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Phytoplankton Chlorophyll-a Biomass and the Relationship with Water Quality in Barrang Caddi, Spermonde, Indonesia

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ABSTRACT
The investigation of spatial changes in phytoplankton biomass and turbidity provide essential information for the survival of the coral reef ecosystem. The phytoplankton biomass variations are driven by many factors, such as nutrient inputs from anthropogenic and natural. In turn, turbidity is determined by sediment resuspension or transport from terrestrial systems. The estimation of phytoplankton biomass is represented by the chlorophyll-a concentration. This study aimed to analyze the chlorophyll-a dynamics to water quality parameters, such as turbidity, suspended solids, dissolved oxygen, pH, salinity and temperature. The in-situ data gathered at 26 stations in the waters of the Barrang Caddi Island in August 2020. The results show that chlorophyll-a and turbidity have a negative correlation in the western and eastern regions, since turbidity inhibits the rate of photosynthesis and causes the decreasing of phytoplankton biomass. Nevertheless, the highest concentration of chlorophyll-a was found in the southern location, in small spots around islands and reefs, including near Barrang Caddi Island. Total Suspended Solid has more significant effect on chlorophyll-a than other water parameters, such as turbidity, temperature, salinity in the study area.

Keyword: Barrang Caddi Island, chlorophyll-a, total suspended solid, turbidity.

INTRODUCTION

Spermonde Islands located in Makassar, South Sulawesi Indonesia consist of hundreds of small islands and have unique characteristics on each island. Unfortunately, several islands in the Spermonde region, relatively close to the urban center, have experienced the environmental degradation. This is due to the environmental changes and anthropogenic factors. One of impacted island is Barrang Caddi Island. The area of this island is 4 hectares and it is located close to Makassar City which is capital province of South Sulawesi. Barrang Caddi island is an inhabited island and also a high tourist attraction. It is located near city center and has high level of human activity, these factors have a great impact on the water quality.

High human activities in the Spermonde Islands have had an impact on increasing organic matter and eutrophication, which can cause algae blooms and low dissolved oxygen in the waters (Retnaningdyah et al., 2019). Zheng & DiGiacomo (2017) showed that phytoplankton biomass was used as a parameter of algal abundance and an essential parameter for water quality, since it was as indicator in determining the level of eutrophication (Poddar et al., 2019; Marlian et al., 2015). Therefore, the concentration of chlorophyll-a has presently been used as a method of measuring phytoplankton biomass. Gupta (2014) indicated that the chlorophyll-a concentration can be represented as an indicator of the level of eutrophication and an indication of the availability of nutrients in waters. Consequently it is used as measuring tool for water quality. The concentration of chlorophyll-a in waters describes the effects of various factors that occur due to human activities (Li & Liu, 2019).

The previous research of the water quality conditions in the Spermonde Islands has been carried out by Rani et al. (2014) and Nasir, et al. (2015), including a study on the distribution of chlorophyll-a (Rashyd, 2011). The previous chlorophyll-a studies used image the satellite data covering in a large area (Spermonde islands). The information on the chlorophyll-a concentration and water quality parameters on specific area such as Barrang Caddi Island has never obtained. The research on chlorophyll-a and water quality has to be done, since high human activity on the island will significantly impact the water quality. Therefore, this study aimed to determine the distribution pattern of chlorophyll-a and the relationship to water quality parameters such as turbidity, pH, dissolved oxygen (DO) and total suspended solids (TSS) in Barang Caddi Island. The results of the study can be used as an early reference in monitoring the impact of human activities on Barrang Caddi Island and other islands in the Spermonde Archipelago. The condition of water quality greatly impacts the health condition of the coral reef ecosystem that lives in the area.

MATERIALS AND METHODS

Study area and sampling procedures

The research area is located on Barrang Caddi Island, coordinated in 119°18’58” – 119°19’25” East Longitude to 5°4’37” – 5°4’58” South Latitude. The samples of in-situ data were gathered in September 2020 from 26 stations located in the Spermonde archipelago, namely in Barrrang Caddi island. This island was selected to represent the east and west, south and north regions. Three data stations were taken near the urban center of Makassar City, South Sulawesi, Indonesia. The research location is shown in Figure 1.

