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Anchovy (*Stolephorus* Sp.) Fishing Grounds Based on Analysis of Chlorophyll-A Content and Sea Surface Temperature in Pemalang Waters, Central Java

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AB S T R A C T

Anchovy, as one of the main commodities, is widely caught using purse seines by fisherman in Pemalang Waters. Sea Surface Temperature (SST) and chlorophyll-a concentration are two key parameters that influence the distribution and abundance of anchovy in Pemalang Waters. This study aims to analyze the distribution of chlorophyll-a concentration and sea surface temperature, as well as their relationship with anchovy catch and potential fishing grounds for anchovy (Stolephorus sp.) landed at PPP Asemdoyong, Pemalang Regency. This research used a quantitative descriptive method. Sample selection used a non-probability sampling technique with purposive sampling. Data analysis was processed using Microsoft Excel, ArcMap 10.8, and SeaDAS software. Chlorophyll-a content was analyzed using spectrophotometry with readings at wavelengths of 630, 647, and 664 nm, while SST was measured directly using a thermometer during field sampling. Image mapping used AquaMODIS satellite with the Inverse Distance Weighting (IDW) method. The results showed that there were 7 coordinate stations with a distribution pattern of sea surface temperature in June 2024 ranging from 29.8°C to 30.6°C, while chlorophyll-a ranged from 0.32 mg/m³ to 1.68 mg/m³. There was a significant correlation between sea surface temperature and chlorophyll-a with anchovy catch, indicated by a coefficient of determination of 68.1%. Estimation of potential anchovy fishing grounds in the waters of Pemalang Regency resulted in three points, namely at 6°73’96.44” S and 109°20’72.54” E located in Zone II with a depth of 24 meters; 6°78’99.21” S and 109°39’44.36” E located in Zone II with a depth of 9 meters; 6°79’47.86” S and 109° 41’ 11.75” E located in Zone IB with a depth of 12 meters.

Keywords: AquaMODIS, Fishing Grounds, Chlorophyll, Sea Surface Temperature, Anchovy.

1. Introduction

Pemalang Regency Waters is one of the fishery support areas on the North Coast of Java, with water potential for fishing areas. The waters of Pemalang in Central Java have a very large capture fisheries potential, especially for anchovies, which are one of the important commodities for the local economy. According to the PPP Asemdoyong Information Center (2023), the highest production and landing of fish in Pemalang Waters, Central Java, are Selar, Anchovies, Kuniran, Petek, and other fish. Anchovies are in second place with the highest catch of 3,878,662 kg, contributing 15.4% of the total landed catch. Anchovies, as a small pelagic species, are often found in large numbers in these waters, which have environmental conditions that support their growth. The nutrientrich oceanographic conditions, supported by ocean currents and water dynamics, make Pemalang Waters an ideal habitat for anchovies.

Anchovies, as a leading commodity, are widely caught using a payang fishing gear by fisherman in Pemalang Waters. Payang fishing gear is an effective fishing method for catching small pelagic fish such as anchovies. Anchovies are one of the important commodities that support the coastal community's economy in Pemalang Waters. However, optimizing anchovy fishing often faces various obstacles, particularly related to identifying potential fishing locations. Most fishermen in Pemalang Waters still rely on traditional knowledge and empirical experience to determine fishing areas, which can lead to low fishing efficiency and uncertainty in catch results. Methods for determining fishing grounds are very necessary for the optimal utilization of fish resources. Information on fishing ground determination can be obtained by analyzing environmental parameters and catch results. Information related to environmental parameters such as sea surface temperature and chlorophyll-a can be obtained by utilizing the development of remote sensing technology or remote sensing. The use of remote sensing technology, such as AquaMODIS satellite imagery, can provide high-resolution and real-time SST and chlorophyll-a data. This technology holds significant potential in aiding fishermen to identify optimal fishing areas.

This research aims to analyze the distribution of chlorophyll-a and sea surface temperature in Pemalang Regency Waters, analyze its relationship with the catch of Anchovies (*Stolephorus sp.*), and analyze the potential fishing areas for Anchovies.

2. Materials and Methods

2.1 Methods

The method used in this research is a descriptive quantitative method. The steps taken in the study include in-situ sea surface temperature data collection, water sample collection, testing the water samples in the laboratory, calculating the chlorophyll-a content in the water samples, and processing the sea surface temperature data and chlorophyll-a concentrations both in-situ and from Aqua MODIS satellite imagery. This descriptive research provides an overview of fishing areas with the output being a map of potential fishing areas and its analysis.

