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Analysis of Fringescale Sardine Fishing Grounds (*Sardinella fimbriata*) Based on Sea Surface Temperature and Chlorophyll-A in Tegal Waters, Indonesia

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Authors' contributions

This work was carried out in collaboration among all authors. This work was carried out in collaboration among all authors. Author MAZ designed the study and retrieved the data. Author HAS performed the statistical analysis, wrote the manuscript. Author BAW search the literature. All authors read and approved the final manuscript.

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ABSTRACT

An alternative that can be done in determining the fishing area is to use remote sensing technology through the approach of sea surface temperature distribution and chlorophyll-a. The purpose of this study was to determine the value of the distribution of sea surface temperature and chlorophyll-a, as well as analyze the relationship between sea surface temperature and chlorophyll-a on Fringescale sardine (*Sardinella fimbriata*). The research method used is the

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descriptive method. The research data taken are *in-situ* data and SNPP Viirs satellite imagery data, as well as capture data from 2018 – 2022. Data analysis used multiple linear regression methods and Pearson correlation analysis. The results showed that the sea surface temperature distribution value ranged from 29.5°C – 29.9°C and chlorophyll-a ranged from 0.0545 mg m^{-3} – 0.4022 mg m^{-3}. The value of sea surface temperature and chlorophyll-a in Tegal waters on land tends to have a higher value compared to high seas waters. Analysis conducted between sea surface temperature and chlorophyll-a on catches found a coefficient of determination of 0.74 or 74% affecting the total catch. The partial correlation between sea surface temperature and catch is 0.81 or 81%. The correlation between chlorophyll-a and catch is 0.86 or 86% where this value is included in the very strong category in influencing the catch of *Sardinella fimbriata*. Fishermen no longer rely on instinct to predict potential fishing zone each season, but it has taken advantage of variables that affect the presence of *S. fimbriata* using potential fishing zone map.

Keywords: Sea surface temperature; chlorophyll-a; sardinella fimbriata.

1. INTRODUCTION

Tegal Regency is one of the regions located in Central Java Province with Slawi being the capital of Tegal Regency. Administratively, Tegal Regency is located between 108°57'6" – 109°21'30" E and 6°50'41" – 7°15'30" S. Tegal Regency has an area of 878.79 km^2 with a coastline of 30 km and a sea area of 121.5 km^2. Tegal Regency is located along the North Coast of Java which is included in Fisheries Management Area (WPP) 712. The amount of production in Tegal Regency tends to increase from 2015 to 2020. In 2015, the total production obtained was 796.63 tons and in 2020 the total production was 1,964.38 tons. The types of fishing gear used in the waters of Tegal Regency are small bottom trawl (117 units), pots (99 units), and mini purse seine (96 units). [1]

One type of fish that has a fairly high potential in Tegal waters is Fringescale sardine (*Sardinella fimbriata*). In 2021, the total production of *S. fimbriata* was 18.86% of the total fish production in Tegal Regency (the second highest after *Stolephorus* spp.). *S. fimbriata* belongs to the small pelagic group that lives in open water. Fish in general have an optimum temperature or habit of living in different temperature ranges. According to Maulina et al. [2], the optimum temperature in *S. fimbriata* is thought to range from 28.9 – 29.5°C. *S. fimbriata* often makes migrations aimed at obtaining its optimum temperature. According to Giri et al. [3] when the sea surface temperature and chlorophyll data were combined, it was found that the water in these places is extremely productive and ideal for fish aggregation.

