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Skipjack Tuna Fishing Grounds Based on Sea Surface Temperature and Chlorophyll-a in Sukabumi Waters, Indonesia

Dara Luminda Nafri [a], Hendrik Anggi Setyawan[a], Bambang Argo Wibowo [a], Bogi Budi Jayanto[a]*

[a] *Department of Capture Fisheries, Faculty of Fisheries and Marine Science, Universitas Diponegoro, Jl. Prof. Jacub Rais, Tembalang, Semarang, Indonesia 50275*

A B S T R A C T

Skipjack tuna (Katsuwonus pelamis) fishing operations based in Archipelago Fishing Port (PPN) Palabuhanratu are still not effective and efficient. This is because the determination of fishing grounds still uses the experience and instincts of fishermen. The purpose of this study was to analyze the distribution of sea surface temperature and chlorophyll-a, and the relationship of these two parameters to skipjack fish catch. The research method used is the descriptive method. The data analysis method uses multiple linear regression analysis and Pearson correlation analysis. Sea surface temperature and chlorophyll-a data were obtained from Aqua MODIS satellite image data, and skipjack tuna catch data was obtained from PPN Palabuhanratu from 2019 – 2023. The result was sea surface temperature and chlorophyll-a together affected the total catch by 0.709 (70.9%). Analysis of the correlation between sea surface temperature and skipjack tuna was 0.824 (82.4%), while the correlation between chlorophyll-a and catch was 0.33 (33%).

Keywords: Aqua MODIS, Corellation, PPN Palabuhanratu.

1. Introduction

Sukabumi waters which are included in Fisheries Management Area (WPP) 573 have the potential for abundant and diverse fish resources. One of the catches that dominates Sukabumi waters is skipjack tuna (*Katsuwonus pelamis*). According to the Fishery Port Information Center (2023), the highest fish production and landing results found in Sukabumi Waters are large pelagic fish groups, with a total skipjack tuna production of 1,174,026 kg (28.9% of total fish production in 2022). In general, fishermen in Sukabumi Regency determine fishing grounds traditionally by looking at differences in water color, and water ripples, or based on experience alone. This results in the effectiveness and efficiency of fishing operations being reduced with the amount of time, cost, and effort spent.

The fishing gear that is usually used to catch skipjack fish is a seine net. Pelagic fishing using seine net is carried out in areas where there is shoaling fish. Pelagic fish that are the target of catch can usually be found in areas where there is upwelling, convergence, and divergence. The location is a place of plankton abundance, has a salinity of about 34 PSU, and an optimum temperature for pelagic fish (Pratama et al., 2022).

The determination of good fishing grounds by fishermen often still uses traditional and simple methods. The lack of information management regarding fishing grounds causes less effective fishing activities in Sukabumi Waters. With the help of remote sensing technology, fishing grounds can be predicted using satellite imagery data. The purpose of this study is to analyze the relationship between sea surface temperature and chlorophyll-a on skipjack tuna catch, as well as to analyze the potential fishing area of skipjack tuna in Sukabumi Waters.

2. Research method

This study consists of primary data and secondary data. The primary data used are sea surface temperature data, chlorophyll-a concentrations, and catches of Skipjack tuna (*Katsuwonus pelamis*) on August 15-20, 2023 in Sukabumi Waters using rice fishing gear. Secondary data are sea surface temperature and chlorophyll-a image data for August 2019-2023 and statistical data on the catch of Skipjack tuna (*Katsuwonus pelamis*) for 2018-2022.

2.1 Data retrieval methods

Primary data taken in the form of SST (Sea Surface Temperature) was obtained using a thermometer, chlorophyll-a was obtained by taking sample water using a sample bottle and laboratory testing, as well as catches and coordinates of fishing locations at the time of fishing activities, with a total of 7 sample collection locations following the fishing path traversed by ships. This method is called the purposive sampling method of data collection. According to Suriani et al. (2023), this is a technique used in determining samples with certain considerations, so that it is expected to represent the entire population.

Consideration is intended so that each sampling point can represent the entire catchment area. The data used and processed is in the form of monthly data for 2019 – 2023. Collecting data on sea surface temperature and chlorophyll-a through the https://oceancolor.gsfc.nasa.gov/.

