

## RESEARCH ARTICLE

# The Impact of Sea Surface Temperature and Containing Chlorophyll-A on The Results of Skipjack Tuna (*Katsuwonus Pelamis*) Catch in The Indian Ocean Waters

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## Abstract

Oceanographic factors can be an indicator in determining the potential of fishing grounds. The sampling technique of sea surface temperature (SST) and chlorophyll-a data in this study was carried out spatially and temporal using satellite image data which can be downloaded from Aqua MODIS. This study aimed to determine variations in SST distribution and chlorophyll-a concentration in Indian Ocean waters using Aqua MODIS imagery from June 2023 to May 2024; analyzing the relationship between the distribution of SST and chlorophyll-a with the number of pelagic fish catches in the Indian Ocean waters. The type of fish used as research material is skipjack tuna (*Katsuwonus pelamis*). The distribution of SST in the Indian Ocean waters for June 2023-May 2024 is between 29,15-31,64 °C, where there is a significant decrease in temperature from 31,10-29,15 °C due to the east monsoon wind and the chlorophyll-a distribution is around between 0,24-0,73 mg/m<sup>3</sup> with the highest average distribution in the western season. This phenomenon causes chlorophyll-a to increase in the western season because the frequency of rainfall in this season is sufficient, causing nutrients to increase due to vertical stirring, which can increase chlorophyll-a at the sea surface. There is no relationship between SST and chlorophyll in the number of skipjack tuna catches in transition II with a strong correlation value and a significance value (F) of 1,0, meaning that SST and chlorophyll-a on skipjack tuna to the skipjack tuna catches not influence for each season, the influence of significant event is thought to be a lag in the food chain and high rainfall. This study reveals that while variations in sea surface temperature and chlorophyll-a concentration are significant understanding oceanographic conditions, they do not directly influence skipjack tuna catch rates, suggesting that other ecological factors, such as food chain dynamics and seasonal rainfall patterns, may play a more critical role.

**Keywords:** SST, Chlorophyll-a, Aqua MODIS, Skipjack Tuna Catch

## 1. Introduction

### 1.1 Sub Introduction

Skipjack tuna is a typical tropical tuna species, one of the significant species in global tuna species (Lehodey, *et al.*, 1997 in Putri and Zainuddin, 2019; Satria and Sadiyah, 2017). Indonesia is one of the tropical countries with high skipjack tuna production. In fisheries management area 713 of Indonesia, total skipjack tuna production reached 21038,8 tons in 2015.

The presence of nutrients namely chlorophyll-a (chl-a), Sea Surface Temperature (SST), and oxygen had a significant effect on the survival of skipjack fish (Zainuddin, *et al.*, 2017; Zainuddin, 2013; Usman, *et al.*, 2017).

So, their movement and vulnerability were affected by their preferred habitat (Mugo, *et al.*, 2010). If the anomaly occurs in its habitat, it will affect the distribution pattern and abundance of skipjack tuna (Muhling, *et al.*, 2015; Pinsky and Fogarty, 2012), including SST and chl-a anomalies (Yu, *et al.*, 2019; Sartimbul, *et al.*, 2010; Syamsuddin, *et al.*, 2016).

Pelagic fish are a group of fish that live most of their lives in the surface layer to the water column (mid-layer). This pelagic fish has a distinctive characteristic, namely that it generally schools and migrates for its various life needs during its activity. Pelagic fish can be further divided into two groups. The first group is large pelagic fish, namely pelagic fish with a

size of 100-250 cm (adult size), and these fish types are generally sharks and fast swimmers, for example, tuna, skipjack tuna, mackerel tuna, mackerel, etc. The second group is small pelagic fish measuring 5-50 cm (adult size), such as mackerel scad, long-jawed mackerel, lemuru, yellow stripe shad, anchovies, flying fish, etc. This classification is intended to facilitate utilization and management, due to the different activity characteristics of these two fish groups.

One of the success factors in producing caught fish is accuracy in estimating fishing grounds (Fuadi, *et al.*, 2018). Successful fishing must pay attention to the fishing ground and oceanographic factors must also be considered because they influence the fishing location. According to Hafiz, *et al.*, (2017), the fishing ground area is greatly influenced by oceanographic factors, including Sea Surface Temperature (SST), and chlorophyll-a.

Temperature and chlorophyll-a greatly influence yield variability catch of marine biological resources, because temperature has a big influence on the biological metabolism of biota (Adnan, 2010 in Situmeang, 2022). Physically, SST can cause upwelling, which brings nutrients to the surface and makes a feeding ground for fish. At the same time, chlorophyll-a can be used as an indicator there is primary productivity for fish (Cahya, *et al.*, 2016).