2.2 Sample Collection Methods

The data collection method used in this research is the purposive sampling method. This method is used for the collection of primary data on sea surface temperature, chlorophyll-a, fishing position, operation time, and catch composition.

a. Primary Data Collection

Primary data used includes sea surface temperature measured using a thermometer. The sea surface temperature measurement follows the fishing track location and the setting of the payang fishing gear. The next data is chlorophyll-a, obtained by taking seawater samples. A total of 7 sample bottles of seawater were taken according to the fishing track locations passed by the ship. These samples were tested in the laboratory to determine the chlorophyll-a values obtained. Other data collected includes catch results obtained during fishing to understand fluctuations and correlate with SST and chlorophyll-a to predict potential fishing locations

b. Secondary Data Collection

The secondary data used is Aqua-MODIS satellite imagery obtained from the website https://oceancolor.gsfc.nasa.gov/. The satellite imagery used includes monthly data from 2019 to 2024. Additionally, data from the Pemalang Regency Fisheries and Marine Service includes data on the fishing fleet and production quantity and value over the past five years from 2019 to 2024.

2.3 Testing Methods for Chlorophyll-A

Chlorophyll-a Sampling Method Seawater samples are collected, totaling 2.5 liters, and placed in jerrycan. These samples are stored in light-blocking bottles within a Styrofoam box. They are then analyzed at the FPIK Undip laboratory. The chlorophyll-a concentration is calculated using the following formula:

$$Ca = 11.85(\lambda664) - 1.54(\lambda645) - 0.08\ (\lambda630)$$

$$\text{Klorofil-a (mg/l)} = Ca \cdot \frac{Vc}{Vs}$$

Explanation:

λ664, λ645, and λ630 : Absorbance readings at specific wavelengths

Ca : Chlorophyll-a concentration (mg/m3)

Vc : Volume of extracted acetone (ml)

Vs : Volume of water sample (L)

2.4 Data analysis Methods

1. Verification of satellite imagery and in-situ data

Insitu verification is used to ensure the accuracy and reliability of satellite data in analyzing potential fishing areas, particularly the parameters in this study, which are Sea Surface Temperature (SST) and chlorophyll-a concentration.

$$\left[\frac{Xinsitu - Ximagery\ x\ 100\%}{n}\right]$$

Explanation:

RE : Relative Error

X_{insitu} : Field measurement data

$X_{imagery}$: Satellite imagery data

N : Number of data points

2. Correlation Analysis of Sea Surface Temperature (SST) and Chlorophyll-a

The correlation analysis between Sea Surface Temperature (SST) and chlorophyll-a with fish catch aims to understand how environmental conditions affect fishery productivity. According to Sari et al. (2019), the correlation analysis equation is written as follows:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{\{(n\sum x^2) - (\sum x)^2\}\{(n\sum y^2) - (\sum y)^2\}}}$$

Explanation :

r : Correlation between chlorophyll-a and SST with catch results

x : Independent variable (SST and chlorophyll-a)

y : Dependent variable (Catch results)

The relationship between variables is compared with the intervals available in the following table:

Table 1 – Variable relationships based on coefficient intervals

No.	Coefficient Intervals	Levels of Relationship
1.	0,900 - 1,000	Very high
2.	0,700 - 0,900	High
3.	0,500 - 0,700	Moderate
4.	0,300 - 0,500	Low
5.	0,000 - 0,300	Very Low

Sumber: (Fitri *et al*., 2023)

3. Results and Discussion

3.1 State of research location

Pemalang Regency is located between 6° 55' - 7° 20' South Latitude (LS) and 109° 17’ - 109º 45' East Longitude (BT). Geographically, Pemalang Regency is quite strategic as it is situated on the northern coast, directly bordering the Java Sea. Pemalang Regency has one Coastal Fisheries Port, PPP Asemdoyong, and four Fish Landing Sites (TPI): TPI Mojo, TPI Ketapang, TPI Tasikrejo, and TPI Tanjungsari. PPP Asemdoyong, being the only fisheries port in Pemalang Regency, plays a central role in supporting the economic activities and welfare of the local fishing community. According to Karningsih et al. (2014), PPP Asemdoyong, located on the north coast, is known as a good fishing industry area due to the freshness and quality of its fish.