2.2 Data analysis method

Aqua MODIS satellite imagery data obtained must first be verified with in-situ data so that the data obtained becomes more accurate. This is also done to find out whether the image data used is feasible or not. According to Sari et al. (2019), the step taken for verification is to correct relative errors. Relative error correction using the formula:

RE $= [(Xinsitu - Ximagery\ X\ 100\%)/n]$

MRE $= \text{M} \sum_0^n \left[\frac{RE}{E}\right]$

Information :

RE = Relative Error

MRE = Mean Relative Error

X_{insitu} = Field measurement data

$X_{imagery}$ = Data obtained from satellite imagery

N = Amount of data

To determine the relationship between sea surface temperature variables and chlorophyll-a to catches, multiple linear regression analysis was carried out. Sea surface temperature and chlorophyll-a as independent variables, while skipjack fish catches as dependent variables. (Billy, 2022), the regression model used is as follows:

$Y = \alpha + \beta_0 + \beta_1 X_1 + \beta_2 X_2$ (3.5)

Information:

Y = Dependent variable (Skipjack tuna catches)

X = Independent variable (sea surface temperature and chlorophyll-a)

α = Constanta

Correlation analysis is used to determine the relationship between dependent variables and independent variables partially. According to Muhidin (2011), the correlation analysis equation is written as follows:

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

Information:

r = Correlation between chlorophyll-a and sst to catch

x = Independent variable (sea surface temperature and chlorophyll-a)

y = Dependent variable (Skipjack tuna catches)

3. Result and discussion

3.1 State of research location

Sukabumi Regency has a coastline of 117 km which is one of the districts that has the longest beach length in West Java. Fisheries activities in Sukabumi Regency are centered on PPN Palabuhanratu. According to the Fishery Port Information Center (2023), the potential of fish resources in Palabuhanratu is quite diverse, including pelagic fish, demersal, shrimp, and other marine biota.

Fig. 1 – Map of Sukabumi Regency

Source: Peta Tematik Indonesia

3.2 Total production and production value of PPN Palabuhanratu

The amount of production and the value of fisheries production indicate the picture of fisheries potential in an area. The amount and value of fisheries production in PPN Palabuhanratu can be seen in Table 1.

Table 1 – Fisheries production and production value

Year	**Production (kg)**	**Production Value (IDR)**
2018	8,324,065	171,587,604,500
2019	10,026,610	225,432,269,250
2020	9,952,252	227,438,539,684
2021	15,609,536	295,773,998,500
2022	4,179,149	75,733,440,500