Fishing areas can be determined if there is information about indicators that influence the existence of fish. The

indicators in question are food availability and oceanographic conditions of waters, for example sea surface temperature (SST) of waters and concentrations of chlorophyll-a parameter (Takwir, et al., 2021). So that, creating and processing forecasting maps of fish catch areas can be made by processing Aqua MODIS level 3 satellite image data, fishermen can find out about places that have the potential for fishing and find out the influence of oceanographic parameters related to fishing at that location (Mursyidin, 2019; Kuswanto, et al., 2017 in Syafira, et al., 2024). This research was carried out to determine the influence of chlorophyll-a and sea surface temperature (SST) parameters on catches of skipjack tuna (*Katsuwonus pelamis*) in Indian Ocean waters.

This research aims to: 1). To determine variations in SST distribution and chlorophyll-a concentration in Indian Ocean waters using Aqua MODIS imagery from June 2023-May 2024, 2). Analyzing the relationship between the distribution of SST and chlorophyll-a with the number of pelagic fish catches in the Indian Ocean waters.

## 2. Materials and Methods

### 2.1 Location and time of research

This research has been carried out at PPN Sibolga a fish landing site with a fishing ground location in the Indian Ocean waters near Nias Island and Tuangku Island strategically, this location waters has great potential in the fisheries sector. The time required for collecting and processing data in this research is from June 2023 to May 2024.

### 2.2 Source of Methode

The research method used is a field survey method and spatial analysis remote sensing spatial using the Aqua MODIS satellite. The stages in this research begin with data collection, with data sourced from remote sensing data, both data sourced from remote sensing data and fishery product statistics and then continue with data processing and analysis. The stages in this research can be seen in Figure 1.

### 2.3 Tools and Materials

The tools and materials used in this study were a set of instruments to facilitate and support the data collection process, data processing, and data analysis. The tools and materials used with their uses are presented in Table 1.

Table 1. Tools and Materials used in this study.

No.	Tools and Materials	Information
<b>Tools</b>		
1.	GPS	Used to find out the coordinate position of skipjack tuna fishing area.
2.	Camera	Used to take pictures needed
3.	Laptop	Media for analyzing data
<b>Materials</b>		
1.	ArcGIS 10.5	Used to map skipjack tuna fishing ground
2.	SeaDas 7.5.3	Get SST and chlorophyll-a concentration values.
3.	Microsoft Excel	Used for data analysis and graph creation.
4.	Aqua MODIS Image, 2022 level 3	As data to determine the distribution of SST and chlorophyll-a concentration distribution in waters
5.	Skipjack Tuna Catch Annual	Used to find out data on skipjack tuna catches.

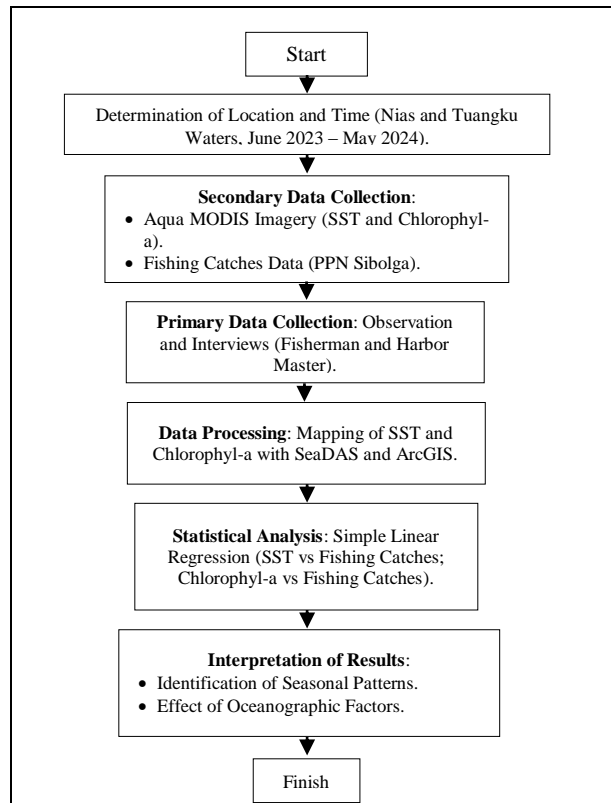


Fig 1. Research Flow Chart.

### 2.4 Data analysis

For research data analysis, 2 methods are used, namely:

#### 2.4.1 Data Collection Techniques

Research data collection techniques use 2 types, namely primary data and secondary data.

Primary data is directly obtained from a source and given to data collectors or researchers. The primary data source is an interview with research subjects through observation or direct observation (Sugiyono, 2016). This data was collected by interviewing fishermen and Harbor Master employees to obtain data and coordinates of skipjack tuna fish.

