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The Effect of Chlorophyll-a and Sea Surface Temperature on Skipjack Tuna Fishing Areas in FMA 714

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Abstract**—** Skipjack tuna (*Katsuwonus pelamis*) is a commercially important pelagic fish species in FMA 714, whose distribution and abundance are closely related to oceanographic conditions, particularly sea surface temperature and chlorophyll a concentration, which are commonly used as indicators of potential fishing grounds. Understanding the relationship between these environmental variables and fish catch is important for supporting sustainable fisheries management and improving fishing efficiency. This study aimed to analyze the influence of sea surface temperature and chlorophyll a distribution on the characteristics of potential skipjack tuna fishing areas in the waters of FMA 714. A quantitative descriptive approach was applied using NOAA oceanographic data and skipjack tuna catch statistics. Temporal variations in SST and chlorophyll a were analyzed, and simple linear regression was used to evaluate their relationship with fish catch. The results showed that oceanographic conditions in FMA 714 were strongly influenced by the monsoon cycle, particularly the upwelling process during the East Season. Sea surface temperature decreased to approximately 28°C in August, while chlorophyll a concentration increased significantly during July–August, reaching 0.48–0.50 mg/m³. Although these water conditions produced dynamic productivity, linear regression analyses showed that sea surface temperature was positively associated with fish catch, while chlorophyll a was negatively associated, though very weakly. Sea surface temperature and chlorophyll a did not have a significant effect on fish catch ($p=0.239$), indicating that these parameters explained only 23.9% of the variation in catch, with the remaining 76.1% influenced by factors outside the research model. The study concludes that SST and chlorophyll a were not significant predictors of skipjack tuna catch production in FMA 714, and that fishing effort likely plays a greater role in determining catch variability.

Keywords— catch production, oceanography, pelagic, purse seine, temporal.

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I. Introduction

Skipjack tuna (*Katsuwonus pelamis*), also known as skipjack, is a large pelagic fish highly sought after both locally and internationally. This fish, which belongs to the tuna, mackerel, and skipjack (TCT) group, has the largest population in tropical waters [1]. The Indonesian National Fisheries Management Area (FMA) 714, which includes the waters of Tolo Bay and the Banda Sea, is considered one of the strategic fishing zones, especially for large pelagic species such as tuna and skipjack [2]. Pelagic fish resources play a strategic role in supporting capture fisheries production in Indonesia, particularly through high-value commodities such as skipjack tuna [3].

Skipjack tuna is highly responsive to changes in aquatic environmental conditions, particularly in terms of food availability and habitat preferences. Furthermore, its extensive migratory behavior means its distribution is non-static, instead following the dynamics of complex marine ecosystems. Therefore, the presence and abundance of skipjack tuna in a given area cannot be separated from the influence of environmental factors that regulate it, especially oceanographic parameters that are the main indicators of water conditions [4].

Oceanographic conditions play an important role in controlling the distribution and abundance of skipjack tuna, as physical parameters and primary productivity directly affect habitat suitability and food availability [5]. Primary productivity in a water body is directly influenced by the concentration of chlorophyll a. Chlorophyll a is the main photosynthetic pigment in phytoplankton, which forms the base of the food chain in marine ecosystems. The presence of abundant

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phytoplankton tends to attract the presence of herbivorous and carnivorous fish, so the concentration of chlorophyll a is often used as an indicator of water fertility to determine potential fishing areas [6].

In addition to chlorophyll a, sea surface temperature (SST) is a parameter that influences skipjack tuna migration patterns. According to the study by Masyahoro et al. [1], skipjack tuna live in waters with an optimal temperature range of 28-32 °C. Drastic changes in SST, whether due to seasonal phenomena or climate anomalies such as the El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD), can affect fishing areas [7].

Although SST and chlorophyll-a are widely used to identify potential fishing grounds, their actual influence on skipjack tuna catch variability in FMA 714 has not been clearly quantified, particularly under the influence of monsoon-driven oceanographic dynamics and varying fishing effort. The novelty of this study lies in its focus on FMA 714 as a skipjack tuna fishing ground. In addition, the study provides new insights into how oceanographic conditions influence skipjack tuna catch in this region, revealing the relationship between environmental variability and catch outcomes.