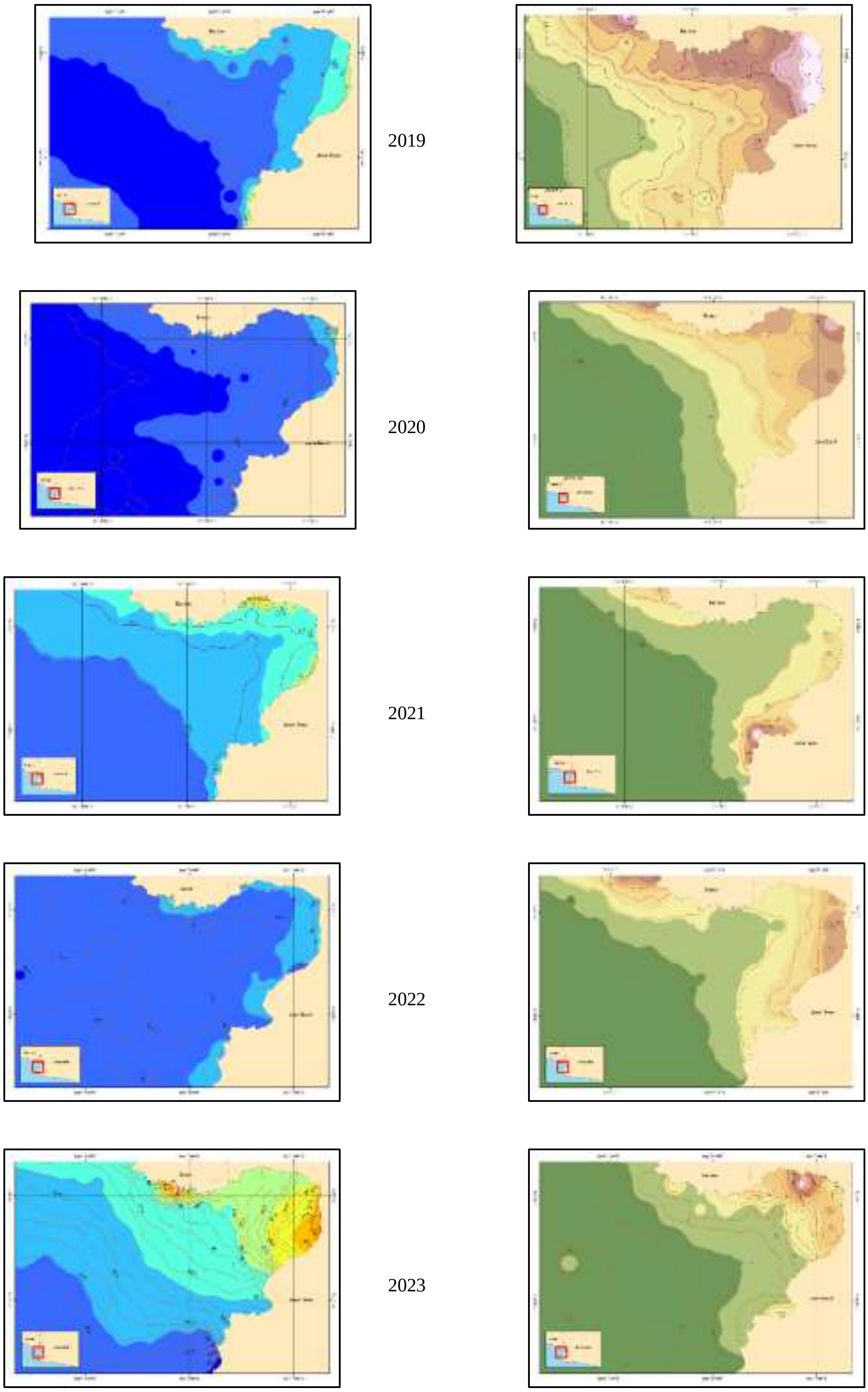
Source: PPN Palabuhanratu, 2023

Based on production data and fisheries production value in PPN Palabuhanratu, the amount of production and production value fluctuates. The highest number and value of production occurred in 2021, and then in 2022 experienced a considerable decline. Factors influencing such changes are climate change and fishing seasons.

3.3 Distribution of SST and chlorophyll-a in Sukabumi Waters

Surface temperature is generally influenced by various factors, namely solar radiation, surface current movements, cloud conditions, and other processes. Sea surface temperatures fluctuate periodically in line with natural factors that affect the condition of these waters. One of the factors that affect the distribution of sea surface temperatures in Indonesian waters is monsoon winds (Daeng & Tangke, 2023). Falih et al. (2022), the temperature will affect metabolic processes, body movement activity, and function as a nerve stimulus for pelagic fish. The distribution of sea surface temperatures found in Sukabumi waters can be seen in the Fig. 2.

Hastuti et al. (2021), chlorophyll-a is one of the most common pigments found in phytoplankton. Chlorophyll-a has an important role in photosynthesis and is an important element in marine ecosystems. The level of fish abundance is also closely related to the availability of food sources in the waters. The concentration of chlorophyll-a, which is often used as an indicator of the presence of phytoplankton, is very influential in producing substances that support fish life. Natsir et al. (2020), the spread of significant chlorophyll concentrations in nearshore waters is caused by an increase in nutrient intake originating from land through river flows. The input of nutrients from land through river runoff can transport nutrients that enter coastal waters. However, in some locations of offshore waters, high concentrations of chlorophyll can still be found.



(a) (b)

Fig. 2 – Distribution of Sea Surface Temperature (a) and Chlorophyll-a (b) in Sukabumi Waters

3.4 Data verification

To determine the value of data error, it is necessary to verify satellite data with field data. Data from 7 sampling points were measured sea surface temperature and chlorophyll-a. The results of verifying sea surface temperature values and chlorophyll-a can be seen in Table 2.