Secondary data was obtained from Sibolga Archipelago Fishing Harbor (Pelabuhan Perikanan Nusantara), namely the catch logbook 2023-2024. Level 3 (monthly) sea surface temperature (SST) and chlorophyll-a image data was taken from Aqua MODIS satellite for June 2023-Mei 2024, downloaded via NASA's official website, namely: <https://oceancolor.gsfc.nasa.gov/l3/>.

#### 2.4.2 Analysis of Simple Linear Regression

Simple linear regression analysis is an analytical tool used to measure the influence between the independent variable (X) and the dependent variable (Y) (Swarinoto, 2011). To see the SST distribution influence on the potential abundance of skipjack tuna, descriptive analysis was carried out in the form of thematic maps and simple linear regression analysis. The general equation of simple linear regression is as follows (Rahadian, et al., 2019):  $Y = a + bx$  where:

$Y$  = skipjack tuna catch,  $a$  = constant,  $b$  = regression coefficient,  $x$  = Sea Surface Temperature (SST).

In this way, can find out the relationship between sea surface temperature and chlorophyll-a on catches of skipjack tuna (*Katsuwonus pelamis*) through satellite imagery.

#### 2.4.3 Simple Linear Regression Test Terms

Data must be valid and reliable and come from primary data. And Data must pass normality tests and basic assumption tests.

#### 2.4.4 Basic for Decision Making Decision

Making a simple linear regression test can lead to two things, namely:

1. Compare the significance value with the probability value of 0,05. If the significance value is  $<0,05$ , it means that variable X affects variable Y. If the significance value is  $>0,05$ , it means that variable X does not affect variable Y.
2. Compare the calculated  $t\_value$  with  $t\_table$ . If the  $t\_count$  value  $> t\_table$ , it means that variable X affects variable Y. If the value of  $t\_count < t\_table$ , it means that the variable does not affect variable Y.

### 3. Result and Discussion

As a result of the interviews with fishermen and harbor master employees, obtained some information on fishing grounds, 10 fishing points were taken for fishing locations. These 10 fishing points will be used as a reference in the processing of SST and chlorophyll-a spatial data for estimating potential skipjack tuna fishing grounds, where on the map specified scale is 1:2.500.000 and the resolution on satellite imagery is 4 km. The fishing point is in the Indian Ocean waters just west of Tuangku Island.

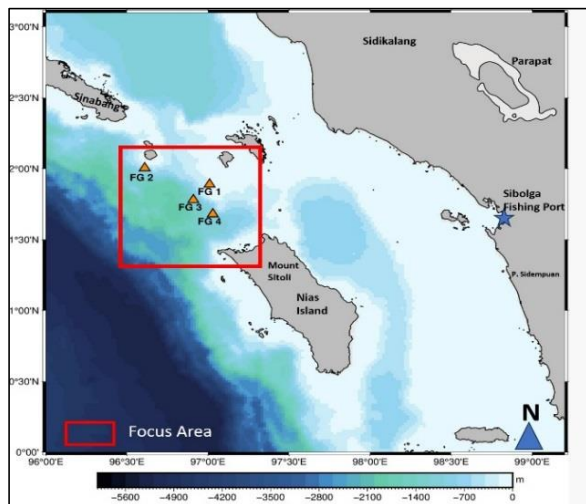


Fig 2. Skipjack Tuna Fishing Ground Estimation Map.

The fishing ground estimation map for skipjack tuna in Indian Ocean waters can be seen in Figure 2.

The success of the fishing process carried out by fishermen depends on the fishing ground. Knowing which fishing grounds are potential will make it easier for fishermen in the fishing process (Bukhari and Kurniawan, 2017 in Situmeang, 2022). Fluctuations in catch results can't be separated from several oceanographic factors that are optimal in these waters, namely sea surface temperature and chlorophyll-a. Fish will look for the optimum temperature in its body and chlorophyll-a is useful for chain process food in water.

#### 3.1 Sea Surface Temperature (SST) Distribution

SST is an oceanographic parameter needed by every aquatic organism to support various life processes for pelagic organisms. Data processed from Aqua MODIS imagery from June 2023-Mei 2024 has values that can be seen in Figure 3 and Table 2.

Based on the seasonal surface temperature variation graph, it can be seen that for October 2023, SST experienced fluctuations with the lowest value, namely 29,50 °C and the highest SST was in May 2024 at 31,68 °C. In August-October

2023, there will be a significant decrease in SST from 30,96 °C to 28,37 °C. According to Supriyadi and Hidayat (2020), sea surface temperatures tend to be lower during the east monsoon month (June-October). This condition occurs due to the influence of the monsoon winds. The average seasonal temperature distribution of Indian Ocean waters also changes with a range of 28,82-31,49 °C, where the highest value is in the Transition I season and the lowest value is in the Transition II season.

Table 2. Average SST for June 2023 - Mei 2024.