Therefore, this study aims to examine the influence of chlorophyll a and SST on the characteristics of potential skipjack tuna fishing areas in FMA 714. The research approach is based on satellite oceanographic data connected with field catch data.

II. Method

2.1. *Research location and time*

This research was conducted in 2026 with oceanographic data and skipjack tuna catch statistics from 2022 in the Fisheries Management Area (FMA) 714. The research location map is shown in **Figure 1**.

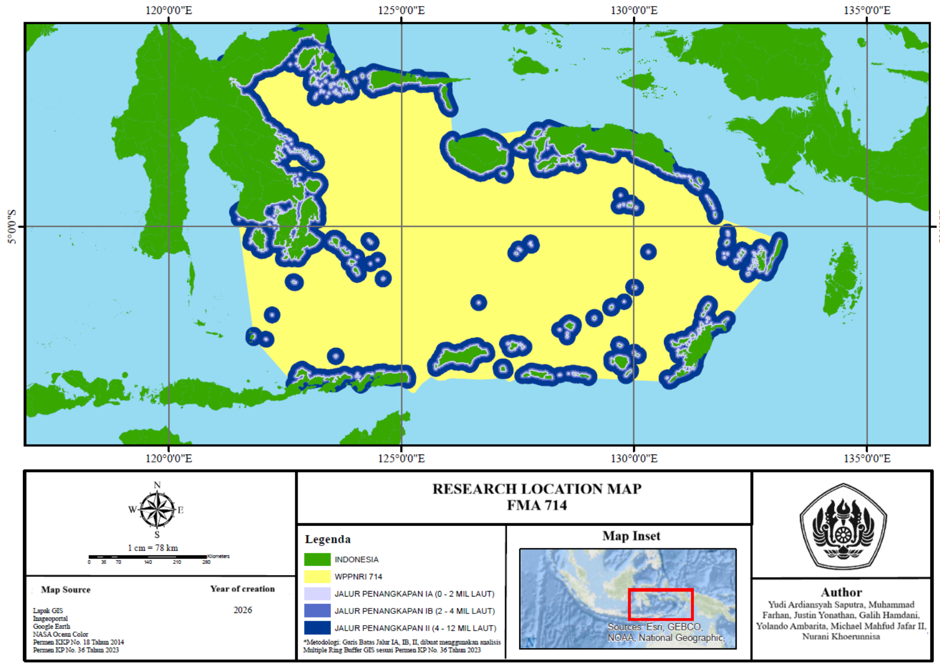

Figure. 1. Research location map.

2.2. *Research procedure*

The research method used is a quantitative descriptive method. The quantitative descriptive method is used to analyze the relationships among SST values, chlorophyll a, and fish catch production in FMA 714. The research data include secondary data on fish catch production for FMA 714, sourced from the 2022 fisheries port statistics. Other data include SST and chlorophyll a data obtained from the NOAA Oceancolour website. SST and chlorophyll a data are visualized using Python software.

2.3. *Data Processing and Analysis*

The research data were analyzed descriptively and using simple linear regression and determination.

1. Descriptive Analysis
   This analysis describes the temporal (monthly) and spatial distributions of SST, chlorophyll a, and fish catch results. The analysis results are visualized with images and tables.
2. Simple Linear Regression Analysis
   This analysis is used to determine the relationship between:
   - Chlorophyll-a (X_1) and catch results (Y)
   - SST (X_2) and catch results (Y)

   Regression equation model:
   $Y = a + bX$
   Explanation:
   Y = fish catch (tons)
   X = oceanographic variable (SST or chlorophyll-a)
   a = constant
   b = regression coefficient
3. Coefficient of Determination (R^2)
   This analysis is used to determine the extent of SST and chlorophyll a's influence on skipjack tuna catch variation.

III. Results and Discussion

3.1. *Sea Surface Temperature Distribution*

The distribution of Sea Surface Temperature (SST) during the observation year resulted in concentration values that varied around the waters of FMA 714. These concentration variations are used as indicators of potential fish catch. Temperature is one indicator of the presence of fish groups in a region, but it is strongly influenced by changes in other environmental conditions [8].

