Water Fertility Based on Chlorophyll a in Aqua MODIS Satellite Imagery in The Waters of Belitung Island

Valentin Vina Ratnapuri[1*], Monischa Br Sebayang[2], Misri Yandi[3], Ali Rizki Maulana[4], Ni Luh Eta Yuspita[5]

[1,2,3,4,5] Department of Precision Agriculture, Bangka Belitung State Manufacturing Polytechnic, Airkantung Industrial Estate, Sungailiat, Bangka, Bangka Belitung Island Province. Indonesia.
[*] Corresponding Author:
Email: valentinvinaratnapuri@gmail.com

Abstract.

The waters of Belitung Island are tropical waters that play a crucial role in supporting the global ecosystem balance through primary productivity, which can be measured using chlorophyll a concentration as an indicator of water fertility. The strategic geographical location of Belitung Island, situated on the border of the Karimata Strait, the Java Sea, and the South China Sea, makes it vulnerable to the constantly changing oceanographic dynamics. This study aims to analyze the spatial-temporal distribution and fluctuations of chlorophyll a in the waters of Belitung Island based on Aqua-MODIS satellite imagery from January to December 2024. Chlorophyll-a data were extracted from Aqua-MODIS satellite imagery using the OCx and CI algorithms, then analyzed using the Inverse Distance Weighting (IDW) interpolation method through ArcGIS and Seadas software. The research results show that the waters of Belitung Island are generally classified as oligotrophic, with an average chlorophyll a concentration ranging from 0.39 to 0.81 mg/m³. The lowest concentration at the April location point was 0.08 mg/m³, and the lowest average was in May (0.39 mg/m³), coinciding with the first transition season due to reduced upwelling and water stratification. Conversely, the highest concentration was detected at the May location point (5.14 mg/m³), and the highest average was observed in June (0.81 mg/m³), when the southeast monsoon triggered increased winds and upwelling, bringing nutrients from the lower layers to the surface. This research demonstrates that monsoon variability and local oceanographic processes have a significant influence on water fertility in Belitung Island, and can be utilized in predicting potential fishing areas.

Keywords: *Aqua-MODIS; Belitung Island; Chlorophyll a; IDW and Water Fertility.*

I. INTRODUCTION

Tropical marine waters play a crucial role in maintaining global ecosystem balance through primary productivity. The primary productivity level of water bodies can be measured using chlorophyll a concentration, which serves as a key indicator of water body fertility [18]. Chlorophyll a is a photosynthetic pigment that represents the abundance of phytoplankton, which are the base of the food chain in the ocean [14,17]. Fluctuations in chlorophyll a have direct implications for the availability of fish resources and the stability of coastal ecosystems [12]. The development of remote sensing technology, one of which is the widespread and consistent monitoring of chlorophyll a using satellite imagery, has enabled this. Aqua-MODIS satellite imagery utilizes the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor, allowing for the spatial and temporal observation of chlorophyll a distribution with relatively high resolution. Combining chlorophyll a concentration with sea surface temperature (SST) plays an important role in predicting and mapping potential fishing zones [12,17]. The waters of Belitung are one of the strategic areas in the Bangka Belitung Islands Province, characterized by unique oceanographic dynamics. The strategic geographical position of Belitung Island, situated on the border of the Karimata Strait, the Java Sea, and the South China Sea, makes it vulnerable [13].

Water vulnerability is influenced by several oceanographic factors, including runoff, upwelling processes, and monsoon fluctuations, which also impact the distribution of chlorophyll a and water productivity in the Belitung Waters each month. The limited research on chlorophyll a in Belitung Waters has resulted in a lack of information on fluctuations in chlorophyll a levels in the area. In 2015, the variability of chlorophyll a distribution was studied using Aqua-MODIS satellite data in the waters of Belitung Island. The study's results showed that chlorophyll a concentration was high during the southwest monsoon season and low during the northeast monsoon season, influenced by upwelling processes, nutrient availability, wind movement, and sunlight intensity. The high or low concentration of chlorophyll a in the waters of Belitung Island helps predict fishing grounds [19].Thus, the author chose the research title "Water Fertility Based on Chlorophyll-a in Aqua-MODIS Satellite Imagery in the Waters of Belitung Island". This research aims to examine water fertility based on chlorophyll a concentration as detected by Aqua-MODIS satellite imagery in the waters of Belitung Island. This research is expected to provide a better understanding of the dynamics and fluctuations in water body fertility, based on chlorophyll a, as well as the potential for fisheries catch amid climate change and regional oceanographic conditions.