Table 2 – Verification of sea surface temperature and chlorophyll-a data values

Sampling Point	SST insitu (ºC)	SST satellite (ºC)	Nilai Error SST (%)	Chlor-a insitu (mg/m³)	Chlor-a satellite (mg/m³)	Nilai Error Chlor-a
1	25.8	26.2	0.05	2.680	2.996	0.04
2	25.2	26.4	0.17	5.612	2.807	0.40
3	25.3	26.2	0.12	3.343	2.747	0.08
4	25.5	26.7	0.17	0.713	3.832	0.44
5	24.1	26.8	0.38	0.402	4.1462	0.53
6	26.3	26.8	0.07	0.569	4.152	0.51
7	26.7	26.8	0.01	0.348	4.240	0.55
Mean Relative Error			**0.14**	***Mean Relative Error***		**0.22**

Based on Table 2, it can be noted that the in-situ verification value of sea surface temperature and chlorophyll-a data against Aqua MODIS satellite image data has a small error value. The error value of the data obtained is included in the category suitable for use in further data processing. According to Angga et al. (2015), an average relative error of less than 30% is a limit that can be used for further analysis. According to Pristiwan et al. (2015), the accuracy test is not absolutely 100% because it is caused by factors such as the difference in in-situ data retrieval time with image recording time, and cloud cover contained in satellite images.

3.5 Relationship of sst, chlorophyll-a, and skipjack tuna

The following is a graph of the relationship between sea surface temperature and the monthly catch of Skipjack tuna (*Katsuwonus pelamis*) in Sukabumi waters in 2020-2022.

Fig 3 – Relationship between Sea Surface Temperature and Skipjack Tuna (*K. pelamis)*

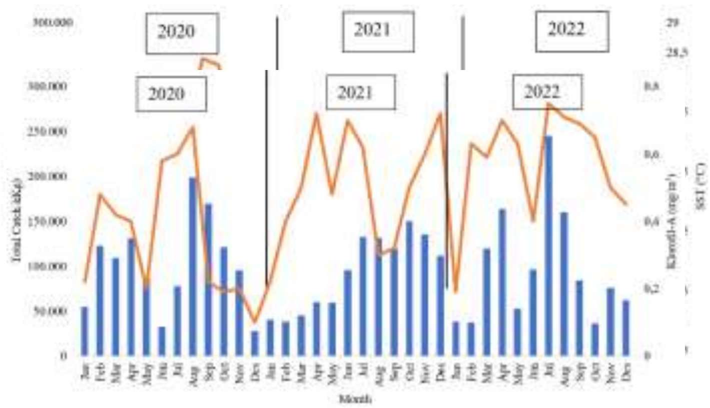


Fig 4 – Relationship between Chlorophyll-a and Skipjack Tuna (*K. pelamis)*

Figure 3. shows a data graph illustrating the correlation between sea surface temperatures and skipjack in Sukabumi waters for the period 2020 – 2022. Based on the graph, the highest skipjack catch occurs at sea surface temperatures ranging from 25 – 28oC. temperatures range from 25°C to 28°C (eastern season). Habib et al. (2019), skipjack tuna (*Katsuwonus pelamis*) can be found in open water with a sea surface temperature range between 27.0°C to 30.0°C with the optimum temperature in the range of 20.0°C to 28.0°C. Sea surface temperature can be used as an indicator to estimate the presence of organisms in an area of water, especially fish because most organisms tend to adapt to changes in the temperature of their environment. The level of sea surface temperature in a body of water is mainly influenced by exposure to solar radiation. Yogiswara & Sutrisna (2021), the fishing season in Indonesia occurs from April to November, this is because during this period the waters in Indonesia tend to be stable due to the influence of east winds that bring warm and dry air. This makes fish migrate to Indonesian waters in search of food. increase the catch. According to Pratama et al. (2022), sea surface temperature is an important indicator to find out clues about how fish metabolism functions in a water area. Temperature changes that are too low can result in a slowdown in fish metabolism and therefore fish growth becomes inhibited. On the other hand, temperature changes that are too high can reduce the availability of dissolved oxygen trigger stress in fish, and can even cause death in fish.