Water sampling and chlorophyll-a quantification

The water samples were taken using a 2-liter Kemmerer Water Sampler. The water samplings were carried out near the sea surface. Temperature and salinity were measured in-situ using an Hg thermometer, while dissolved oxygen was measured using DO meter. Turbidity was analyzed in the laboratory based on the nephelometric method (Strickland & Parsons, 1972). The concentration of Chlorophyll-a (Chl-a) in phytoplankton was measured by using the spectrometric method, which was employed by Maslukah et al. (2019). There were several stages of chlorophyll-a processing. Firstly, a total of 1 liter of each water sample was filtered using a cellulose paper filter sized 0.45 m using of a vacuum pump. Further, the suspended solids and the filter paper were extracted using 90% acetone and ground until dissolved. The samples were then incubated in a freezer at 4 °C for 16 hours. Hereinafter, the ready sample was placed into a centrifuge and rotated at 4000 rpm for 10 minutes. Furthermore, the extracts were then analyzed using a spectrophotometer at trichromatic wavelengths (664, 648 and 630 nm).

The concentration of Chl-a was calculated using the APHA standard (2005) with formulas 1 and 2 as below:

$$Ca = 11.85\,(\lambda 664) - 1.54(\lambda 647) - 0.008(\lambda 630) \quad (1)$$

$$Chl\text{-}a\ (mg\ m^{-3}) = Ca \times \frac{v}{V} \quad (2)$$

where: $\lambda 664$, $\lambda 645$ and $\lambda 630$ – the reading result of the absorbance value at that wavelength; v – volume extract (liter); V – volume of sample (m^3).

Data analysis

Water quality data such as turbidity, salinity, pH, TSS, DO, temperature and chlorophyll-a were presented in a distribution pattern using an interpolation method based on Inverse Distance Weight (IDW) with Arc.GIS 10.3 software. The Inverse Distance Weight method is a simple deterministic method by considering the surrounding points (Pramono, 2008). This method assumes that the interpolation value is more similar to the nearest sample. The weight of the value will change linearly based on the distance to the nearest sample and is not affected by the location of the sample data (Achilleos, 2011). This distribution pattern visually and informatively describe for each parameter. Spearman correlation was applied to determine the relationship of the chlorophyll-a concentration to water quality parameters such as Total Suspended Solid (TSS), temperature, salinity, turbidity using SPSS 16.0.