The pattern of fishing seasons of several types of fish has changed or shifted in several regions in Indonesia. The changing seasonal pattern of fish often confuses fishermen in determining the fishing area. Accurate information on fishing grounds is needed, this aims to increase the number of catches [4]. The abbreviation of fish in the waters can be predicted by knowing oceanographic parameters, such as the distribution of chlorophyll-a and sea surface temperature. The large amount of chlorophyll-a will make fish gather where chlorophyll-a is a food source for fish. Temperature is one of the factors that affect the life of organisms, temperature can affect fish metabolism [5]. The distribution of temperature can also affect the distribution of fish. The use of geographic information systems in determining the *S. fimbriata* fishing ground in the waters of Tegal Regency is important. Geographic information systems could visualize geographic area data. Supporting data can be provided easily such as sea surface temperature data, chlorophyll-a distribution or other environmental factors. The purpose of this study was to determine the value of the distribution of sea surface temperature and chlorophyll-a in Tegal waters and analyze the relationship of the two parameters to the catch of *S. fimbriata*.

2. MATERIALS AND METHODS

The research site is ± 8 nautical miles from the fishing base and is ± 5 nautical miles from the Karang Jeruk Conservation Area, Tegal. The selection of the location of the fishing operation is based on the instinct and experience of fishermen who have been carried out previously where the fishing operation area is not far from the Karang Jeruk Conservation area which allows fishermen's catches to be more optimal. The location of the study can be seen in Fig. 1.

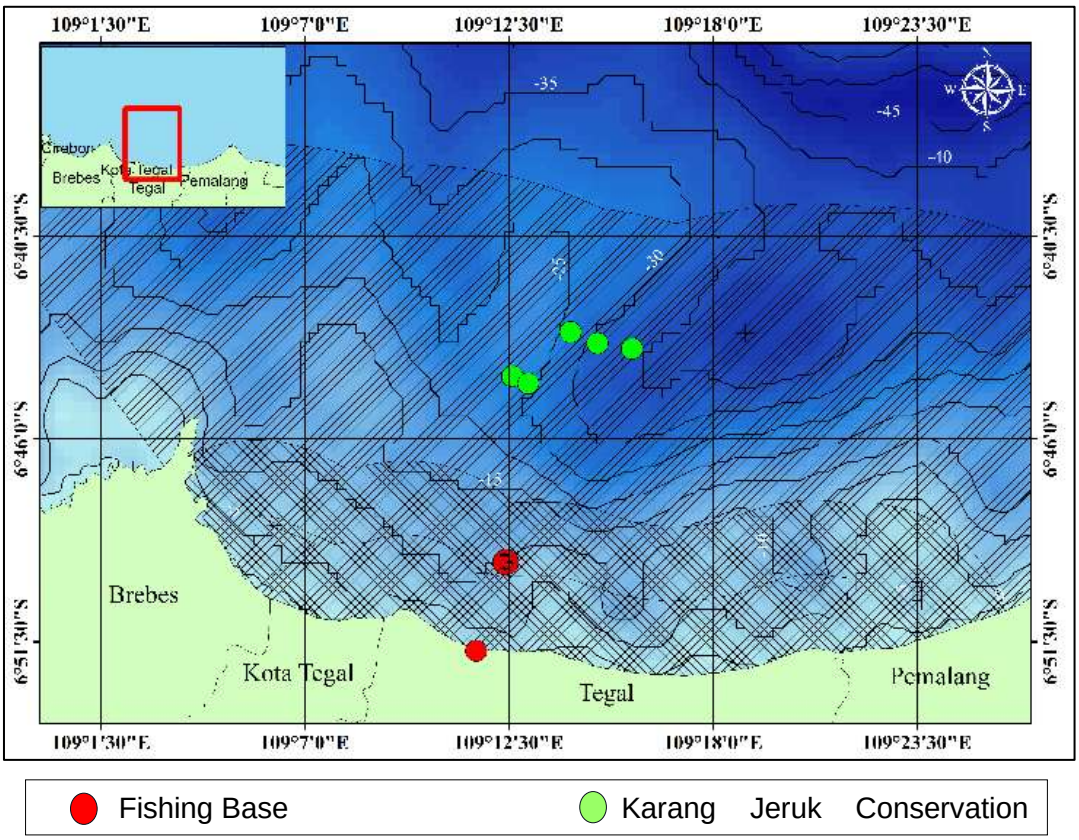

Fig. 1. Map of the research location

This research made use of two main data, namely primary data and secondary data. The primary data used are sea surface temperature data, chlorophyll-a concentrations and catches of *S. fimbriata* in Tegal Regency waters using mini purse seine. Secondary data are sea surface temperature and chlorophyll-a image data for November 2018-2022 and statistical data on the catch of *S. fimbriata* for 2018-2022.