Average SST for June 2023 - May 2024			
SEASON	Month	A/M	A/S
EAST	June	31.73	
	July	30.71	31.10
	August	30.86	
TRANSITION II	September	29.59	
	October	29.50	29.15
	November	28.37	
WEST	December	29.87	
	January	30.96	30.75
	February	31.43	
TRANSITION I	March	31.92	
	April	31.32	31.64
	May	31.68	

Information:

\*A/M = Average per Month

\*A/S = Average per Season

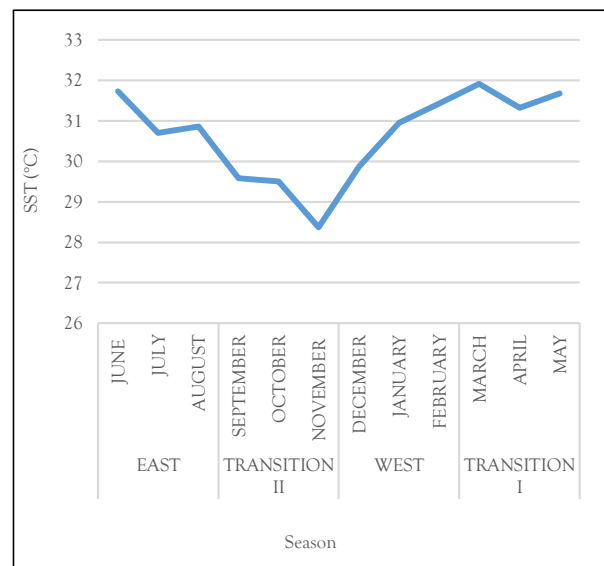


Fig 3. SST Fluctuations in the Indian Ocean waters (Source: Aqua MODIS, 2024).

#### 3.2 East Season SST Distribution

The east monsoon occurs in June-August, as mainland Asia experiences intense warming, becoming a center of low air pressure. Based on the results of image data processing, the spatial distribution of the east season SST can be seen in Figure 4 and Table 2. SST in Indian Ocean waters in 2023-2024 ranges

from 30,71-31,73 °C. The lowest SST will be in July 2023 and the highest in June 2023.

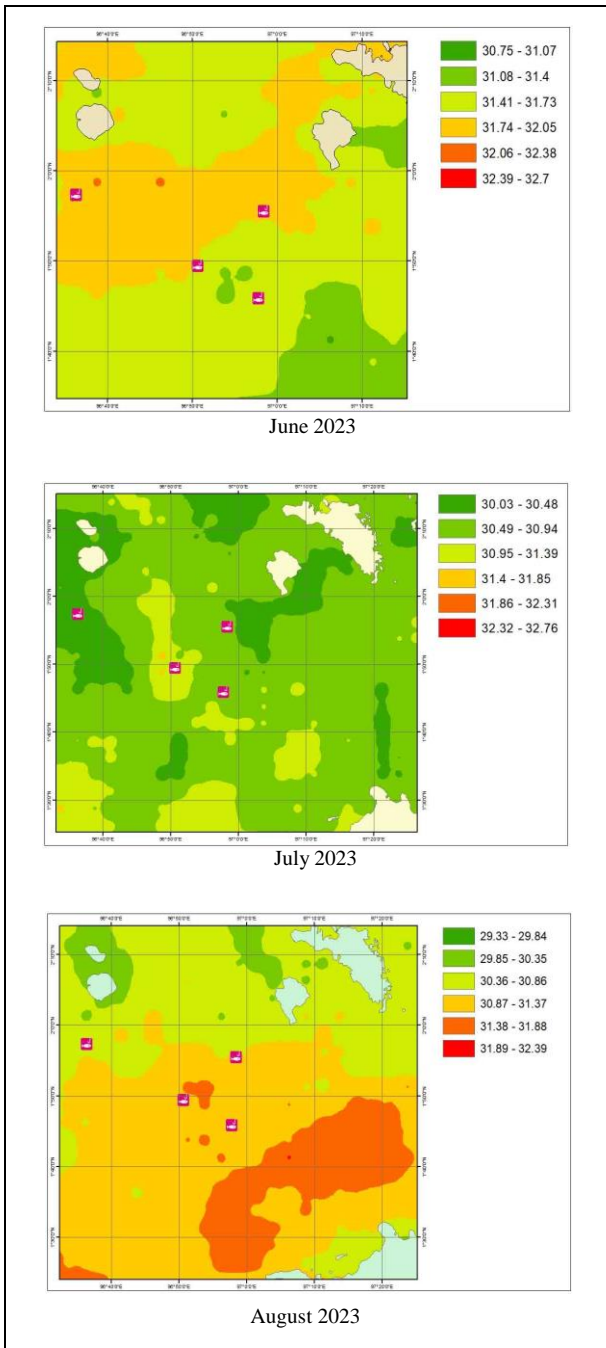


Fig 4. Distribution of the Eastern Season SST 2023-2024.