Based on Figure 4, April and July in Sukabumi waters have higher concentrations of chlorophyll-a than other months. The high concentration of chlorophyll-a results in high skipjack fish production as well. This shows that the availability of abundant food sources greatly affects the catch of fish obtained by fishermen. (Suhendar et al., 2020) chlorophyll-a concentration is the main indicator for estimating primary productivity and is an important variable in the process of photosynthesis. The concentration of chlorophyll-a in a body of water depends largely on the level of sunlight present. (Zikri et al., 2023), The primary source of food for small pelagic fish, phytoplankton, can be detected by measuring the amount of chlorophyll-a in the water. Fish are drawn to areas with high levels of chlorophyll-a because they are rich in phytoplankton, which signals favorable circumstances for them to thrive. Fish prefer to congregate and engage in more activities in areas where food sources are abundant, providing fishermen with the chance to catch more fish.

The catch of Skipjack tuna (*Katsuwonus pelamis*) in the eastern season always gets high yields, with chlorophyll-a concentration values ranging from 0.19 - 0.72 mg/m^3. The concentration level and presence of chlorophyll-a greatly affect the catch of Skipjack tuna, but increasing the catch takes time due to the food chain process with phytoplankton as food chain producers and used as a food source by zooplankton. Hatta et al. (2022), pelagic fish populations are closely related to chlorophyll-a and plankton abundance, this is because phytoplankton is the main producer that has an important role in determining the supporting capacity in the food chain for pelagic fish. In addition to the abundance of plankton, environmental parameters also have a significant impact on the number and presence of various types of pelagic fish. However, an increase in chlorophyll-a concentration is not always directly proportional to an increase in catch, this is due to the zooplankton predation process against phytoplankton. The increasing population of phytoplankton as a food source triggers the growth of zooplankton so that the zooplankton population increases. As zooplankton populations increase, the rate of predation on phytoplankton by zooplankton increases so that phytoplankton populations decrease. Yuniarti et al. (2022) stated that chlorophyll-a concentration is one of the important indicators in the process of photosynthesis by phytoplankton, and can serve as a main indicator to measure the primary productivity of water. The concentration of chlorophyll-a can be influenced by the season, in the rainy season the concentration of chlorophyll-a ranges from 0.0161 to 0.0277 mg / l, with an average value of about 0.022 mg / l. While in summer chlorophyll-a concentrations increased ranging from 0.72 to 2.82 mg / l with an average concentration of about 1.578 mg / l.

4. Data analysis

4.1 Normality test

Sea surface temperature and chlorophyll-a concentrations represent several parameters that have a significant impact on catches. To determine the relationship between independent variables and dependent variables, multiple linear regression analysis is needed. One of the conditions for performing multiple linear regression analysis is that the data must be normally distributed. The data normality test table using the Kolmogorov-Smirnov method can be seen in Table 3.

Table 3 - Normality Test

		Unstandardized Residual
N		7
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	42.52547577
Most Extreme Difference	Absolute	.214
	Positive	.214
	Negative	-.172
Test Statistic		.214
Asymp. Sig. (2-tailed)		.200c,d

The data can be said to be normally distributed if the Sig value > 0.05. In the normality test that has been carried out, the result of the Sig value of 0.200 which indicates that the data on sea surface temperature, chlorophyll-a, and Skipjack fish catches are normally distributed.

4.2 Heteroscedasticity test

The heteroscedasticity test is used when there is a mismatch between one observation and another. The heteroscedasticity test in this study used the Glejser Test. The results of the heteroscedasticity test can be seen in Table 4.

Table 4 - Heteroscedasticity Test

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-376.777	386.575		-.975	.385
	Chlorophyll_a	3.169	6.273	.227	.505	.640
	SST	15.655	15.017	.467	1.043	.356

Based on Table 4. It is known that the Sig value for sea surface temperature is 0.356 and the Sig value for chlorophyll-a is 0.640. The requirement of data can be said to be that heteroscedasticity does not occur, namely if the Sig value > 0.05. It can be concluded that the Sig value between the sea surface temperature variable and chlorophyll-a meets the requirement of more than 0.05. According to Faustyna and Jumani (2015), the Heteroscedasticity Test aims to find out in a regression there is a similarity in residual variance, if the observed variance remains then it is called homoscedasticity, and if it is different it is called heteroscedasticity, and a good model certainly does not occur heteroscedasticity.