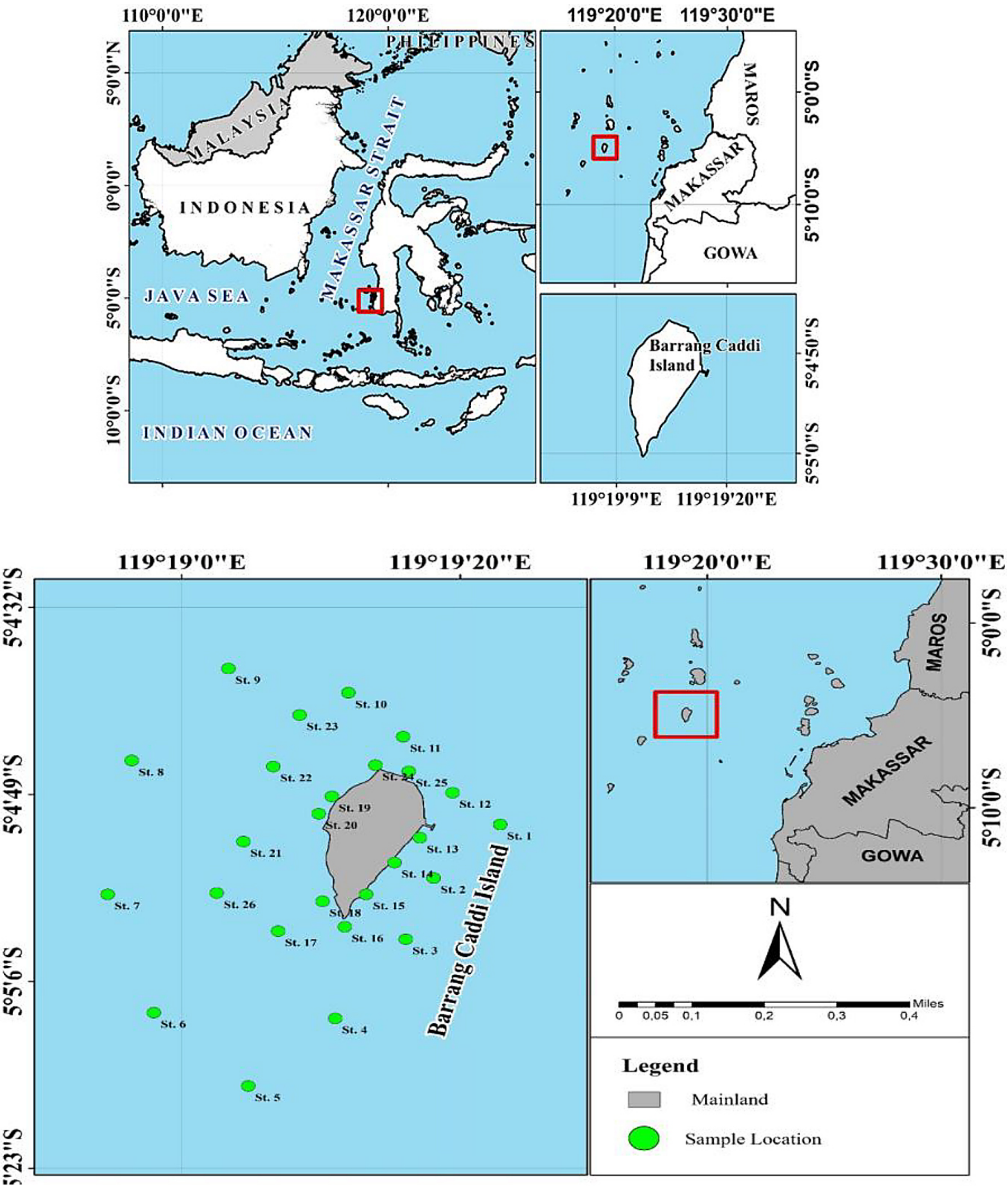

Figure 1. Research area and sampling location on Barang Caddi Island, Makassar, Indonesia

RESULTS AND DISCUSSION

The measurement of water quality from turbidity, salinity, pH, TSS, DO, temperature and chlorophyll-a in detail for each station is shown in Table 1. Turbidity is in the range of 0.4–3.17 NTU, salinity is 32–34$^{0}/_{00}$, pH is 7.44–7.83, total solids suspended oxygen (TSS) between 58.93–94.80 mg/L, dissolved oxygen (DO) between 2.2–6.7 mg/L, temperature between 28–30 °C and chlorophyll-a in the range 0.11–2.10 mg/m^3.

The results of previous research by Rasyid (2011) using satellite data in Spermonde waters showed the concentration of chlorophyll-a in the east monsoon reached 0.15–1.15 mg/m^3 (mg/m^3 ~ µg/L) and in August was in the range of 0.0–1.0 mg/m^3 (Rasyid et al., 2014). It was indicated when an upwelling process in east monsoon has occurred in the southern region of the Makassar Sea.

The distribution pattern of chlorophyll-a in waters

The distribution pattern of the chlorophyll-a concentration in stations BC 1 to BC 26 is illustrated in Figure 2. The highest chlorophyll-a concentration was found at station BC 21, which is located west of Barrang Caddi Island. The