### 3.3 Transition II season SST Distribution

From the results of image data processing, the spatial distribution of SST for Transition II season can be seen in Figure 5 and Table 2. SST in Indian Ocean waters for 2023 ranges from 28,37-29,59 °C. The lowest SST will be in November 2023 and the highest SST will be in September 2023.

The transition II season is the lowest season average of 3 other seasons is with temperature of 28,37 °C. This happens because there is a change in frequency rain is quite frequent so it is a factor that can cause SST has decreased. It is known that this season is the rainy season (October to March). This is supported by Giarno, *et al.*, (2012) which states that the initial pattern of the rainy season using HOWI starts from the north

moves south, and zonally spreads from west to east. Meanwhile, the dry season begins from the south heading north.

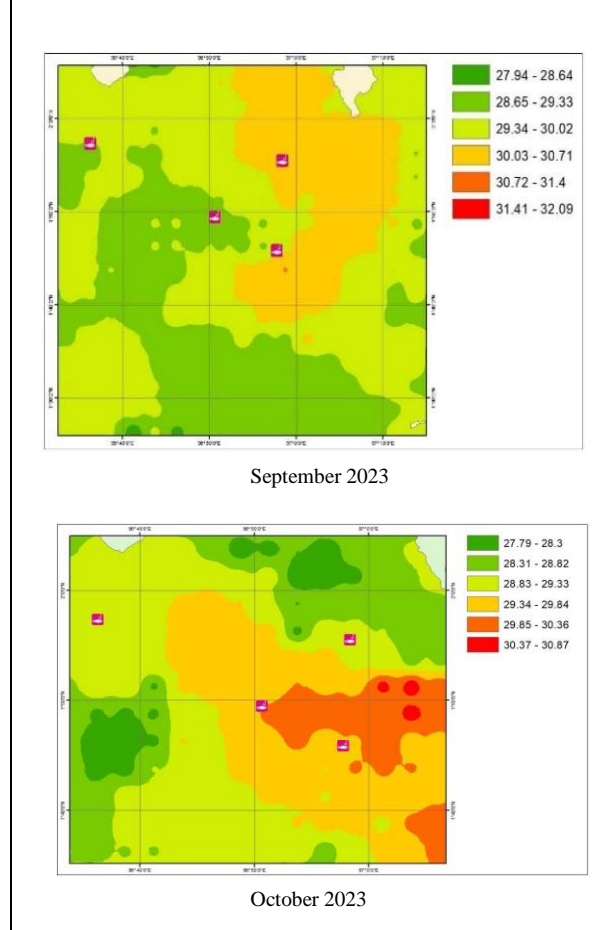


Fig 5. Distribution of SST for Transition II season 2023.

### 3.4 West Season SST Distribution

From the results of image data processing, the spatial distribution of the west season SST can be seen in Figure 6 and Table 2. The SST value in Indian Ocean waters for the West Season in 2023-2024 ranges from 29,87-31,43 °C. The highest value will be in February 2024 and the lowest will be in December 2023.

In December 2023-February 2024 is there west season where is this season is a west season of the relatively warm but in February 2024, SST level reaches 31,43 °C, due to the influence of the El-Nino phenomenon so temperature increases.

### 3.5 Distribution of SST for Transition I season

SST in Indian Ocean waters in March 2024-May 2024 enters Transition I season, ranging between 31,32-31,92 °C.

Figure 7 shows that the high SST and entry into Transition I season are the influence of the movement and speed of the west monsoon and east monsoon winds. SST is high in the Transition I season because the season transitions form strong winds. Therefore, SST still influenced by the western season, but it is starting to decrease. This in accordance with Bukhari and Kurniawan (2017) who stated that, transition I season (March-May) occurs due to a change in season from the west season to the east season, but there is still the influence of the west season whose speed has begun to decrease. The high temperature in transition I season is due to the sun being at the equator, causing the SST in transition I season to increase (Alfajri, *et al.*, 2017).