Based on the data processing results, the SST distribution in the study waters shows highly dynamic fluctuations, with an average range of 26°C-32°C. This movement pattern is influenced by geographical location, the apparent movement of the sun, and the dynamics of water mass circulation [9]. A significant increase in temperature is observed at the beginning of the year, with peaks (highest) occurring in March and June at 32°C. Entering the months of July to October, the temperature distribution shows a drastic declining trend, with the lowest point (minimum) reaching 26°C in October. Sea surface temperature visualization in FMA 714 is shown in **Figure 2**.

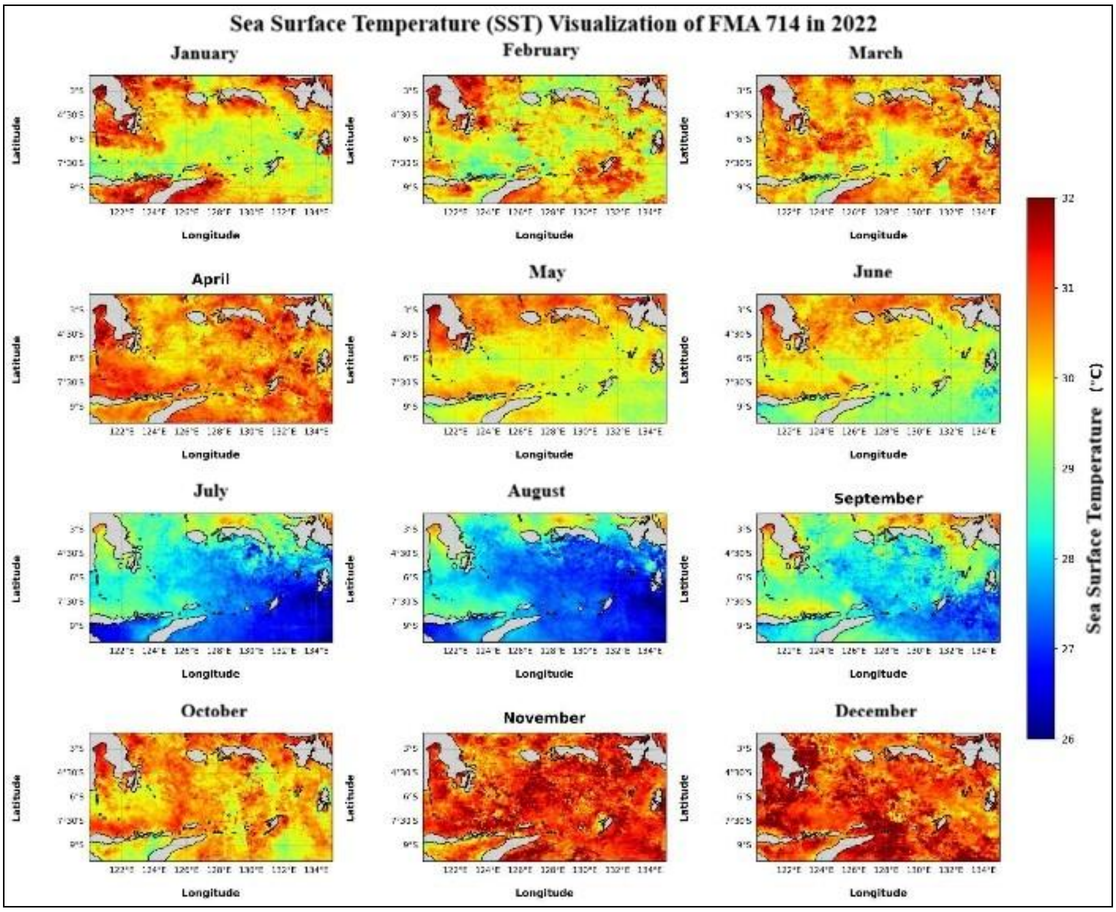

Figure. 2. Visualization of SST FMA 714 Year 2022.