2.1 Data Retrieval Methods

Sea surface temperature data collection is obtained by measuring directly in the field using a thermometer. The position of the fishing ground is in an area close to the Karang Jeruk Conservation Area. In situ data collection of sea surface temperature and determination of fishing locations are carried out randomly. According to Sani et al. [6], the 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 fishing area.

Processing of chlorophyll-a test data is carried out by taking sample water which is then carried out a filtering process using filter paper which is then added chemicals such as $MgCO_3$ solution which is useful for protecting the sample so as to prevent damage to the test sample. The filter paper is put into a test tube where the filter paper has previously been given acetone solution and put into the freezer before calculating the value. Testing chlorophyll-a sample values using spectrophotometric methods. This method is useful for measuring the absorption rate of a sample in a certain length range.

The data used and processed is in the form of monthly data 2018 – 2022. Collection of sea surface temperature and chlorophyll-a data through the website (https://oceancolor.gsfc.nasa.gov/).

2.2 Data Analysis Methods

2.2.1 Image data verification

The monthly sea surface temperature and chlorophyll-a distribution data used in this study are SNPP VIIRS level 3 satellite image data downloaded on the https://oceancolor.gsfc.nasa.gov/. The

downloaded data is then processed by mapping the forecast map of potential fishing zones. Other secondary data used in this study were data on the number of catches and the number of fishing trips sourced from the Marine, Fisheries and Livestock Service Office of Tegal Regency.

Satellite imagery data that has been obtained requires verification with in situ data so that the data obtained becomes more accurate. According to Ghufron et al. [7], stating that satellite image data is needed verification with in situ data so that the value of accuracy and feasibility of a data is known. The step to verification is to correct relative errors. Relative error correction using the formula:

$$RE = \left[\frac{Xinsitu - Xcitra \ X \ 100\%}{n}\right] \quad (1)$$

$$MRE = M \sum_0^n \left[\frac{RE}{E}\right] \quad (2)$$

Where:

RE = Relative Error
MRE = Mean Relative Error
$X_{in\ situ}$ = In Situ Data
X_{citra} = Satellite Imagery Data
N = Amount of Data

2.2.2 Multiple linear regression analysis

Multiple linear regression analysis is a statistical method that can be used to determine the relationship of one dependent variable with two or more independent variables. The purpose of this method is to determine and measure the relationship of the independent variable to the dependent variable. In this method, the relationship between the dependent variable and the independent variable is explained by an equation that contains a regression coefficient, which indicates how much change occurs in the dependent variable when the independent variable changes. According to Suyono [8], the linear regression model states a linear relationship to two variables, namely the dependent variable and the independent variable where one variable is considered to affect other variables.

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

Where:

Y = Dependent Variable (Total Catch)
X = Independent Variable (Sea Surface Temperature and Chlorophyll-a)
A = Constanta

2.2.3 Correlation analysis

Correlation analysis from sea surface temperature data and chlorophyll-a aims to determine the relationship between the two variables used without looking at the relationship between the two variables. According to Sari et al. [9], the correlation analysis equation is written as follows:

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{\{(n\Sigma X^2) - (\Sigma x)\}\{(n\Sigma y^2) - (\Sigma y)^2)\}}} \quad (4)$$

Where:

R = Correlation between chlorophyll-a and sea surface temperature with catch
X = Independent variable (sea surface temperature and chlorophyll-a)
Y = Dependent variable (total catch)