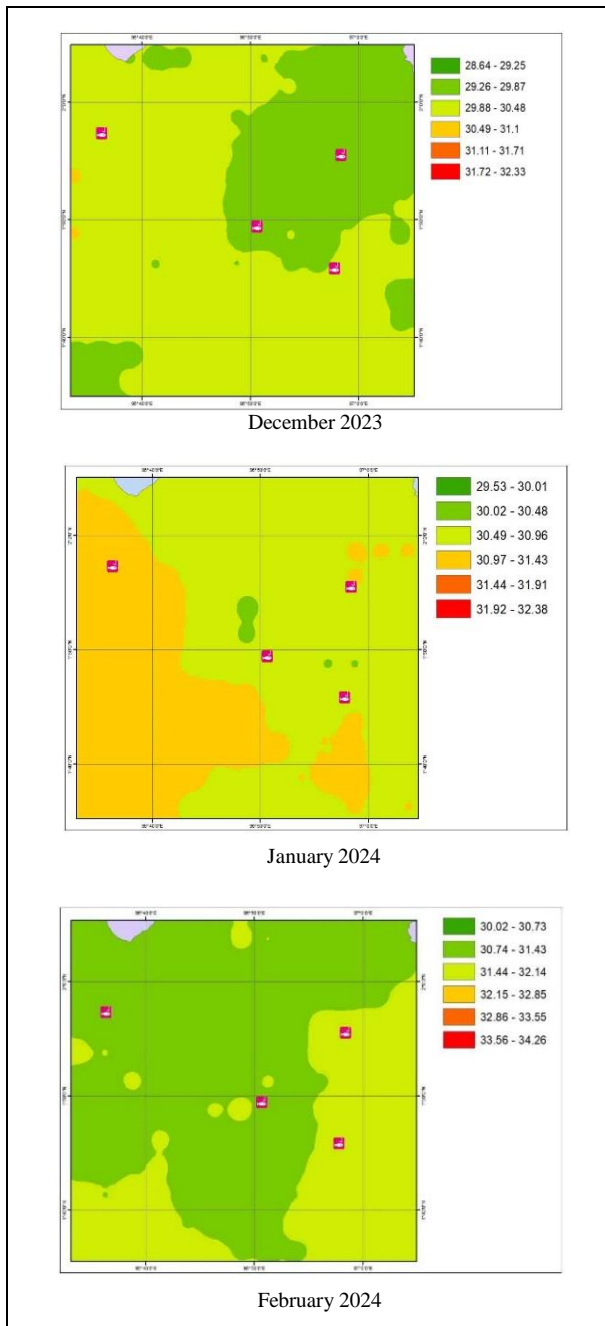


Fig 6. Distribution of SST for the West Season in 2023-2024.

### 3.6 Distribution of Chlorophyll-a Aqua MODIS Image.

In the pelagic food chain, the food chain starts from phytoplankton as a primary producer. This phytoplankton is at the first trophic level. Furthermore, herbivorous organisms such as zooplankton eat directly phytoplankton. These herbivores are then called then called level-two trophic organisms. They are also called primary consumers (Samiaji, 2018). Organisms on the third trophic level are small carnivores. They eat with how to utilize the energy produced by phytoplankton through primary consumers, so they are called secondary consumers. They eat small carnivores and utilize the energy produced by phytoplankton from secondary consumers or small carnivores, so they are called tertiary consumers (Bukhari and Kurniawan, 2017). Changes in distribution concentration chlorophyll-a followed by catch per month in each year is thought to be due to there being a time lag event in the food chain.

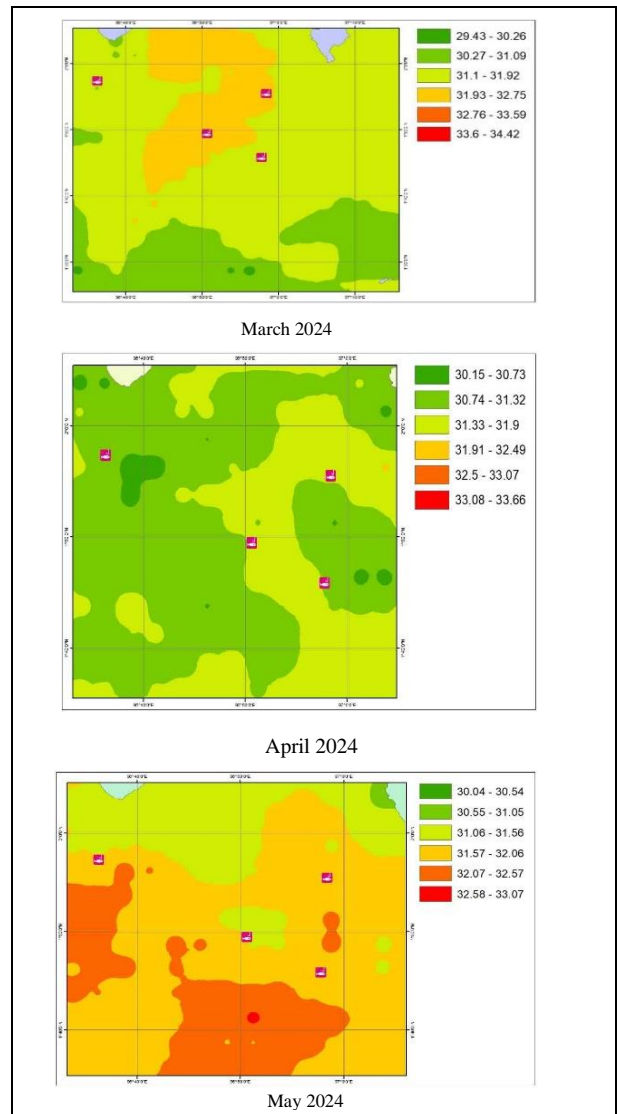


Fig 7. Distribution of SST for Transition I season in 2024.