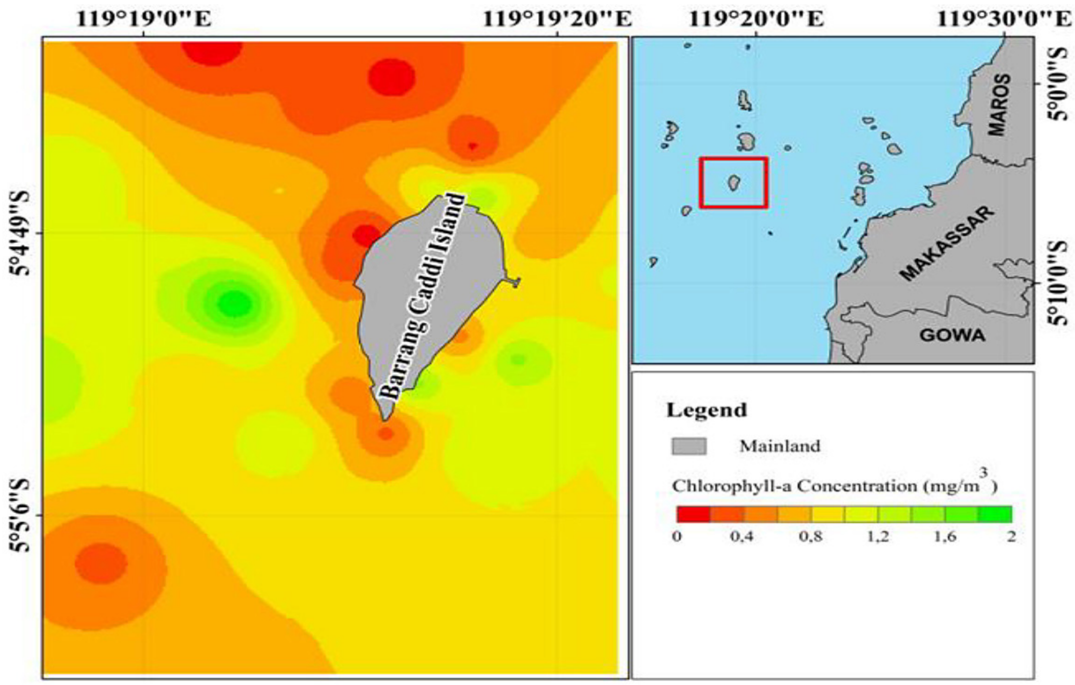

Figure 2. Spatial distribution pattern of the chlorophyll-a concentration on Barrang Caddi Island

Table 1. Value of chlorophyll-a, turbidity, salinity, pH, TSS, DO and temperature

No.	Stations	Chlorophyll-a (μg/L)	Turbidity (NTU)	Salnity (0/00)	pH	TSS (mg/L)	DO (mg/L)	Temperature (°C)
1	BC 1	1.02	0.63	32	7.54	66.07	2.2	29
2	BC 2	1.43	0.44	32	7.48	84.31	6.5	28
3	BC 3	1.17	0.59	32	7.59	74.07	6.7	29
4	BC 4	0.96	0.45	33	7.55	61.11	6.1	29
5	BC 5	0.66	1.5	34	7.65	58.93	6.2	28
6	BC 6	0.35	0.94	34	7.62	69.09	6.2	28
7	BC 7	1.35	0.49	34	7.65	68.52	6.2	28
8	BC 8	1.18	0.45	33	7.73	65.52	6.4	29
9	BC 9	0.12	0.49	33	7.7	60.11	6.3	29
10	BC 10	0.12	0.47	34	7.28	64.81	6.1	29
11	BC 11	0.19	0.58	33	7.51	66.67	6.4	29
12	BC 12	0.64	0.4	34	7.65	77.67	6.3	29
13	BC 13	0.94	0.75	33	7.63	70.37	6.4	30
14	BC 14	0.56	0.61	33	7.66	66.67	6.4	29
15	BC 15	1.42	0.56	33	7.73	73.58	6.3	29
16	BC 16	0.37	0.96	33	7.46	71.30	6.3	29
17	BC 17	1.17	0.55	33	7.44	94.80	6.3	29
18	BC 18	0.45	2.7	33	7.72	88.89	6.3	30
19	BC 19	0.11	0.68	33	7.83	66.67	6	29
20	BC 20	0.27	0.94	33	7.69	70.69	6.1	30
21	BC 21	1.93	3.17	34	7.74	85.19	6.1	29
22	BC 22	0.80	0.56	34	7.73	79.25	6	30
23	BC 23	0.32	0.86	32	7.68	77.36	6.1	30
24	BC 24	1.06	0.67	33	7.72	62.96	6	30
25	BC 25	1.33	0.89	33	7.69	76.92	6	30
26	BC 26	0.86	0.58	33	7.77	69.81	6	30

presence of chlorophyll-a shows the biomass of phytoplankton the growth of which is influenced by other water qualities such as turbidity, TSS and salinity. The results of the research by Rasyid (2011), the value of chlorophyll-a in Spermonde waters shows a spatial and temporal variation in patterns. Chlorophyll-a was found to be high in the southern location, namely in small spots around islands and reefs, including near Barrang Caddi Island. The high chlorophyll-a concentration in coastal waters is related to the presence of nutrient sources from run-off or land areas (Marlian et al., 2014).