4.3 Multicollinearity test

The multicollinearity test between sea surface temperature parameters and chlorophyll-a on skipjack tuna catches can be seen in Table 5.

Table 5 – Multicollinearity Test

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	-1460.132	664.661		-2.197	.093		
	Chlorophyll_a	-7.015	10.785	-.179	-.650	.551	.960	1.041
	SST	73.940	25.819	.786	2.864	.046	.960	1.041

Based on Table 5. The tolerance value between sea surface temperature and chlorophyll-a for the catch of Skipjack fish is 0.960. This value is above the tolerance value, which is greater than 0.10. The VIF value obtained is 1,041. This value is below 10 so this can prove that the data used does not occur multicollinearity between the independent variable and the regression model. Helmiawan et al. (2019), the multicollinearity Test aims to test whether the regression model found a correlation between one or all independent variables. A good regression model should not have correlations among independent variables or be multicellular.

4.4 Multiple linear regression analysis and correlation analysis

The results of multiple linear regression analysis in this study can be seen in Table 6.

Table 6 – Multiple linear regression

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.842[a]	.709	.564	52.08286

a. Predictors: (Constant), SST, Clorophyll_A

The results of the correlation analysis between sea surface temperature and chlorophyll-a on the catch of skipjack tuna can be seen in Table 7.

Table 7 – Correlation analysis

		Chlorophyll_a	SST	Catch
Chlorophyll_a	Pearson Correlation	1	-.199	-.336
	Sig. (2-tailed)		.669	.461
	N	7	7	7
SST	Pearson Correlation	-.199	1	.824*
	Sig. (2-tailed)	.669		.023
	N	7	7	7
Catch	Pearson Correlation	-.336	.824*	1
	Sig. (2-tailed)	.461	.023	
	N	7	7	7

*. Correlation is significant at the 0.05 level (2-tailed)

Based on Table 6. It is known that the coefficient of determination (R^2) is 0.709 which indicates that 70.9% of the catch is affected by sea surface temperature and chlorophyll-a. The value of the coefficient of determination obtained is included in the strong category. Machmud & Yuningsih (2021) the value of the correlation coefficient included in the category of strong relationships has an interval of 0.600 to 0.799 and for significant testing, the results are obtained that sig less than 0.05 eats H_0 is rejected, which means that there is a significant positive relationship between the dependent variable and the independent variable.

Based on Table 7. It is known the results of the above correlation analysis between sea surface temperature and chlorophyll-a on the catch of Skipjack fish. Sea surface temperature and chlorophyll-a have a relationship with Skipjack fish catches. The correlation of chlorophyll-a was -0.336 or 33% which showed that chlorophyll-a had a moderate influence on the catch of skipjack fish. The correlation value of sea surface temperature obtained is 0.824 or 82.4% which shows that sea surface temperature has a considerable influence on the catch of skipjack fish. A negative value in the chlorophyll-a variable indicates that the relationship of chlorophyll-a to catch is inversely proportional. When chlorophyll-a concentration levels increase, the amount of catch does not go hand in hand as well, this is because the food chain process takes time with phytoplankton as food chain producers and used as food sources by zooplankton and small pelagic fish. Other factors such as sea surface temperature which has the same correlation when the value of sea surface temperature rises, the number of catches also increases, this shows that sea surface temperature is an important parameter to determine the potential fishing area of Skipjack. Simbolon (2010), the optimum temperature for skipjack fishing in Indonesian waters ranges from 28°C-29°C although the optimum temperature sometimes varies according to temporal and spatial changes. This shows that the temperature of the waters affects the distribution of fish, and of course will affect the catch. However, the number of skipjack catches is not only influenced by water temperature but also influenced by the condition of other oceanographic parameters such as currents, salinity, and chlorophy-a content, and is influenced by technical factors of fishing operations. Potential fishing zone