The existence of a food chain system in waters creates mutual relationships and interdependence between species and other organisms, which is SST and chlorophyll-a are important indicators in the process food chain in a body of water. As said by Bukhari and Kurniawan (2017), the determination of potential fishing areas is based on three indicators, namely the number of fish, temperature, and chlorophyll-a.

Table 3. Average Chlorophyll-a for June 2023-May 2024.

Average Chlorophyll-a for June 2023 - May 2024			
SEASON	MONTH	A/M	A/S
EAST	JUNE	0.15415	
	JULY	0.28479	0.24
	AUGUST	0.2735	
TRANSITION II	SEPTEMBER	0.21449	
	OCTOBER	0.24415	0.44
	NOVEMBER	0.8495	
WEST	DECEMBER	1.1928	
	JANUARY	0.784	0.73
	FEBRUARY	0.21495	
TRANSITION I	MARCH	0.2222	
	APRIL	0.354	0.29
	MAY	0.30088	

Information:  
 \*A/M = Average per Month  
 \*A/S = Average per Season

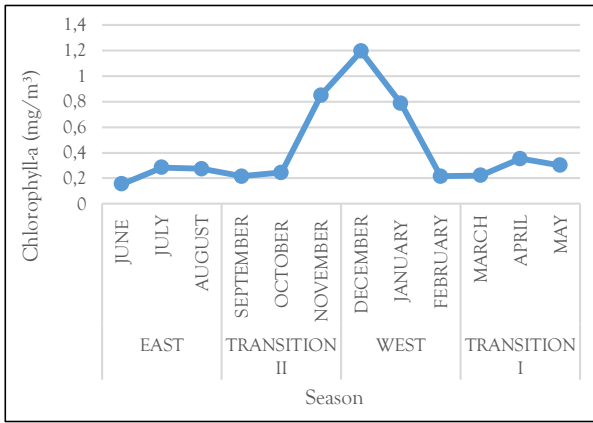


Fig 8. Fluctuations of Chlorophyll-a in Indian Ocean Waters.

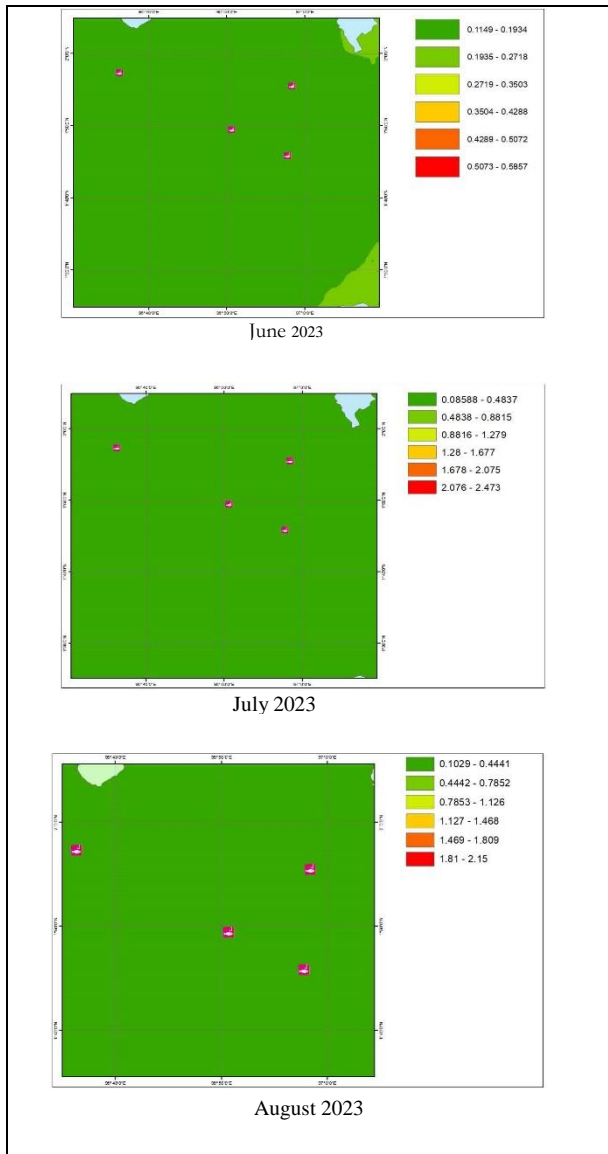


Fig 9. Spatial Distribution of Chlorophyll-a in the East Season 2023-2024.