3. RESULTS AND DISCUSSION

There were fluctuations in sea surface temperature in Tegal Waters in 2019-2021. Sea surface temperature variations are strongly influenced by monsoon winds that occur in the the Java Sea. Based on Fig. 2, the peak fishing season of *S. fimbriata* occurs in the transition season (March – May) with temperature values ranging from 29.5 – 30.4 °C. This is in accordance with the statement of [2], the distribution of *S. fimbriata* in Pekalongan waters is influenced by sea surface temperature. The optimum temperature preferred by *S. fimbriata* is in the range of 28.9 – 29.5 °C. According to Takarina et al. [10], temperature can be used to identify and evaluate a fishing ground. Sea surface temperature has a direct impact on animal physiology, particularly their metabolism and reproductive cycle. Indirect effects of temperature on the solubility of oxygen in marine biota.

Chlorophyll-a parameters also varied throughout 2019-2021 in Tegal Waters. From Fig. 3 chlorophyll-a concentrations are highest in August and December. High concentrations of chlorophyll-a will also increase the catch of *S. fimbriata*. This suggests that the availability of abundant food sources may affect the presence of *S. fimbriata*.

The high concentration of chlorophyll-a has no direct impact on the total catch. There is a time gap between increased chlorophyll-a and increased catch. This can be seen in Fig. 3, high chlorophyll-a concentrations in April 2019 and 2020 will be followed by high catches in the following 2-3 months. According to Ghufron et al. [7] and Syahdan et al. [11], the value of chlorophyll-a concentration found in waters can be used as an indication to determine the abundance of fish resources in the sea, but sometimes it is also not directly proportional to the catch obtained. This is because chlorophyll-a takes time to be eaten first by herbivorous fish. The value of chlorophyll-a concentration in the Java Sea ranges from 0.22 – 1.15 mg m^{-3}. The distribution value of chlorophyll-a is closely related to the food chain. The high content of chlorophyll-a in a body of water will have an impact on increasing the productivity of existing zooplankton to create a food chain.

Chlorophyll-a can be used as an indicator of the availability of phytoplankton which is the main food resource for small pelagic fish. The high value of phytoplankton in the waters indicates conditions rich in chlorophyll-a so that it attracts the attention of fish to make the area a place to live. The abundance of food resources makes fish tend to gather and do more activities in the area, making fishermen could get more catches. According to Fauziah et al. [12] and Purwanto et al. [13] chlorophyll-a is one of the oceanographic factors that has an influence on the variability of the number of catches. Chlorophyll-a can provide information on a body of water where there is primary productivity within the food chain that occurs. The food chain starts from phytoplankton which is the main food source for small pelagic fish which then small pelagic fish become food for large pelagic fish.

Based on Fig. 4 (a), information on the distribution of sea surface temperatures in Tegal waters is known in the second transition season, which is in November from 2018-2022. The value of sea surface temperature distribution is obtained from the range of values of 27.3 - 30.8°C. The lowest sea surface temperature value occurred in 2020 at 27.3°C and the highest value occurred in 2019 at 30.8°C. The distribution of temperature in the waters of Tegal, namely in waters near the land has a relatively higher temperature than those far from the land. Temperatures that are near land have more factors that influence it such as ocean currents flowing from land that carry warmer water that raises the temperature of water near waters. The influence of land can also have an impact where the land reflects the sun's heat which causes the surrounding air to also become hot. A certain temperature range in a body of water can affect the spread of fish that live and thrive in those waters. Drastic temperature changes will greatly affect fish found in a water area. The movement of fish is strongly influenced by changes in temperature which are closely related to the adaptability of the fish.