3.2 Total production and production value of PPP Asemdoyong

Total production and production value of PPP Asemdoyong: Fisheries production is the total amount of fish caught from certain waters within a region or location. The value of fisheries production can be measured economically by analyzing the revenue generated from the sale of fish catch or aquaculture. Based on data from PPP Asemdoyong in Pemalang Regency, the total production and production value of fisheries from 2019 - 2023 are as follows:

Table 2 – Fisheries production and production value

No.	Production (kg)	Production Value (Rp)
2019	44.820.699	389.258.111.131
2020	12.338.282	107.155.322.727
2021	15.359.902	133.397.442.579
2022	22.158.548	192.442.212.245
2023	25.180.168	218.684.332.096

Source: PPP Asemdoyong, 2024

Based on Table 2, it is known that the total production and production value at the Coastal Fisheries Port (PPP) Asemdoyong have fluctuated over the past five years. The highest production and production value were in 2019, while the lowest were in 2020.

3.3 Distribution of SST and chlorophyll-a in Pemalang Waters

The distribution pattern of Sea Surface Temperature (SST) has a significant impact on potential fishing areas. Optimal water temperature is one of the key factors affecting the distribution, migration, and abundance of fish. Meanwhile, chlorophyll-a is a photosynthetic pigment found in phytoplankton, microscopic organisms that form the base of the marine food chain. Chlorophyll-a significantly affects potential fishing areas as it is a primary indicator of oceanic primary productivity. Changes in chlorophyll-a concentration can reflect variations in marine productivity and affect fish distribution. Below is the data on sea surface temperature and chlorophyll-a concentration obtained from KM. Sukses fishing operations in Pemalang Waters, presented in Table 2:

Table 3 – Distribution of SST and chlorophyll-a in Pemalang Waters

Statiun	Sea Surface Temperature (°C)	Chlorophyll-a (mg/m^3)
1	30,2	1,68
2	30,4	1,14
3	30,6	0,32
4	30,6	0,40
5	30,5	0,43
6	29,8	0,45
7	29,8	0,48

3.4 Data verification

Verifying imagery data is crucial to ensure the accuracy and reliability of information obtained through remote sensing. This comparison helps identify and correct potential inaccuracies in the imagery data, such as cloud cover effects or calibration errors. Below is the table for in-situ data verification of sea surface temperature and chlorophyll-a with Aqua-MODIS satellite imagery data:

Table 4 – Verification of sea surface temperature and chlorophyll-a data values

Statiun	Insitu CHL (mg/m^3)	Imagery CHL (mg/m^3)	Error Value CHL (%)	Insitu SST (°C)	SST Imagery (°C)	Error Value SPL (%)
1	1,68	2,10	5,92	30,2	30,70	7,14
2	1,14	2,95	25,86	30,4	30,75	5,00
3	0,32	0,85	7,44	30,6	30,85	3,57
4	0,40	0,70	4,21	30,6	30,80	2,86
5	0,43	0,85	5,91	30,5	30,90	5,71
6	0,45	0,95	7,06	29,8	30,85	15,00
7	0,47	0,95	6,73	29,8	30,85	15,00
Mean Relatives Error			9,01			7,76

The results show that the highest error rate in SST data is found at stations 6 and 7 with a value of 15%, and the lowest is at station 4 with a value of 2.86%. The highest error in chlorophyll data is at station 2 with 25.78% and the lowest at station 4 with 4.21%. These differences are due to the time differences between satellite image recordings and field data collection, which can affect chlorophyll-a concentration results. This is supported by Zakiyah et al. (2019), who state that the differences in concentration values between imagery and in-situ data can be caused by the time gap between image recordings and water sample collection, and conditions such as thin cloud cover and remaining geometric errors in the field.

The verification results also show the relative error correction values with an average mean relative error (MRE) percentage of 7.76% for SST data and 9.01% for chlorophyll-a. According to Sukojo and Ariandi (2019), the closer the MRE value is to zero, the better the imagery correction. This value is expressed as a percentage, indicating the average relative error between values predicted by satellite imagery and actual field-measured values.