The pattern of SST decline from mid-year to the end of the year indicates the influence of seasonal dynamics, particularly the upwelling phenomenon that commonly occurs during the east wind period in Indonesian waters. The upwelling process causes cold water masses from the lower layers to rise to the surface, significantly reducing the SST [10]. In addition, SST variations are closely related to the monsoon system, which controls heat distribution in Indonesian tropical waters; during the east season, sea surface cooling tends to occur due to increased vertical mixing [11].

After reaching its lowest point, the temperature began to increase again in the second transitional season, rising in November (30.8°C) and December (31.2°C). The temperature increase at the end of the year in this area occurs because the sun moves closer to the southern region, increasing the intensity of solar radiation and triggering the warming of surface water masses [12]. Thus, the SST pattern found in the waters of FMA 714 is generally consistent with the oceanographic characteristics of Indonesian waters, which are controlled by the monsoon system, upwelling dynamics, and the semi-annual apparent movement of the sun.

3.2. *Chlorophyll a Distribution*

Chlorophyll a is one indicator of water fertility. Fertile waters naturally contain high concentrations of chlorophyll a [13]. In the FMA 714 area, the distribution of chlorophyll a exhibits dynamic temporal variations, which are ecologically closely related to fluctuations in Sea Surface Temperature (SST) and seasonal influences. Based on satellite data processing over a 1-year period, chlorophyll a concentrations in this area range from 0.197 to 0.483 mg/m³.

Temporal variation analysis shows that the peak chlorophyll-a concentration occurs in July with an average value of 0.483 mg/m³, followed by August at 0.418 mg/m³. The high concentration during these periods indicates abundant nutrient availability in the surface layer, most likely triggered by upwelling that brings nutrients from deeper layers to the surface, thereby increasing primary productivity in the waters [14]. Conversely, the lowest chlorophyll a concentration is observed in April with an average value of 0.197 mg/m³. This decrease in concentration coincides with a significant increase in sea surface temperature during the first quarter of the year. Visualization of chlorophyll a in FMA 714 in 2022 is shown in **Figure 3**.