Spatial distribution pattern of total suspended solids (TSS) and turbidity

Turbidity and TSS are visible indicators of water quality. These suspended particles are derived from soil erosion, runoff, dumping, stirred bottom sediment or due to algae blooms. TSS and turbidity have a positive correlation, as an increase in TSS will increase the level of turbidity. Turbidity is a major water quality parameter that represents the amount of light absorbed or scattered in the water column by suspended particles (Zweifler et al., 2021).

Turbidity is a parameter that is often associated with TSS and frequently used in monitoring coastal areas (Jafar-Sidik, 2017). Turbidity and TSS have a similarity pattern, since they both measure water clarity. However, they do not measure the same thing. Turbidity is a reading of the results of sample measurements related to the optical properties of water. The presence of dissolved material in the water can cause high turbidity. Meanwhile, TSS is the result of manual measurement and requires the right technique and often has to be analyzed in the laboratory. Davis and Cornwell (1991) showed that the turbidity of the waters was influenced by the presence of suspended and dissolved from organic and inorganic materials.

Turbidity is used to see the extent of the scattering of light in water. Thus, turbidity can reveal some suspended solids, algae, organic matter, and other very small particles that cause the liquid to become cloudy. Macdonald, et al. (2021) explained that the suspended material consists of inorganic material, usually sediment from land and/or suspended seabed sediment, as well as particulate organic matter, such as phytoplankton (measured as chlorophyll-a), zooplankton and bacteria. These particles are large enough that they do not pass through the filter. Chester (1990) explained that suspended solids are the materials retained by a 0.45 m sieve.

On the basis of Figure 3, the highest value of turbidity has shifted. The relationship between TSS and turbidity is shown in Tables 2 and 3.

Distribution pattern of sea surface temperature and dissolved oxygen

Sea surface temperature and dissolved oxygen concentration are important factors that control ocean productivity, carbon cycles, nutrients, and marine organisms. The sea surface temperature affects the dissolved oxygen concentration. Dissolved oxygen (DO) will decrease due to an increase in sea surface temperature (SST). The spatial distribution pattern of sea surface temperature

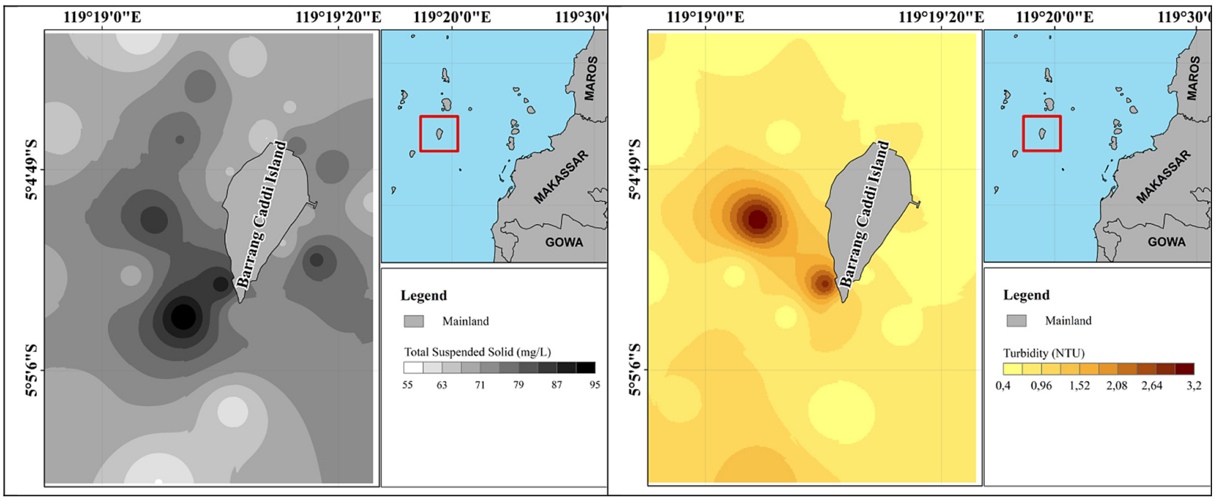

Figure 3. Spatial distribution pattern of total suspended solids (TSS) (left) and turbidity (right)