II. METHODS

The research area is located in the waters of Belitung Island, which lies between 107°08'44.88"W and 108°33'45"E, and -2°18'45"N and -3°28'45.012"S, as shown in Figure 1.

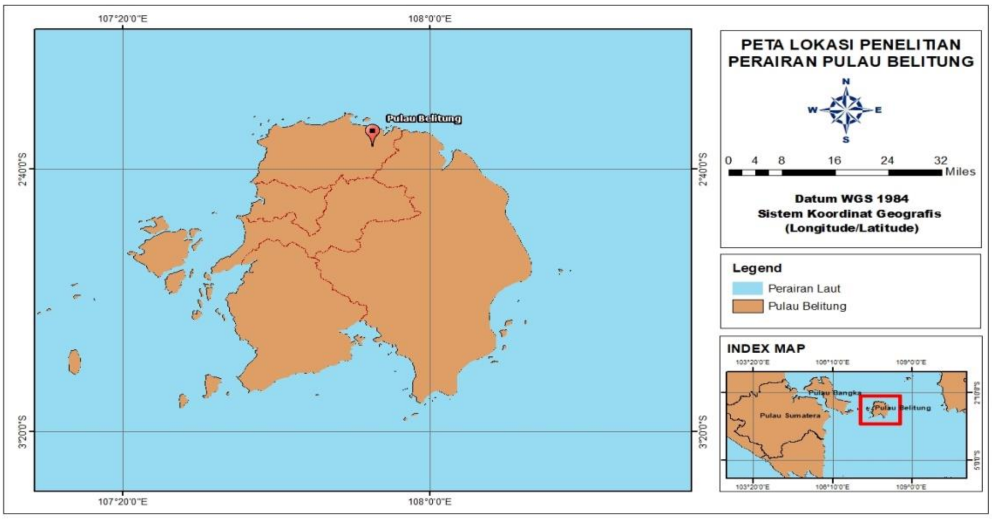


Fig 1. Map of the Research Location in the Waters of Belitung Island

Location determination is based on Law Number 23 of 2014, which outlines the utilization of marine resources between provincial regions, extending up to 12 miles from the coastline and a maximum of 24 miles from the coastline, and explains the division of authority between provinces in the utilization of marine resources [16]. The research data for this study were collected from January 2024 to December 2024. The research data collection period is based on the west monsoon season (December-March), transition season I (April-May), southeast monsoon season (June-September), and transition season II (October-November) [2]. This research utilizes software including Microsoft Word, Microsoft Excel, ArcMap/ArcGIS, and Seadas. The chlorophyll a concentration in the water was obtained from the conversion of Aqua MODIS satellite images (Monthly). The chlorophyll a data from Aqua MODIS satellite images, used at level 3 with a 4 km resolution, were downloaded from the website https://oceancolor.gsfc.nasa.gov/. The conversion of satellite images on the Oceacolor website follows the Cl algorithm, which is a three-band reflectance algorithm that utilizes the difference between the sensor-specific Rrs values in the green band and the reference values linearly in the blue and red bands. Where the formula for Cl is as follows:

$$CI = Rrs(\lambda green) - [Rrs(\lambda blue)+(\lambda green-\lambda blue)/(\lambda red-\lambda blue)*(Rrs(\lambda red)-Rrs(\lambda blue))]$$