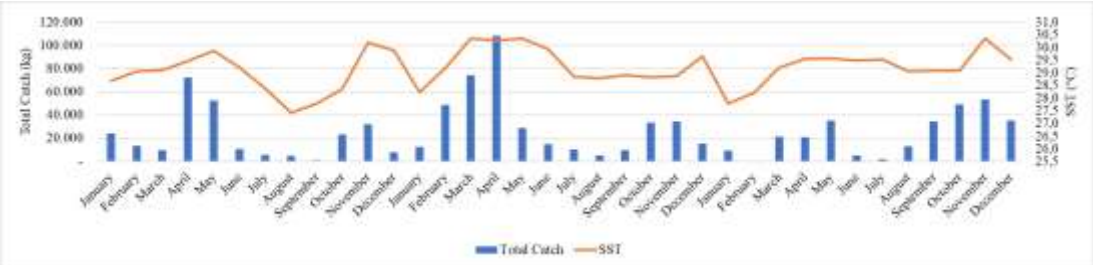

Fig. 2. Graph of SST relationship to catch

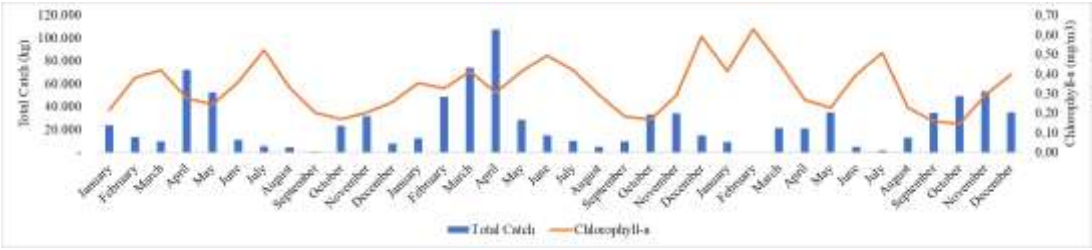

Fig. 3. Graph of chlorophyll-a relationship to catch

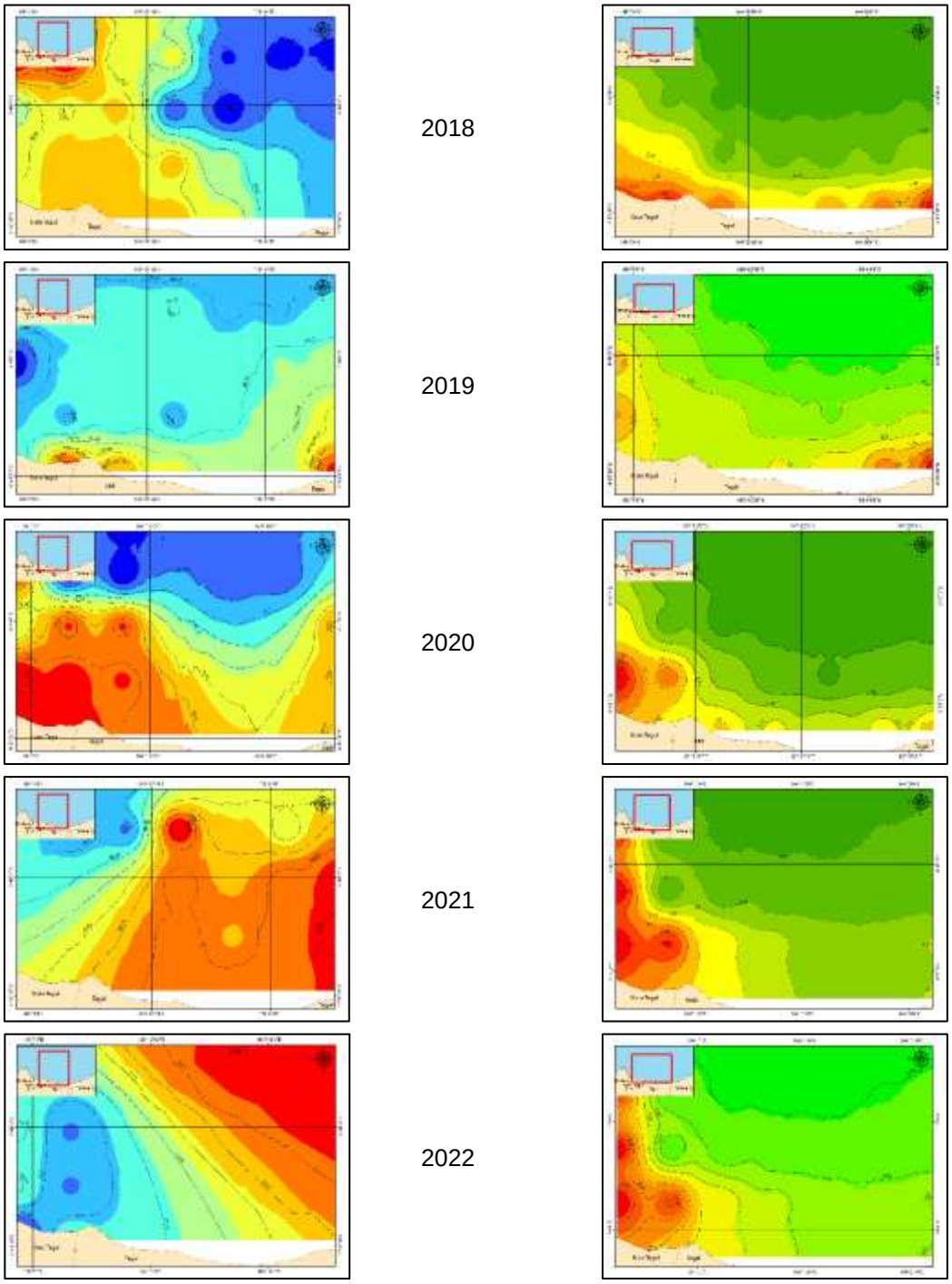

Fig. 4. Spatial distribution of Sea Surface Temperature (a) Spatial distribution of Clorophyll-a (b)

Based on Fig. 4 (B), information on the distribution of chlorophyll-a concentration values in Tegal waters is known in the transition season, which is in November from 2018-2022. The value of sea surface temperature distribution is obtained from the range of values of 0.20 to 4.59 mg m^3. The lowest chlorophyll-a concentration value occurred in 2019 of 0.20 mg m^3 and the highest concentration value occurred in 2020 with a concentration value of 4.59 mg m^3.

Chlorophyll-a concentration values in areas far from land on average have lower concentration values than areas near land. There are several factors that affect the value of chlorophyll concentration such as river water flow that comes carrying nutrients from land to waters where this can increase the production of algae containing chlorophyll-a. Sea waves also affect the value of chlorophyll-a distribution in waters, waves that hit the beach can cause mixing seawater with sediments near the coast, besides that there is also sunlight that provides more exposure than waters far from land so that solar radiation accelerates the growth of chlorophyll-a in waters. Other factors that can affect the distribution of chlorophyll-a values are also such as temperature, salinity, ocean currents or weather.

According to Zulhaniarta et al. [14], the high concentration of chlorophyll-a around the waters is caused by high nutrients originating from land and carried by river discharges. High and low concentration values can be caused by the influence of the entry and exit of freshwater and seawater masses. In offshore waters chlorophyll-a concentration values tend to be low. The research conducted by Rivai et al. [15] the distribution of some fish may be impacted by the concentration of chlorophyll-a in the water, which can be used as an indicator of a marine environment's productivity. A level above 0.2 mg m-3 can support some fishing operations in a region, according to a widely used method of determining the degree of primary productivity using chlorophyll-a concentration.

The results of multiple linear regression analysis between sea surface temperature and chlorophyll-a concentration on *S. fimbriata* catch, it is known that the coefficient of determination (R^2) is .742 which shows that 74.2% of catches are influenced by both parameters, namely sea surface temperature and chlorophyll-a. The value of coefficient determination obtained is included in the strong category. According to Maulina et al. [2], the coefficient of determination (R^2) was obtained at .63 which means that as many as 63% of sea surface temperature variables and chlorophyll-a affect the catch of *S. fimbriata* in the waters of the Java Sea and based on Fishing Port Type B (PPN) Pekalongan. There are other factors that are thought to affect catches, namely water depth, currents and salinity.