3.5.Relationship of SST, chlorophyll-a, and anchovy

Relationship of SST, Chlorophyll-a, and Anchovy: The relationship between Sea Surface Temperature (SST) and chlorophyll-a concentration with fish catch is very significant in the marine ecosystem. The interaction between SST and chlorophyll-a creates conditions that determine fish abundance in an area. Optimal SST can support high chlorophyll-a concentrations by allowing the mixing of nutrients from the lower layers to the surface, increasing phytoplankton productivity. When both parameters are in ideal conditions, the chances of achieving higher fish catch rates significantly increase.

Below is the graph of the relationship between the distribution of sea surface temperature and chlorophyll-a with anchovy catch by KM. Sukses in Pemalang Waters, Central Java, presented in the image below:

Fig 1 – Relationship between Sea Surface Temperature and Anchovy (*Stolephorus* sp)

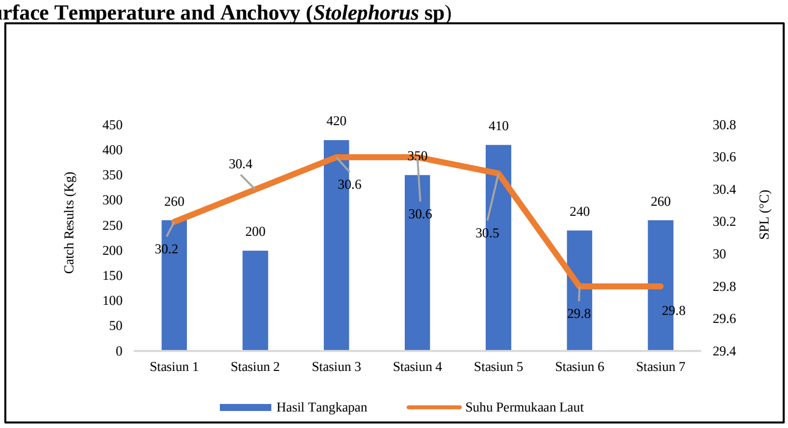
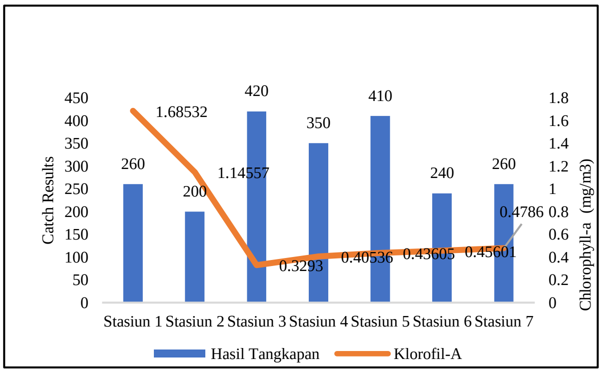


Fig 2 – Relationship between Chlorophyll-a and Anchovy (*Stolephorus* sp)



Based on Figure 1, the results show that SST reached its highest values at stations 3 and 4 with temperatures of 30.6 °C, resulting in catches of 420 kg and 350 kg, respectively. The lowest SST was at stations 6 and 7 with temperatures of 29.8 °C, yielding catches of 240 kg and 260 kg. Sea surface temperature tends to have a positive relationship with fish catch; when the temperature is optimal, the fish catch tends to increase, and when it is not optimal, the fish catch tends to decrease. Generally, anchovies prefer relatively warm waters, which support their metabolic rate and increase food availability. This is supported by Gamawan (2018), who stated that anchovies (Stolephorus sp) tend to congregate at temperatures between 29°C and 30°C. Another opinion by Gunarso (1985) suggests that anchovies prefer temperatures between 26°C and 32°C. Hafiz et al. (2017) found that the habitat temperature for small pelagic fish, especially anchovies, ranges between 29°C and 30°C. Higher temperatures increase the metabolic activity of fish, making them more active in searching for food. Additionally, warm temperatures usually enhance plankton production, which is the primary food source for small fish like anchovies.