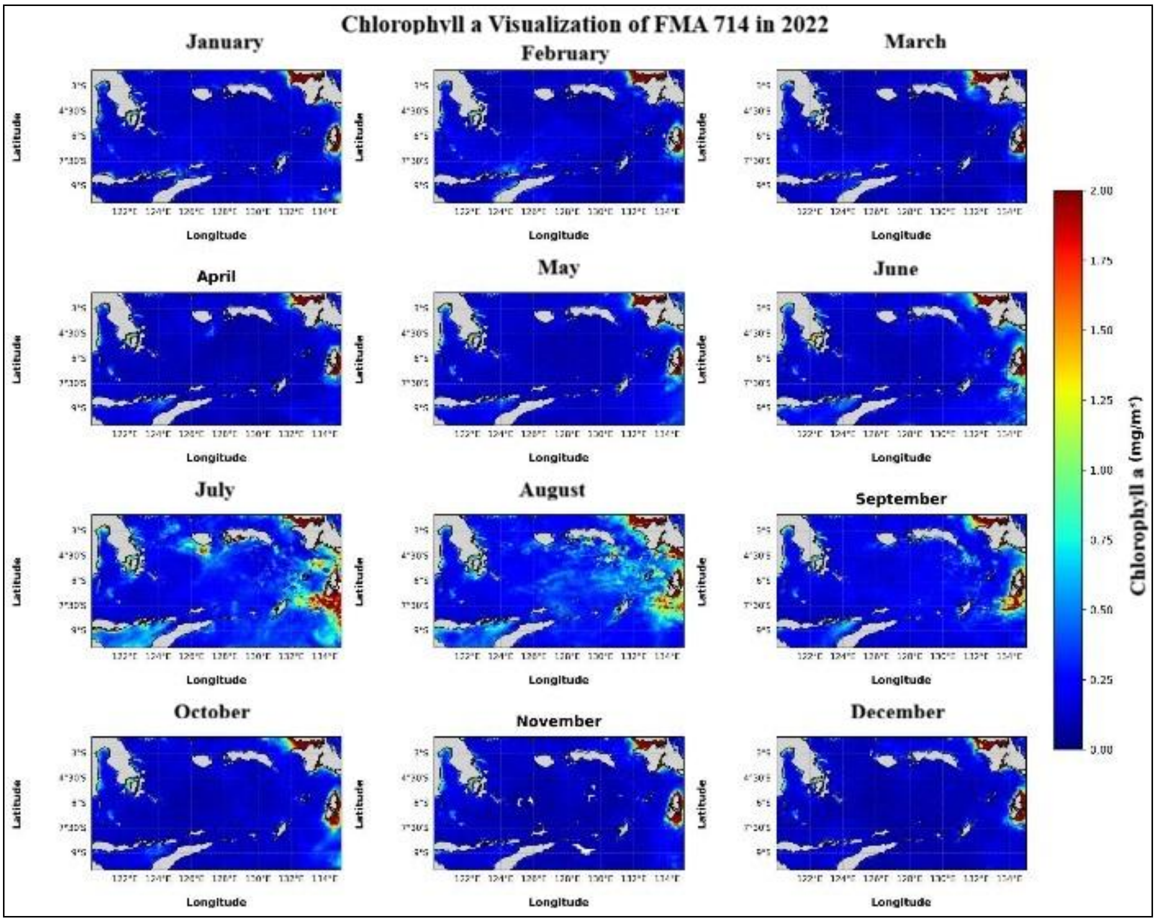

Figure. 3. Visualization of chlorophyll a FMA 714 Year 2022.

The inverse relationship between SST and chlorophyll a has been well documented, with a decrease in temperature due to upwelling often followed by an increase in phytoplankton biomass in response to nutrient availability [15]. Upwelling increases nutrient supply in the surface layer, driving primary productivity and potentially enhancing prey availability for large pelagic fish such as skipjack tuna (*Katsuwonus pelamis*) [16, 17]. Thus, the results of this study show that chlorophyll a dynamics in FMA 714 are controlled by the same oceanographic physical processes as SST, but with an opposite biological response.

3.3. *Fishing Gear in FMA 714*

Based on the composition of Fishing Gear (FG) operating in the Fisheries Management Area of the Republic of Indonesia (FMA) 714, the fishing fleet is dominated by small pelagic purse seines, with a single vessel type accounting for 2,328 units. This dominance indicates that the primary fishing orientation in these waters relies on the intensity of exploitation of pelagic fish resources, which tend to form schools in the surface layer. The types of fishing gear operating in FMA 714 are shown in **Table 1**.

TABLE 1.
Fishing Gear in FMA 714

Fishing gear name	Total
Handline	587
Tuna handline	520
Small pelagic purse seine with one boat	2328
Tuna longline	13
Pole and line	236

The group of fishing gear designed to specifically catch large pelagic species, such as tuna and skipjack, also makes a significant contribution. These types of fishing lines include 587 longlines, 520 tuna handlines, and 263 pole-and-line. Conversely, tuna gillnet operations were recorded as the least frequent, with only 13 units operating, reflecting the still-limited industrial-scale capture of tuna in the deeper water column of this ecosystem zone.

3.4. *The Relationship Between Sea Surface Temperature and Chlorophyll-a with Catch Results*

Fish catches in 2022 showed fluctuations, so they did not form a clear linear pattern. The main production peaks occurred in June (207,658 tons) and November (205,120 tons), while the lowest points were in April (90,173 tons) and July (104,190 tons). The breakdown of production, SST conditions, and chlorophyll a in FMA 714 in 2022 is shown in **Table 2**.

The relationship between oceanographic parameters (SST and chlorophyll a) and skipjack tuna catches in the FMA is described using a simple linear regression to examine the trend of each variable, as shown in **Figure 4**. Meanwhile, the relationship between sea surface temperature and skipjack tuna catches is shown in **Figure 5**.