The results of the correlation analysis between sea surface temperature and chlorophyll-a on the catch of *S. fimbriata*. Both oceanographic parameter variables have a relationship with the catch of *S. fimbriata*. The result of the correlation of sea surface temperature of -.81 or 81% shows that sea surface temperature has a considerable influence on catches. The correlation value of chlorophyll-a obtained is 0.861 or 86.1% chlorophyll-a affects the catch, this shows sea surface temperature, and the distribution of chlorophyll-a has a considerable influence on the catch obtained. According to Maulina et al. [2], the increase in sea surface temperature value affects the high increase in the number of *S. fimbriata* catches, while the increase in chlorophyll-a that occurs causes a decrease in *S. fimbriata* catches. Sea surface temperature has a direct effect on the amount of catch while chlorophyll-a has no real effect on partial catch. The correlation between sea surface temperature and chlorophyll-a as an independent variable and the catch of *S. fimbriata* in Java Sea waters as a dependent variable was 0.795. Research conducted by Yulius et al. [16] reported a high concentration of chlorophyll-a indicates the occurrence of a food chain. Some pelagic fish, such as *S. fimbriata*, have a strong correlation to increased chlorophyll-a concentrations, although they are not directly affected by sea surface temperatures.

Based on Fig. 5. potential fishing zone in the waters of Tegal Regency which was processed using SNPP VIIRS satellite imagery data, it is known that the potential fishing zone in the waters of Tegal Regency is affected by sea surface temperatures and the distribution of chlorophyll-a. The distribution map of sea surface temperature is known by blue to red gradation color which shows low temperature information to high temperature. The average distribution of sea surface temperatures in November 2022 in the waters of Tegal Regency ranges from 28.5°C to 30.2°C, which is the optimum temperature for *S. fimbriata*. The average value of chlorophyll-a concentration is around the value of 1.32 mg m^{-3}. According to Maulina et al. [2] fish are included in poikilothermic animals which means body temperature is influenced by environmental temperature. *S. fimbriata* tend to like waters that have warm temperatures. The optimum temperature for *S. fimbriata* ranges from 28.9°C to 29.5°C and chlorophyll-a concentration of 0.55 mg m^{-3}.

The potential fishing zone of *S. fimbriata* fishing ground in the waters of Tegal Regency using mini purse seine is with coordinate points in