chlorophyll-a is calculated using two coefficients ($\alpha 0CI$ = -0.4287 and $\alpha 1CI$ = 230.47), where the formula for chlorophyll-a is as follows [4]:

$$Chlor\_a = 10^{\alpha o_{CI} + \alpha_1 X + \alpha_2 X^2 + \alpha_3 X^3 + \alpha_4 X^4}$$

chlorophyll-a is calculated using the OCx algorithm, which is a polynomial relationship between the Rrs ratio and chlor_a, where:

$$\log_{10}(Chlor\_a) = \alpha_0 + \sum \alpha_i \left[\log_{10} \underline{(Rrs(\lambda blue)} \quad \right]^i$$

Rrs (λblue) is the most significant value among several input Rrs values, and the coefficients α0-α4 are sensor-specific. The coefficients used for the MODIS sensor include:

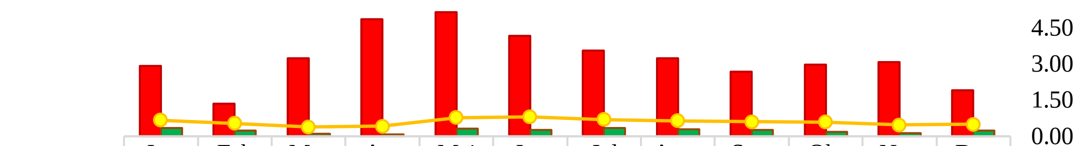
1. Algorithm : OC3M, Cl
2. OCx Rrs (blue/green) : Rrs (443 > 488) / Rrs (547)
3. α(1,2,3,4) : 0.26294; -2.64669; 1.28364; 1.08209; -1.76828 [11].

Data analysis using the data interpolation method with the IDW (Inverse Distance Weighting) method. The IDW method is a linear combination (weighted average) based on spatial location or the distance between points. Weighting in IDW functions inversely with the distance from the sample points to the estimation location [15].

III. RESULT AND DISCUSSION

The research results indicate that the waters of Belitung Island are characterized as oligotrophic, meaning they have low fertility. The average monthly chlorophyll-a concentration in Figure 2 shows a range of 0.39 – 0.81 mg/m^3, where the chlorophyll-a value is < 0.25 (µg/L or mg/m^3), indicating low water fertility [6]. The lowest chlorophyll-a concentration in Figure 2 is found at the location point in April, which is 0.08 mg/m^3, and the average chlorophyll-a concentration in May is 0.39 mg/m^3. The lowest chlorophyll a concentration is found at the location point in April, which is still within the first transition season. This is because during the northwest monsoon from December to April, the upwelling process is reduced due to positive wind stress curl, which inhibits the formation of upwelling currents and vertical nutrient mixing. The formation of different layers or stratification in strong marine waters also causes chlorophyll a to be lowest in April because it prevents the mixing of nutrients from the deeper layers of the water [8].