TABLE 2.
Production Characteristics and Oceanographic Conditions of Skipjack Tuna Fishing Areas in FMA 714 in 2022

Month	Production (Tonnes)	SST (°C)	Chlorophyll a (mg/m^3)
January	187.642	30,0	0,254
February	187.783	30	0,231
March	133.302	30,2	0,219
April	90.173	30,5	0,197
May	103.651	30	0,248
June	207.658	29,8	0,258
July	104.190	28,2	0,483
August	117.844	28	0,418
September	169.579	28,8	0,300
October	176.405	30,4	0,234
November	205.120	31,1	0,210
December	139.816	31	0,201

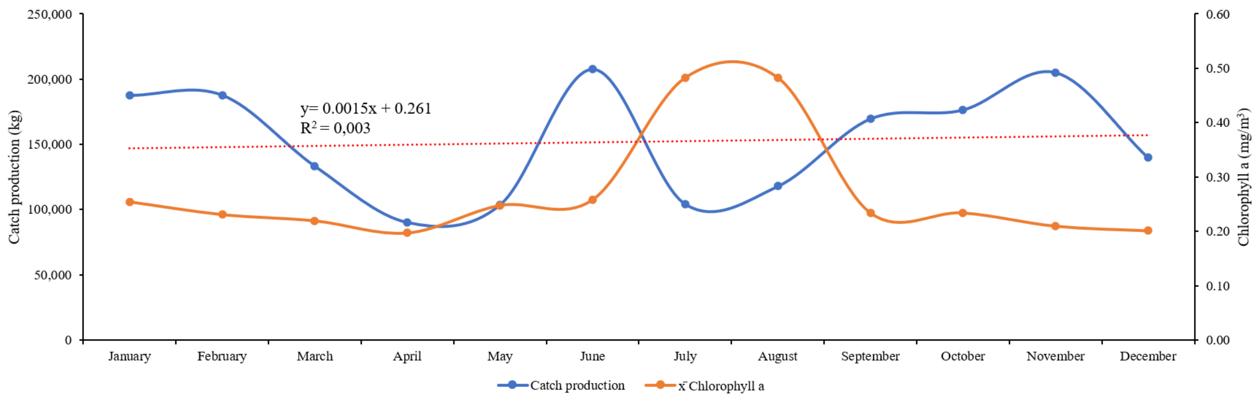

Figure. 4. The relationship between chlorophyll a and skipjack tuna catch production.

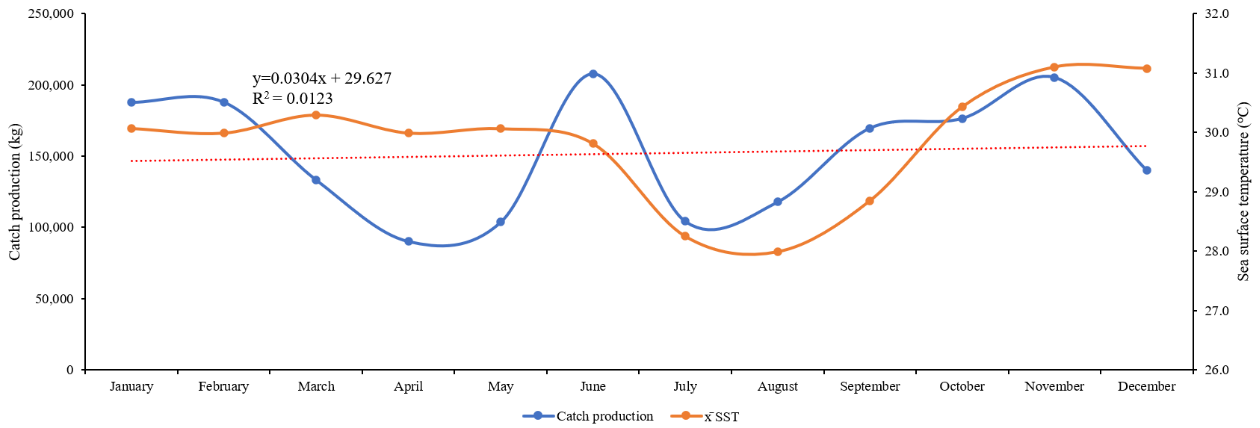

Figure. 5. The relationship between sea surface temperature and skipjack tuna catch production.

The results of the linear regression analysis show that the relationship between chlorophyll a and catch yield produces a coefficient of determination (R^2) value of 0.003, while the relationship between SST and catch yield produces an R^2 of 0.0123. These values indicate that both of these oceanographic parameters explain less than 2% of the variation in catch yield.

