrient to support the life of organisms in a water (Muchtat, 2008). Nitrate has a close relationship ($r=0.965$) with a pH ($\alpha < 0.05$). This is because the pH tends to increase during the day due to chemical and biological processes that occur in the form of photosynthesis from phytoplankton, microalgae and aquatic plants that produce O_2 which has an impact on the pH of the waters rising.

DISCUSSIONS

Analysis of the correlation between parameters of Ch-a, nutrients and environmental parameters in this research using PCA analysis. The advantages of this PCA analysis are that it can eliminate multicollinearity problems, the data are used for various types of research without reducing the number of original variables, and provide more accurate conclusions than other methods such as linear regression, etc (Soemartini, 2008). The basic principle of the PCA procedure is to simplify the observed variables by simplify their dimensions. This process by eliminating the correlation between the independent variables through the transformation of the original independent variable to a new variable that is not correlated at all or commonly referred to as the principal component.

In PCA analysis there are 3 stages, namely determining the main components to be arranged, criteria for eigenvalues and criteria for percentage of variance. In this study, there are 2 principal components, namely F1 and F2. Determining the composition of F1 and F2 can be seen from the value of the eigenvector which has a large and positive value. The F1 component is formed from the parameters such as salinity, DO, brightness, while the F2 component is formed from pH, temperature, chlorophyll-a, ammonia and nitrate (Table 3). The eigenvalues are shown in Table 4, where eigenvalue of F1 is 4.347 and F2 is 2.417. According to Maindonal & John (2006), the required eigenvalue is at least >1 and is close to 1, so this value can explain the diversity of data on the main variable. Furthermore, the criteria for the percentage of variance, the results of PCA analysis show that with two axes it can explain 75.16% or more than 70% as required in the use of PCA (Ridho *et al.*, 2020), where the first axis contributes 48.30% and the second axis contributes 26.86% (Figure 6).

Table 3. Eigenvectors from principal component

	F1	F2	F3
Salinity (‰)	0.306	-0.249	-0.445
PH	-0.273	0.423	-0.331
DO (mg/L)	0.407	-0.054	-0.350
Brightness (%)	0.469	-0.051	0.133
Temperature (OC)	0.252	0.368	-0.421
Chlorophyll-a ($\mu\text{g/L}$)	0.195	0.374	0.472
Ammonium (ppm)	0.132	0.598	0.165
Nitrate (ppm)	-0.347	0.285	-0.355
Phosphate (ppm)	-0.456	-0.201	0.010

Table 4. Eigenvalue from principal component

	F1	F2	F3
Eigenvalue	4.347	2.417	2.236
Variability (%)	48.297	26.860	24.843
Cumulative %	48.297	75.157	100.000

Parameters located in one quadrant can be interpreted that these parameters have the closeness (Maindonal & John, 2006). Using PCA analysis, it can be seen relationship between parameter, however the value of relationship between variable cannot be seen in PCA analysis, it can be seen through the Pearson correlation coefficient. The results of PCA correlation between chl-a, to nutrients, and environmental parameters are shown in Figure 6. The results of PCA analysis show that chl-a has a close relationship with ammonium and sea surface temperature, this is indicated by the 3 variables in the same quadrant, this is in line with the Pearson correlation value which shows a positive relationship.

It supports with Person's correlation chl-a to ammonium and sea surface temperature are $r=0.826$, and $r=0.103$ respectively. The sea surface temperature also has directly relationship to brightness, when it more brightness, the warmer sea surface temperature can be occurred in the water. It strengthened the Pearson's correlation chl-a to brightness is higher than the sea surface temperature by $r=0.492$. From above discussion, the factors that affect chl-a in Pulau Tengah are influenced by nutrients and environmental parameters, specifically the most influential nutrient is ammonium, while the most influential environmental parameter are brightness and sea surface temperature.

Furthermore, from PCA analysis detect that nitrate and pH has a tight relationship, which is shown to be in one quadrant (Figure 6). This is also in line with the Pearson value which is very close $r=0.965$ and has a significant level $\alpha < 0.05$. This happens there is a relationship with the Nitrogen Cycle.

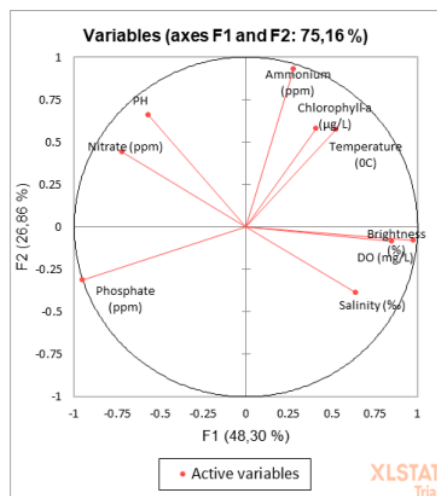


Figure 6. Correlation PCA of chl-a, nutrient and environment parameters in Tengah Island, TNKJ

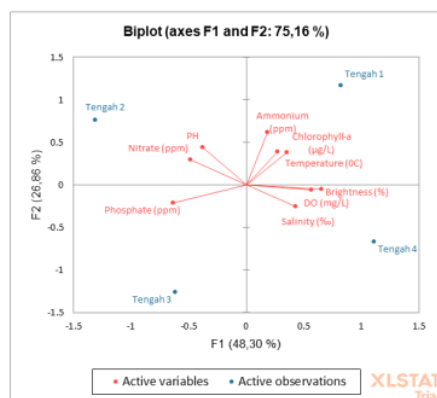


Figure 7. PCA Biplot of chl-a, nutrient and environment parameters in Tengah Island, TNKJ

The distribution of observational variables in 4 quadrants, as a representation that shows the influence between variables (Figure 7). PCA analysis can also see the distribution pattern of stations with the distribution of chl-a, nutrient and environmental parameters shown in Figure 7. In general, the stations in Tengah Island have a different pattern for each station. The highest concentration values were found at Station 1, reinforced by high chl-a and ammonium values. This apply, as consequence of the location of Station 1 is adjacent to the jetty and the closets to the land, so that the input of domestic waste is so dominant. However, the lowest concentration value was found at Station 4, strengthened by

the location is blocked by Sintok Island (north side) and Karimunjawa Island (west side). While station 2 & 3 have value in the middle range from the highest at station 1 and the lowest at station 4. This is due to geographically the station 2 & 3 are border to high seas in east side, so that its distribution is influenced are dominantly by currents, tides and waves (Abigail *et al.*, 2015)

CONCLUSIONS

In general, the pattern of chl-a on nutrients and environmental parameters has a unique relationship (does not have the same pattern) for each water. This is because the concentration of chl-a is influenced by the dominant pollutant input and environmental parameters formed in these waters. In this study, the dominant pollutant input is pollutant that contains high ammonia, which is more dominant from domestic waste and microbial activity than pollutant sources containing nitrate and phosphate. This is led by human activities through tourist resorts and jetty located in Tengah Island. Furthermore, the concentration of chl-a is also influenced by water quality parameters, especially brightness (moderate and positive) and sea surface temperature (low and positive). In general, Tengah Island waters are in great condition and still suitable for coral reef habitat as indicated by the value of chl-a, nutrients, and water quality within the permitted of sea water quality standards (Permen LH no. 51/2004).

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