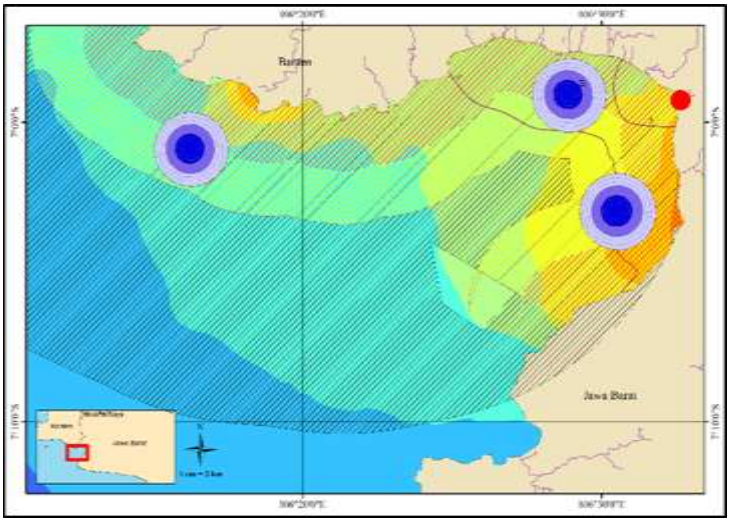


Fig 5 – Potential Fishing Zone Skipjack Tuna in Sukabumi Waters

It can be seen on the map image the distribution of known sea surface temperatures with blue to red gradient colors showing low to high-temperature information. The average distribution of sea surface temperatures in August 2023 in Sukabumi waters ranges from 24.13°C to 28.85°C, which is the optimum temperature for Skipjack tuna. The average value of chlorophyll-a concentration is around the value of 1.62 mg / m^3. According to (Herawaty et al., 2020) which states that the ideal temperature for Skipjack tuna is between 26-32°C, and the ideal temperature for spawning is between 28-29°C. While not the skipjack fishing season occurs in January, February, March, April, May, July, and December allegedly due to the availability of feeding, temperature, and other parameters that are not favorable for the migration of skipjack fish.

Skipjack fishing potential area in the waters of Sukabumi Regency using seine net, namely with coordinate points in potential area 1, namely 106°16'12.801" E 7°0'51.286" S. The second potential fishing area is located at 106°28'52.1"E 6°59'2.949" S. The third fishing potential area is located at 106°30'31.466" E 7°2'58.516" S. The first point of the fishing potential area has a sea surface temperature of 25.95°C and a chlorophyll-a concentration value of 2.227 mg/m^3. The second point of the fishing potential area has a sea surface temperature of 26.46°C and a chlorophyll-a concentration value of 1,800 mg/m^3. The third point of the fishing potential area has a sea surface temperature of 27.28°C and a chlorophyll-a concentration value of 4,920 mg/m3. Determination of fishing potential areas is required to know the characteristics of the fish that are the target of catch. Knowledge of the oceanographic parameters of fish is very important to maximize the process and catch. The value of sea surface temperature and chlorophyll-a concentration values in the three potential areas are areas that meet the requirements of oceanographic parameters indicated to be preferred or become the habitat of skipjack fish. The location of the potential fishing area is 1-2 nautical miles and is in lines 1A and 1B, namely from the coastline of 2 nautical miles to 4 miles with a depth of 10-20 meters. Safruddin et al. (2020),offshore locations where sea surface temperatures range from 29 to 29.9 °C and chlorophyll-a levels range from 0.10 to 0.15 mg/m^3 are preferred by skipjack tuna.

5. Conclusion

The conclusion that can be drawn is that there is a strong influence between sea surface temperature and chlorophyll-a on the catch of Skipjack tuna in August 2023 in the waters of Sukabumi Regency with a coefficient of determination value of 70.9% and a correlation value between sea surface temperature and catch of 82.4% affecting the total catch and chlorophyll-a concentration obtained a correlation value of -33% which indicates this value affects the yield Catch. The estimation of the skipjack tuna fishing potential zone in the waters of Sukabumi Regency was obtained at three points, namely at 106°16'12.801" E 7°0'51.286" S; 106°28'52.1"E 6°59'2.949" S, and 106°30'31.466" E 7°2'58.516" S.

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