Examining a more complex picture, the analysis was continued with multiple linear regression using SPSS, with the results shown in **Table 3**.

TABLE 3.
SPSS Analysis Results of Production Estimation with Independent Variables

Variable	Coefficient	t-value (Sig.)
Constant	-476447.069	0.536
SPL (X1)	20570.854	0.396
Klorofil-a (X2)	-1953.017	0.993
R^2	0.239	
Adjusted R^2	0.070	
F hitung sig.	0.293	

The results indicate that when SST and chlorophyll a are combined in a single model, the coefficient of determination (R^2) increases to 0.239. This indicates that together, these two parameters can explain 23.9% of the variation in skipjack tuna catch, while the remaining 76.1% is influenced by other factors outside the study model. However, the low Adjusted R^2 value (0.070) and the ANOVA test result with a significance value of 0.293 ($p>0.05$) indicate that the effect is not statistically significant at the 95% confidence level.

According to Purwanto and Ramadhani [18], the presence of fish in a water area is not only determined by static oceanographic parameters. Current dynamics and water mass structure often determine the presence of effective fishing grounds. In addition, on a partial basis (t-test), SPL shows a Sig. value of 0.396, and chlorophyll a shows a Sig. value of 0.993. This figure reinforces the findings from the previous graph analysis that these two variables have not yet become strong single predictors of catch volume at the research location.

The results of estimating the production function of skipjack tuna in FMA 714 Table 3 can be written in the form of an equation:

$$Y= - 476447 + X1\ 20570.854 - X2\ -1953.017$$

Where:
Y = fish catch (tons)
X1 = SST (°C)
X2 = Chlorophyll-a (mg/m³).

To simplify the estimation process, this equation is linearized. Following the approach according to Soekartawi [19], this step is carried out by applying the logarithmic function to the equation, resulting in the following outcome:

$$\mathrm{Ln}\ Y= \mathrm{Ln} - 476447 + 20570.854\ \mathrm{Ln}\ X1 - 1953.017\ \mathrm{Ln}\ X2$$

The advantage of using the Cobb-Douglas function is that its regression coefficients automatically reflect the elasticity level of variable X (production factors) with respect to variable Y (output). According to Soekartawi [19], this allows one to see how sensitive changes in output are to each influencing factor, with the equation model as follows:

$$Y= -476447 + 20570.854\ X1 - 1953.017\ X2$$

The equation shows that sea surface temperature is positively associated with fish catch. The regression coefficient for SST is 20570, indicating that a 1°C increase in sea surface temperature is estimated to increase the catch by 20,570.854 kg, assuming other variables remain constant. However, the partial test results show that the SST variable does not have a statistically significant effect.

The chlorophyll a variable in this study shows a negative relationship with the catch, with a regression coefficient of -1,953.017. However, the significance value is very large, indicating that the relationship is not statistically significant. This indicates that an increase in chlorophyll a concentration is not directly followed by an increase in fish catch in FMA 714.

3.5. *Discussion*

Chlorophyll a is the main photosynthetic pigment contained in phytoplankton and is used as an indicator of primary productivity in waters. Chlorophyll a concentration is often used to describe the fertility level of a body of water because phytoplankton form the basis of the food chain in marine ecosystems [20]. Phytoplankton is utilized by zooplankton and other low-trophic-level organisms, which in turn become a food source for small pelagic fish as well as large pelagic fish [21]. Therefore, areas with high chlorophyll a concentrations generally have greater potential for fish resources than waters with low chlorophyll a concentrations.

The development of remote sensing technology allows for monitoring chlorophyll a concentration spatially and temporally through satellite imagery. Chlorophyll a data can be obtained from satellite sensors such as the Moderate Resolution Imaging Spectroradiometer (MODIS) managed by the National Aeronautics and Space Administration (NASA) [22]. These data are freely available and can be used to analyze water productivity dynamics over a certain period. In fisheries research, chlorophyll a data are usually downloaded in monthly, seasonal, or annual time ranges, then processed using Geographic Information System (GIS) software to produce chlorophyll a distribution maps that depict the fertility levels of water bodies.