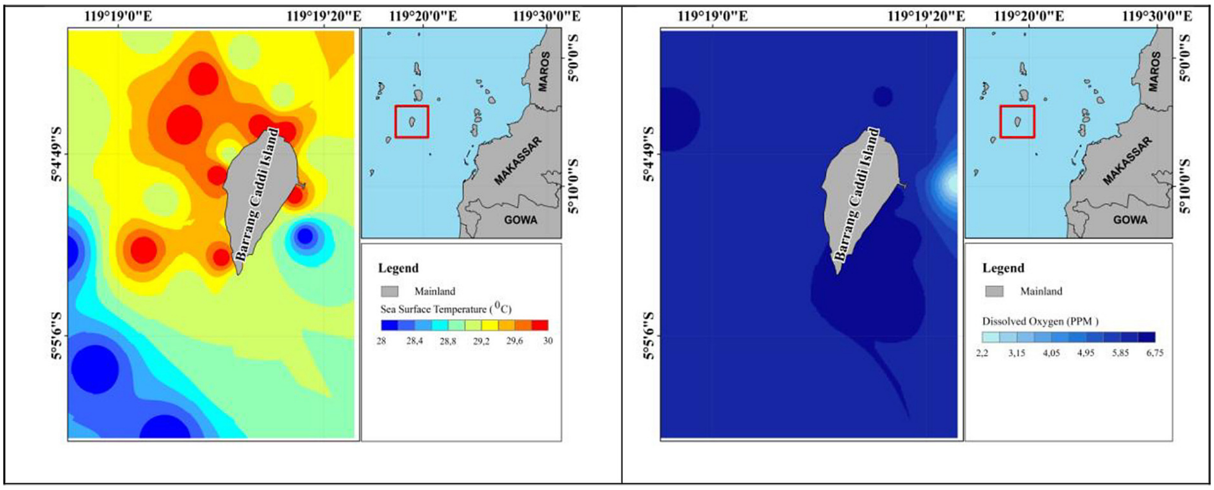

Figure 4. Distribution pattern of sea surface temperature (left) and dissolved oxygen (right)

and dissolved oxygen is illustrated in Figure 4. The sea surface temperature of the southern part of Barang Caddi Island is lower than the area near the mainland. Conversely, dissolved oxygen, which is found high in the southern region and close to the mainland. This illustrates that the changes in temperature in the study area which is a tropical area do not directly affect the dissolved oxygen. The results of Nasir et al. (2015) showed that the sea surface temperature was in the range of 29.5–31.9 °C (higher than the research results), while dissolved oxygen was in the 4.63-4.95 mg/L range (Retnaningdyah et al., 2019).

Distribution pattern of salinity and pH

The distribution pattern of salinity and pH is visualized in Figure 5. The eastern part of the island has lower salinity than in the western region. This is due to the eastern part is the closest area to the city center of Makassar City. Moreover, there is an input of river flow from the mainland of Makassar City which influences the salinity and pH values. The eastern part is characterized by a low pH value. This phenomenon indicates that the eastern region is heavily influenced by the human activity at the city of Makassar.

The relationship between chlorophyll-a to water quality

Chlorophyll-a is one of the parameters that determine the primary productivity in waters. The distribution and concentration of chlorophyll-a are related to the presence of phytoplankton (Marlian et al., 2015). The phytoplankton biomass is identified by measuring chlorophyll-a, the presence of which is influenced by water turbidity, temperature, pH, salinity, and DO. Turbidity is affected by high suspended solids