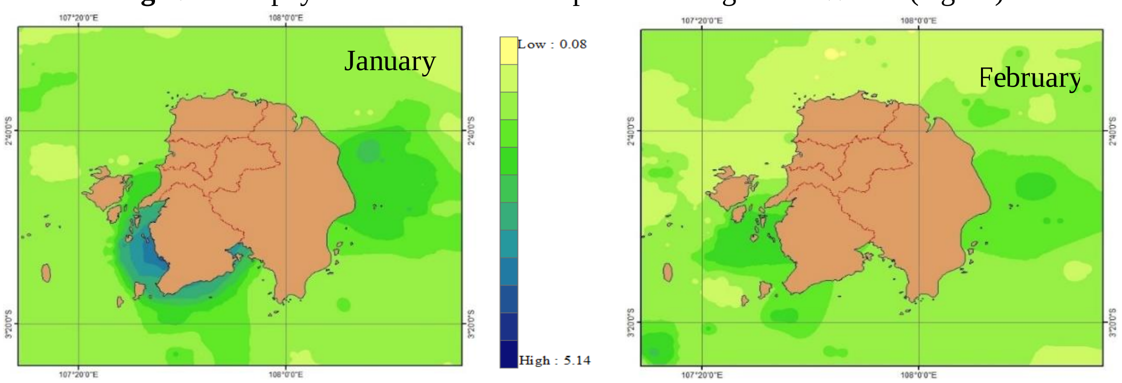
The lowest average concentration occurs in May, as it marks the end of the west monsoon season, which is part of the first transitional season. The end of the first transitional season is usually characterized by low upwelling intensity, resulting in decreased water nutrients and reduced phytoplankton productivity. In May, a combination of monsoon wind patterns also affected the distribution of chlorophyll a in the waters [10].The distribution of chlorophyll a in Figure 3 indicates that the April map is dominated by yellow, indicating low chlorophyll a concentrations in April, which range from 0.07 to 4.84 mg/m^3. This indicates that the waters in April are Oligotrophic, with chlorophyll a levels ranging from < 0.25 (µg/L or mg/m^3). The fertility of oligotrophic waters is low, characterized by minimal nutrient content, which results in low primary productivity of phytoplankton [6]. The chlorophyll a distribution map for April shows that waters within +10 km of the mainland of Belitung Island are more dominated by blue, indicating mesotrophic waters. The relatively high water fertility in this coastal area is due to the influx of organic material from land, and the mixing processes caused by waves, currents, and tides, which make nutrients stored in the sediment easily rise to the water surface [1,9].



	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agus	Sept	Okt	Nov	Des
Maks	2.92	1.36	3.24	4.85	5.14	4.17	3.54	3.24	2.69	2.97	3.07	1.90
Mins	0.35	0.24	0.10	0.08	0.33	0.25	0.33	0.29	0.27	0.19	0.12	0.24
Mean	0.66	0.54	0.39	0.41	0.77	0.81	0.69	0.64	0.61	0.59	0.48	0.50

Maks Mins Mean

Fig 2. Chlorophyll-a Concentration Graph in Belitung Island Waters (mg/m^3)