The relationship between chlorophyll a and fishing areas has been widely reported in various studies. An increase in chlorophyll a concentration is often associated with an increase in fish abundance due to the availability of greater food resources. However, fish responses to changes in chlorophyll a do not always occur immediately because of the time lag in energy transfer between trophic levels in the marine food chain [23].

In addition to chlorophyll a, sea surface temperature (SST) is one of the oceanographic parameters that plays an important role in determining the distribution and abundance of fish. Each fish species has an optimal temperature range that supports physiological processes, growth, reproduction, and migration. Changes in water temperature can affect fish distribution patterns because organisms tend to move to habitats with environmental conditions suitable to maintain their survival [24].

In addition to affecting the distribution of adult fish, temperature also plays an important role in the spawning process, egg hatching, larval growth, and juvenile rearing. Temperature conditions that are outside the optimum range can reduce fish survival rates and disrupt the reproductive process. Therefore, sea surface temperature information is often used in fish habitat studies and potential fishing area modeling [20, 24].

Currently, sea surface temperature data can be easily obtained through various satellite-based remote sensing platforms, such as MODIS-Aqua, Advanced Very High Resolution Radiometer (AVHRR), and NOAA products. These data are available in various spatial and temporal resolutions, including daily, monthly, and seasonal temperature change analyses. In fisheries research, sea surface temperature data are generally processed using image processing and GIS software to produce temperature distribution maps, which are then related to fish catch data [22].

Based on the theory explained, this study observes how much influence chlorophyll a and sea surface temperature have on the catch of skipjack tuna in FMA 714. Scientifically, these results confirm that the relationship between oceanographic parameters and fish catch is not always linear, but is influenced by many other factors. Capture fisheries production is influenced by a combination of environmental factors, fish behavior, and operational factors such as fishing effort and fishing gear technology [25].

Moreover, although chlorophyll a is often used as an indicator of water productivity, an increase in chlorophyll does not always directly correlate with catch results due to the time lag in the trophic chain from phytoplankton to target fish [26]. The results of a study by Pratama et al. [27] show that chlorophyll-a concentrations have a strong relationship with pelagic fish production, particularly skipjack tuna. However, this relationship is not always linear with regard to pelagic fish abundance. This is because chlorophyll-a merely represents the abundance of phytoplankton as primary producers. Pelagic fish, such as skipjack tuna, do not consume phytoplankton directly but rely on zooplankton and small fish that derive their energy from phytoplankton as their primary food source. Thus, the influence of chlorophyll-a on pelagic fish abundance occurs indirectly through the food chain in aquatic ecosystems [28].

The same also applies to SST, where SST plays a greater role in shaping the distribution and migration of fish rather than directly determining catch amounts [29]. Thus, the low value of the coefficient of determination in this graph does not indicate that SST and chlorophyll a are unimportant, but rather shows that their relationship to the catch results is complex and influenced by other variables not included in that simple regression model.

IV. CONCLUSION

The variables of SST and chlorophyll a together have not shown a significant effect on fish catch production. This is indicated by the significance value of the simultaneous test (Sig. = 0.293), which is greater than the 0.05 significance level. In addition, the coefficient of determination of 0.293 indicates that sea surface temperature and chlorophyll a explain only 23.9% of the variation in fish catch, while the remaining 76.1% is influenced by other factors.

The distribution and catch of pelagic fish in FMA 714 are influenced not only by sea surface temperature and chlorophyll-a parameters, but also by oceanographic dynamics and more complex fishing factors, such as fishing gear. The purse seine, used with a single vessel, is the most commonly used fishing gear, with 2,328 fleets. This is another factor in the production of skipjack tuna catches in FMA 714. Therefore, the use of only SST and chlorophyll a parameters is not sufficient to fully explain the fluctuations in fish catches in the study area.

V. SUGESSTION

This research can be further developed by analyzing fish-catching seasons temporally using longer time-series data. It is hoped that this analysis can provide a more accurate estimate of the optimal fish-catching periods in Fishery Management Area (FMA) 714.

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