Based on Figure 2, the results show that the highest chlorophyll-a value was at station 1, with a value of 1.68 mg/m³ and a catch of 260 kg, while the lowest chlorophyll-a value was at 0.32 mg/m³, with a catch of 420 kg. The results indicate that some points have low and uniform concentrations, while others have relatively high concentrations. The difference in chlorophyll-a concentration values in Pemalang Waters is closely related to the abundance of phytoplankton, where chlorophyll-a is a pigment found in phytoplankton cells, causing the chlorophyll-a distribution to follow the phytoplankton pattern itself. The concentration of chlorophyll-a in relation to anchovy catches indicates that the increase in chlorophyll-a values does not have a significant impact on catch increases. Many factors contribute to this, one being the anchovy food chain process that takes time, with phytoplankton as the primary producers in the food chain. Kuswanto et al. (2017) suggest that this may be due to a time lag in the food chain. When phytoplankton increases in the waters, the impact is not immediately reflected in the increase in anchovy numbers. The anchovy food chain process involves several trophic levels, with phytoplankton as the first trophic level being eaten by zooplankton as the second trophic level, and zooplankton being eaten by anchovies as secondary consumers or the third trophic level. This is reinforced by Gamawan (2018), who states that the abundance of phytoplankton and zooplankton forms the primary food chain for anchovies.

4. Data analysis

4.1 Normality test

The normality test in this study examines whether the residuals from the regression model linking anchovy catches with sea surface temperature and chlorophyll-a are normally distributed. Below is the table of normality test results using the Kolmogorov-Smirnov method:

Table 5 - Normality Test

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized Residual
N		7
Normal Parameters[a,b]	Mean	0.0000000
	Std. Deviation	49.19832975
Most Extreme Differences	Absolute	0.166
	Positive	0.149
	Negative	-0.166
Test Statistic		0.166
Asymp. Sig. (2-tailed)		0.200[c,d]

The Kolmogorov-Smirnov test is used to check the significance or probability value > 0.05, indicating that the data is normally distributed. The result shows that the Asymp. Sig. (2-tailed) value is 0.200, which means that the sea surface temperature, chlorophyll-a, and anchovy catch data are normally distributed.

4.2 Heteroscedasticity test

The heteroscedasticity test examines whether the residual variance remains constant across the range of SST and chlorophyll-a values. Identifying heteroscedasticity is crucial because non-constant residual variance can lead to biased standard errors and inefficient parameter estimates. Below is the heteroscedasticity test using the Glejser test method:

Table 6 – Heteroscedasticity Test

Coefficients [a]						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	1256.302	652.518		-1.925	0.126
	Sea Surface Temperature	41.996	21.528	0.556	1.951	0.123
	Chlorophyll-a	33.268	14.715	0.645	2.261	0.087

Based on the table above, it is known that the Sig value for sea surface temperature is 0.123 and the Sig value for chlorophyll-a is 0.087. The requirement for data to be considered free from heteroscedasticity is if the Sig value is > 0.05. It can be concluded that the Sig values for both sea surface temperature and chlorophyll-a meet this requirement, being greater than 0.05.

4.3 Multicollinearity test

The multicollinearity test is conducted to ensure there are no strong linear relationships between the independent variables, which are SST and chlorophyll-a. Below are the results of the multicollinearity test using SPSS software:

Table 7 – Multicollinearity Test

Coefficients [a]			
		Collinearity Statistics	
Model		Tolerance	VIF
1	Sea Surface Temperature	0.995	1.005
	Chlorophyll-a	0.995	1.005

Based on the table above, the tolerance value between sea surface temperature and chlorophyll-a for anchovy catches is 0.995, which is above the tolerance value threshold of greater than 0.10. The VIF value obtained is 1.005, which is below 10, thus proving that there is no multicollinearity between the independent variables and the regression model.

4.4. Multiple linear regression analysis and correlation analysis

The multiple linear regression model can identify and measure more complex linear relationships between SST, chlorophyll-a, and anchovy catches. Below are the multiple linear regression test results using SPSS software:

Table 8 – Multiple linear regression

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.825[a]	0.681	0.522	60.25540