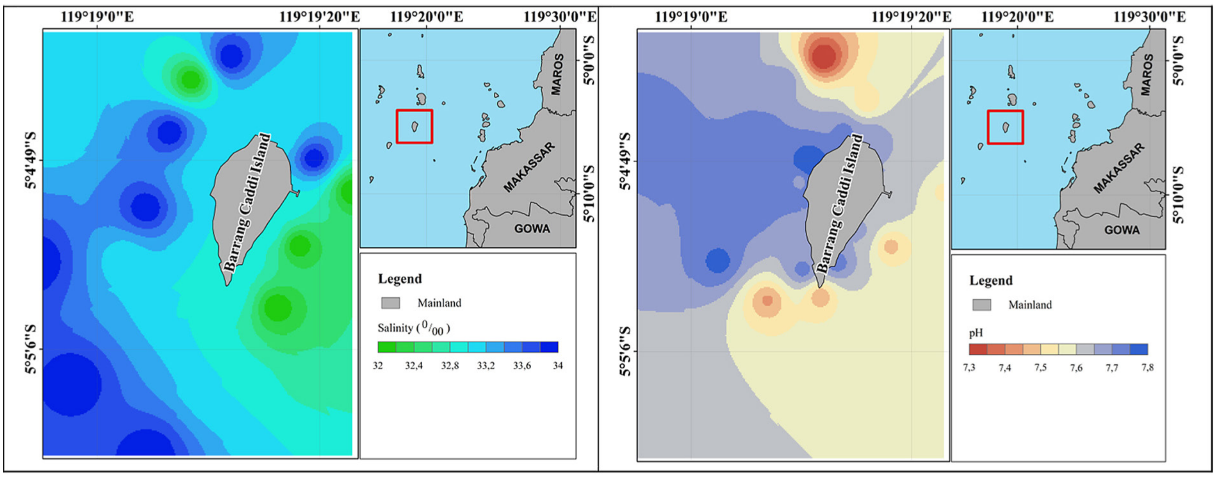

Figure 5. Distribution pattern of salinity (left) and pH (right)

Table 2. Correlation of chlorophyll-a, turbidity, salinity, pH, TSS, and DO (n = 26)

Specification	Chlorophyll-a (µg/L)	Turbidity (NTU)	Salnity ($^0/_{00}$)	pH	TSS (mg/L)	DO (mg/L)
Turbidity	-0.17	1.00	0.03	0.22	0.15	-0.25
Salinity	-0.11	0.03	1.00	0.13	-0.09	-0.19
pH	0.08	0.22	0.13	1.00	0.05	-0.35
TSS	0.32	0.15	-0.09	0.05	1.00	0.15
DO	0.11	-0.25	-0.19	-0.35	0.15	1.00
Temperature	-0.14	0.27	-0.23	0.42	0.25	-0.36

in the water column, including organic material (i.e. phytoplankton) and other inorganic. The presence of phytoplankton will impact the water temperature become higher and the solubility of oxygen become lower. Moreover, the presence of phytoplankton affects the concentration of dissolved oxygen (Di) as a result of the process of photosynthesis and respiration. The direction of the relationship between chl-a as an indicator of phytoplankton biomass on suspended solids, turbidity, temperature, pH, salinity and dissolved oxygen is shown in Table 2.

Table 2 shows that chlorophyll-a is not significantly influenced by such water quality parameters as turbidity, salinity, pH, TSS, DO and STT, as indicated by low correlation values. The results of the correlation test for each parameter varied and the direction of the relationship has positive and negative values. From 6 water quality parameters, TSS gives a highest correlation and positive relationship. This illustrates that the presence of high TSS was followed by an increase in chlorophyll-a. This is in line with the researches results of Buditama et al. (2017) in Cirebon waters explained that TSS is associated with chl-a. A high TSS value is followed by an increase in chl-a.

Due to the varied conditions of the research location, further relationship analysis was carried out, emphasizing the characteristics of each region. This was to determine the most influential factor on chlorophyll-a under more uniform conditions. The correlation test was divided in 2 regions, namely West and East. The results of the correlation test are shown in Table 3.

The results of the correlation analysis in the western and eastern region are shown in Table 3. In the eastern region, chlorophyll-a has a negative correlation with salinity and turbidity, but has a positive correlation with TSS. The negative correlation explains the low values of salinity and turbidity, while the chl-a concentration tend to be high. Low turbidity in the waters due to the intensity of sunlight in the waters to be sufficient and driven the photosynthesis process of phytoplankton to be high. Meanwhile, low salinity is an indicator of water mass from land that has higher nutrients. Sew and Todd (2020) explained that

Table 3. Correlation of chlorophyll-a on suspended solids (TSS), turbidity, salinity, pH and dissolved oxygen (DO) in the eastern and western regions of Barrang Caddi islands