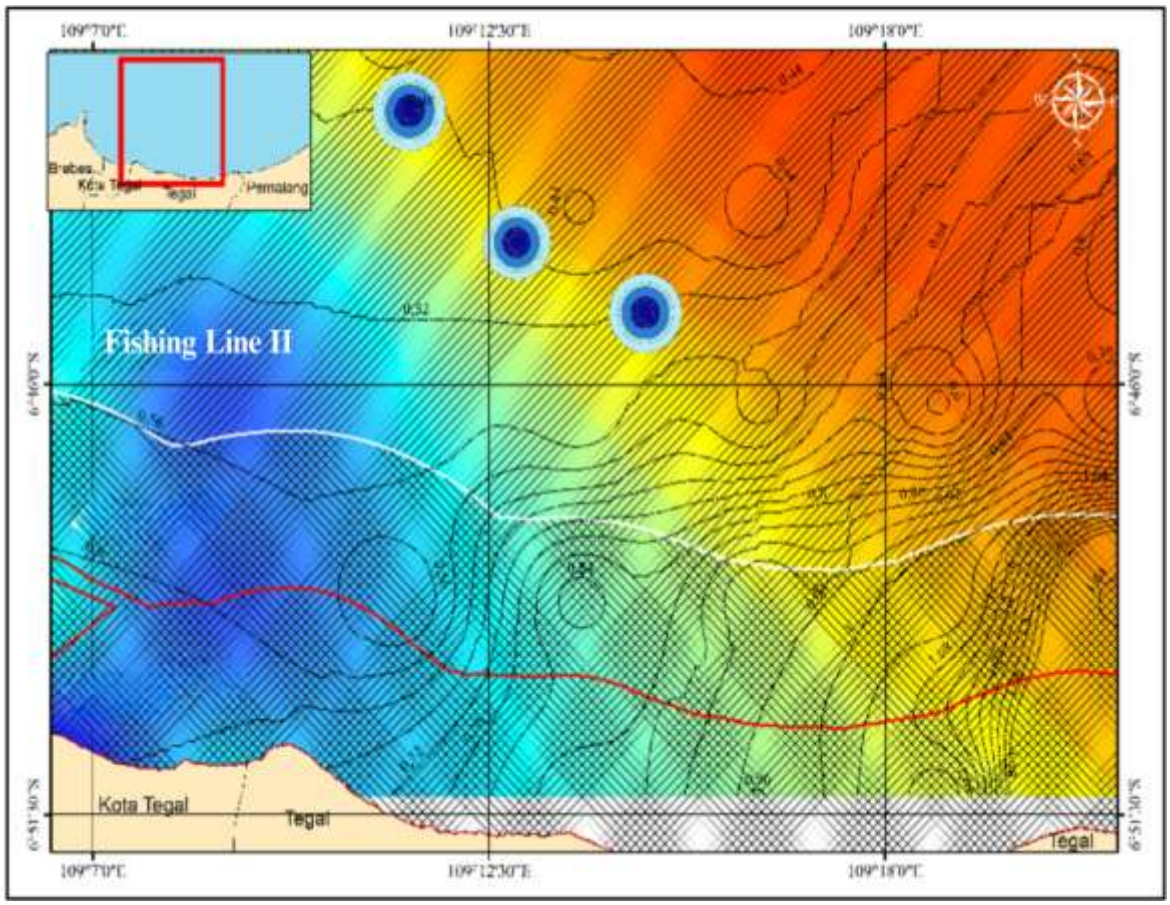

Fig. 5. Potential fishing zone of *S. fimbriata*

potential zone 1, namely at 6°42'31.65" S and 109°11'22.44" E. In the area of potential zone 2 is located at 6°44'11.76" S and 109°12'52.92" E. The third potential fishing zone is located at 6°45'2.80" S and 109°14'37.73" E. At the first point of the potential fishing ground has a sea surface temperature of 29.6 °C and a chlorophyll concentration value of 0.48 mg m^{-3}. The second area has the same value of sea surface temperature and chlorophyll-a concentration as the first area. In the third region, the sea surface temperature value is 29.7°C and the chlorophyll-a concentration value is 0.52 mg m^{-3}.

Determination of potential fishing zone is required to know the characteristics of the fish that are the target of catch. Knowledge of oceanographic parameters of fish is very important to know to maximize the process and catch. The value of sea surface temperature and chlorophyll-a concentration values in the three potential zones are areas that meet the requirements of oceanographic parameters indicated to be the habitat of *S. fimbriata*.

4. CONCLUSION

The conclusion of this study is that the distribution pattern of SPL and chlorophyll-a values in November 2018 – 2022 in the waters of Tegal Regency is higher in waters near land than waters far from land. There is a strong influence between sea surface temperature and chlorophyll-a on the catch of *S. fimbriata* in November 2022 in the waters of Tegal Regency with a coefficient of determination value of 74% and a correlation value between sea surface temperature to catch, which is 81%, affecting the total catch and chlorophyll-a concentration, a correlation value of 86% is obtained, which indicates that this value is included in the very strong category.

The use of remote sensing data is very useful for estimating potential fishing zones. By knowing the potential fishing zones, fishermen can increase fishing productivity. Fishermen no longer rely on instinct to predict potential fishing zone each season, but it has taken advantage of variables that affect the presence of *S. fimbriata*.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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