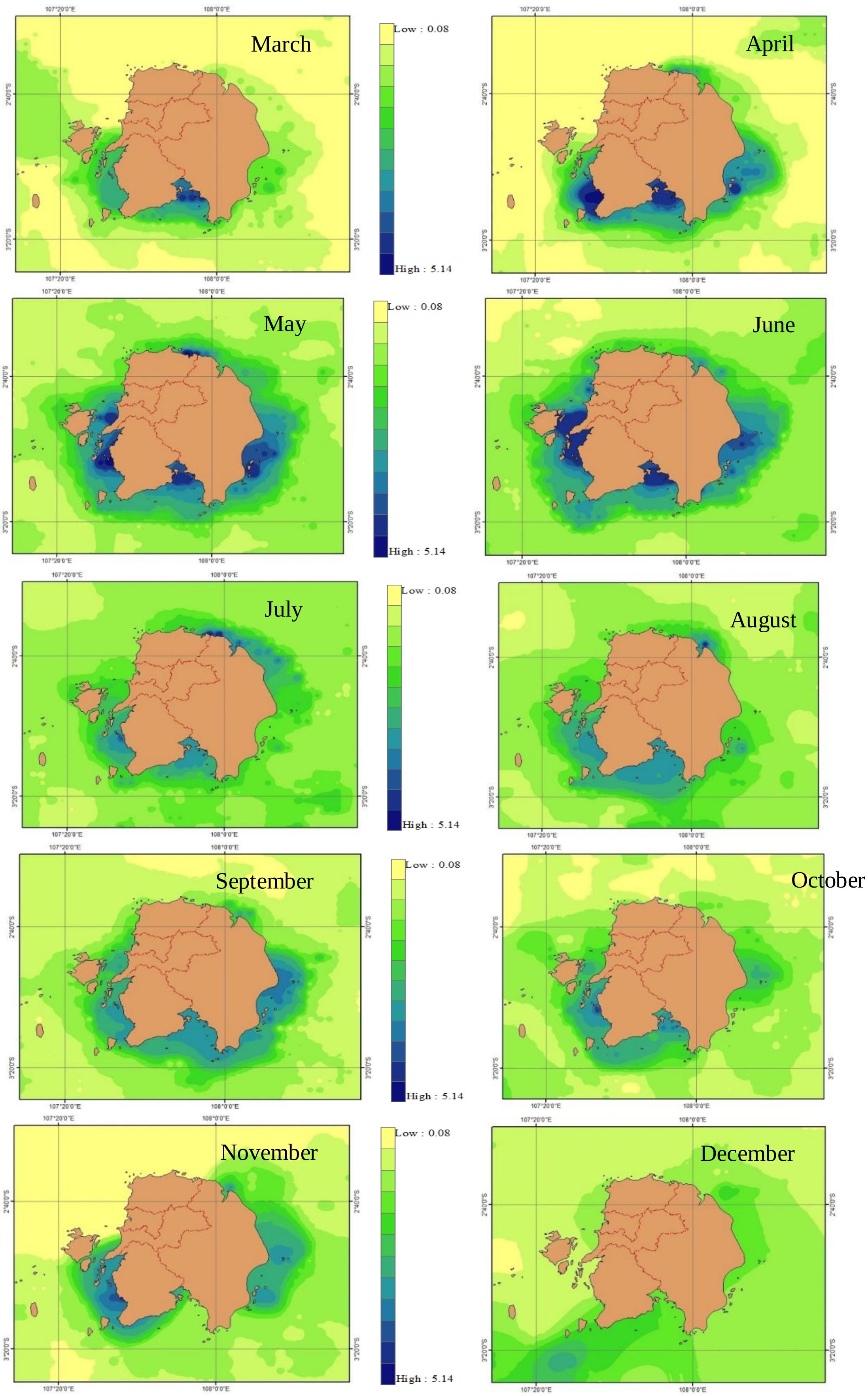


Fig 3. Spatial and Temporal Distribution of Chlorophyll-a (mg/m^3)

The fluctuation of chlorophyll a in Figure 2 shows that the highest chlorophyll a concentration occurred at the location point in May, which was 5.14 mg/m^3, and the highest average chlorophyll a in June was 0.81 mg/m^3. The highest chlorophyll a concentration at the location point in May occurred during the first transition season, which was attributed to changes in wind patterns. The increase in chlorophyll a concentration in May was attributed to the wind shifting from the Southeast toward the Northwest, accompanied by the movement of nutrient-rich water masses [5]. Figure 3 shows the spatial distribution of the highest chlorophyll a levels in June and May, where the maps for May and June are dominated by the color blue, with a chlorophyll a range of 2.4–5.14 mg/m^3, indicating mesotrophic waters with moderately high water fertility. The high chlorophyll-a concentration at the location point in May indicates the initial stratification of nutrient movement in the surface layer of the sea, reaching its peak in June, which marks the beginning of the southeast monsoon season. June is the peak concentration of chlorophyll a, primarily due to the strong wind speeds that trigger the vertical upwelling process. Vertical upwelling brings nutrient supplies from the depths of the water to the surface layer (the euphotic zone), resulting in an abundance of nutrients in June, the beginning of the monsoon season [3,7].

IV. CONCLUSION

The results of the analysis of chlorophyll a distribution and fluctuation in the waters of Belitung Island show an average chlorophyll a value of 0.39 – 0.81 mg/m^3, where this chlorophyll a value is < 0.25 (µg/L or mg/m^3), indicating low water fertility. The lowest chlorophyll concentration was observed at the location point in April, at 0.08 mg/m^3, with the lowest average chlorophyll-a concentration recorded in May at 0.39 mg/m^3. The highest chlorophyll a concentration in this study occurred at the location point in May, which was 5.14 mg/m^3, and the highest average chlorophyll a concentration in June was 0.81 mg/m^3. The waters in May and June were mesotrophic, with a chlorophyll a concentration range of 2.4–5.14 mg/m^3.

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