Region	Specification	Chlorophyll-a (µg/L)	Turbidity (NTU)	Salnity ($^0/_{00}$)	pH	TSS (mg/L)	DO (mg/L)	Temperature (°C)
Eastern	Turbidity	-0.35	1.00	0.43	0.12	-0.48	0.03	-0.15
	Salinity	-0.54	0.43	1.00	0.48	-0.32	0.35	0.00
	pH	0.19	0.12	0.48	1.00	-0.09	0.20	0.35
	TSS	0.48	-0.48	-0.32	-0.09	1.00	0.27	0.09
	DO	-0.05	0.03	0.35	0.20	0.27	1.00	-0.04
	Temperature	0.08	-0.15	0.00	0.35	0.09	-0.04	1.00
Western	Turbidity	-0.24	1.00	-0.14	0.21	0.36	-0.21	0.41
	Salinity	0.35	-0.14	1.00	0.16	0.12	-0.08	-0.42
	pH	-0.23	0.21	0.16	1.00	-0.30	-0.52	0.08
	TSS	0.01	0.36	0.12	-0.30	1.00	0.30	0.10
	DO	0.51	-0.21	-0.08	-0.52	0.30	1.00	-0.42
	Temperature	-0.56	0.41	-0.42	0.08	0.10	-0.42	1.00

salinity will affect the growth of phytoplankton, which in this study used chlorophyll-a concentration indicators. The presence of a clear environment and high nutrients lead the eastern region of the island to have high primary productivity in this study, which it is indicated by high value of chl-a in the eastern region.

The role of turbidity on chlorophyll-a in the western region has the same pattern as in the east of the island. However, salinity has a different effect. Salinity is positively correlated with chlorophyll-a in the western region. This is due to high value in chl-a and the temperature value is relatively low in the western region. Moreover, the western region of the island is dominated by reef flat area.

A more interesting analysis in this study is the correlation between TSS and turbidity in the two regions showing a difference correlation. TSS in the western region has a positive correlation with turbidity, and conversely, in the eastern region it has a negative correlation. This is due to source of turbidity in western and eastern region is different. Turbidity in the western region is sourced from inorganic material (not phytoplankton), this is strengthened by lack of correlation between TSS and chl-a (small correlation value). In turn, the eastern region has a different pattern, where the water column becomes turbid as a result of high levels of phytoplankton activities (chl-a), which is indicated by a positive correlation between TSS and chl-a shown in Table 3.

The trophic status of Barrang Caddi Island

Ignatiades (2005) classified marine waters, including in the oligotropic category if the chlorophyll-a concentration value ranges from 0.16–0.37 mg/m^3, mesotrophic (0.45–0.61 mg/m^3) and eutrophic from 1.16–1.84 mg/m^3. Moreover, Smith et al. (1999), the mesotrophic status occurs at concentrations of chlorophyll-a, 1–3 µg/L and hypereutrophic at concentrations > 5 µg/L). The average concentration of chlorophyll-a in the study area was in the range of 0.11–1.93 mg/m^3. On the basis of this classification, the fertility of the waters of Barrang Caddi Island in this study categorized as oligotrophic in offshore waters, namely at stations 9, 10, 11 and 23 which are located in the north of Barrang Caddi Island. In turn, the stations located at the edge (BC 2, 3, 7, 8) and reef fractures (BC 21) have a tendency to be categorized as eutrophic area. In line with the research by Faizal et al. (2011) the Spermonde archipelago, South Sulawesi, was categorized as an oligotrophic area.

CONCLUSIONS

The concentration of chlorophyll-a shows high values in the western and southern parts of the Barrang Caddi island. Overall, the result of the correlation test of chlorophyll-a and total suspended solids (SST) has a positive correlation with coefficient of 0.32 (r = 0.32). However, further analysis was conducted by dividing into two regions (western and eastern), and obtained the pattern of differences in characteristics. Chlorophyll-a in the eastern region has a positive correlation with TSS and is influenced by salinity. Moreover, high levels of chlorophyll-a were found near the coast and characterized by low salinity values. In contrast to the western region, the areas far from the mainland have higher concentrations of chlorophyll-a. The role of temperature is more influential in the western part of the island and the high chlorophyll-a lead the concentration of dissolved oxygen (DO) to be high. Furthermore, the turbidity value has a negative correlation effect both in the western and eastern regions. High turbidity has disrupted the process of photosynthesis and caused the low concentration of chlorophyll-a.

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