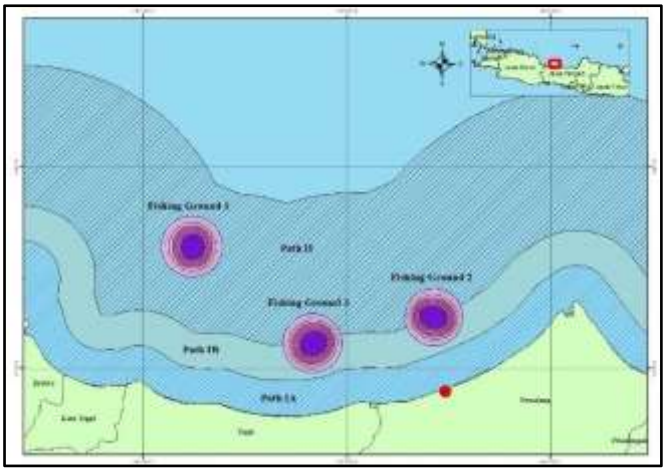
Table 9 – Correlation analysis

Correlations				
		Sea Surface Temperature	Chlorophyll-a	Catch Results
Sea Surface Temperature	Pearson Correlation	1	-0.068	0.646
	Sig. (2-tailed)		0.885	0.117
	N	7	7	7
Chlorophyll-a	Pearson Correlation	-0.068	1	-0.556
	Sig. (2-tailed)	0.885		0.194
	N	7	7	7
Catch Results	Pearson Correlation	0.646	-0.556	1
	Sig. (2-tailed)	0.117	0.194	
	N	7	7	7

Based on Table 8, the R-squared coefficient of determination obtained in the multiple regression test is 0.681. This means that 68.1% of the variance in anchovy catch (Y) can be explained by the sea surface temperature and chlorophyll-a variables (X1, X2), while the remaining 31.9% is influenced by other factors not included in the regression model. Some other factors suspected of influencing the catch include water depth, currents, and salinity.

From Table 9, the correlation coefficient value of sea surface temperature with anchovy catch is 0.646, indicating a strong relationship. The positive sign indicates a direct relationship between the two variables—an increase in one variable is followed by an increase in the other. In contrast, the correlation coefficient value of chlorophyll-a with anchovy catch is -0.556. This negative value indicates an inverse relationship between chlorophyll-a concentration and catch results. When the chlorophyll-a concentration increases, the anchovy catch does not correspondingly increase, likely due to the time lag in the food chain process where phytoplankton, the primary producer, serves as the food source for zooplankton and small pelagic fish like anchovies.

Fig 3 – Potential Fishing Zone Anvchovy in Pemalang Waters



Potential fishing ground maps are created based on three indicators: the number of fish catches, the distribution of sea surface temperature, and the concentration of chlorophyll in the Pemalang Waters. The map identifies three potential anchovy (Stolephorus sp) fishing spots, determined through the correlation of in-situ data and AQUA-Modis satellite imagery data. The results show that the potential fishing areas are at coordinates: 6°73'96.44" S and 109°20'72.54" E at Track II with a depth of 24 meters, 6°78'99.21" S and 109°39'44.36" E at Track II with a depth of 9 meters, 6°79'47.86" S and 109°41'11.75" E at Track IB with a depth of 12 meters. These points have chlorophyll-a concentrations ranging from 0.3 – 1.68 mg/m³. The potential fishing areas have sea surface temperatures ranging from 29.5 °C – 31 °C, suitable for anchovies. These spots are likely to be optimal fishing areas where anchovies tend to gather in groups. According to Sitorus et al. (2022), the determination of potential points is based on the contour distribution of chlorophyll-a and SST, which are interrelated. The intersection points between the contours generated by SST and the distribution of chlorophyll-a are likely good fishing grounds for small pelagic fisheries.

5. Conclusion

The conclution that can be drawn from this research are as follows:

1. The sea surface temperature distribution pattern in Pemalang Waters, Central Java, in July 2024, ranges from 29.8°C to 30.6°C, while chlorophyll-a ranges from 0.32 mg/m³ to 1.68 mg/m³. The obtained temperature and chlorophyll-a levels are influenced by factors such as land currents, waves, upwelling, and other factors.
2. There is a strong correlation between sea surface temperature and chlorophyll-a with anchovy catches, indicated by a correlation coefficient of 0.681. The R-squared value suggests that 68.1% of anchovy catch variations are jointly influenced by chlorophyll-a and SST, with the remaining 31.9% influenced by other unobserved factors.
3. The estimation of potential anchovy fishing areas in Pemalang Waters identified three points: at 6° 73' 96.44" S and 109° 20' 72.54" E in Track II with a depth of 24 meters; at 6° 78' 99.21" S and 109° 39' 44.36" E in Track II with a depth of 9 meters; and at 6° 79' 47.86" S and 109° 41' 11.75" E in Track IB with a depth of 12 meters.

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