The average value of the distribution of chlorophyll-a concentrations in Indian Ocean waters in seasonal changes also occurs with a range between 0,21449-1,1928 mg/m<sup>3</sup> where the highest value is in the West Season. Based on these dynamics, the waters of the Indian Ocean are categorized as having potential chlorophyll-a distribution.

The level of chlorophyll-a in the water will affect this water fertility level where the higher chlorophyll-a in the water, the level of fertility water is higher. This is followed by Kuswanto, *et al.*, (2017) which states that chlorophyll-a is one of the indications of water fertility. Fertile waters certainly contain chlorophyll-a high concentration.

Based on Figure 8, can see the monthly variations that illustrate seasonal characteristics of the chlorophyll-a concentrations that occur in Indian Ocean waters. Based on the graph of seasonal chlorophyll-a variations, variation of the chlorophyll-a distribution concentrations experienced fluctuations with the lowest value, namely 0,15415 mg/m<sup>3</sup> in June 2023 and the highest value in December 2023 of 1,1928 mg/m<sup>3</sup>. In Transition I season and II, chlorophyll-a distribution in Indian Ocean waters is rising.

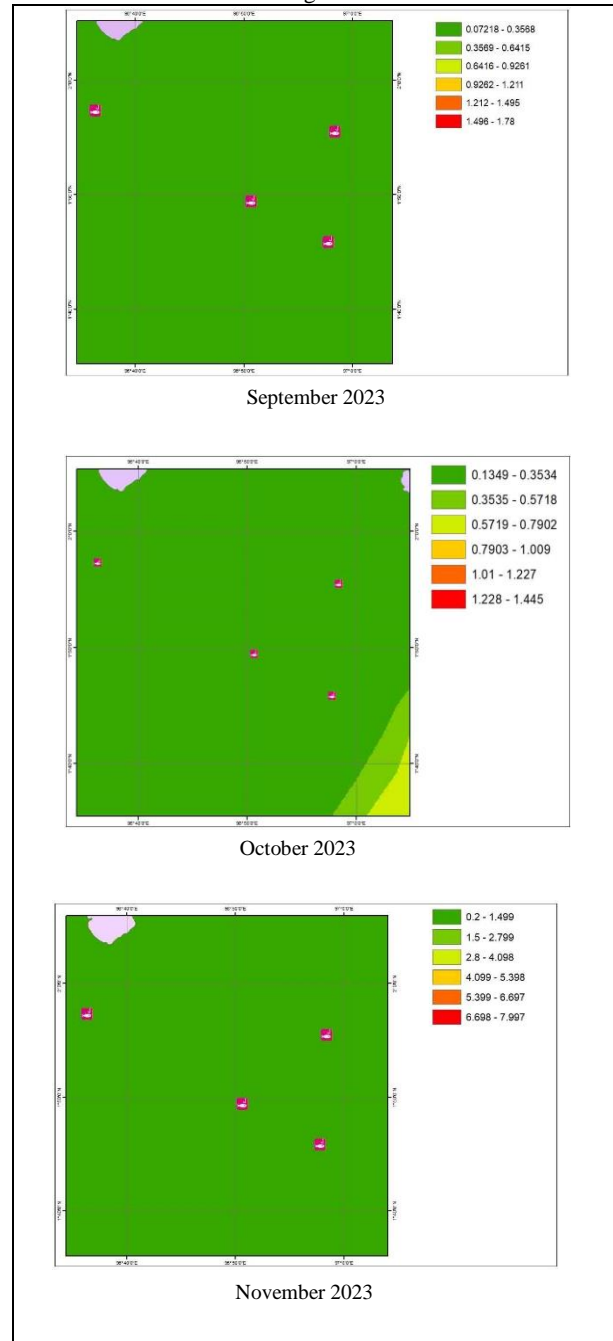


Fig 10. Spatial Distribution of Chlorophyll-a Transition II Season 2023.

### 3.7 East Season Chlorophyll-a Distribution

Based on image data processing results of the spatial distribution of chlorophyll-a during the east season can be seen in Figure 9. Chlorophyll-a distribution in Indian Ocean waters in 2023-2024 has the highest value in July 2023 at 0,28479 mg/m<sup>3</sup> and the lowest was in June 2023 with a value of 0,15415 mg/m<sup>3</sup>.

The abundance of chlorophyll-a in the east season and transition II season is thought to be caused by the East Season wind which causes emptiness masses along the waters which are then replaced by water masses from the deep sea carries a higher nutrient content (Supriyadi and Rahmat, 2019).

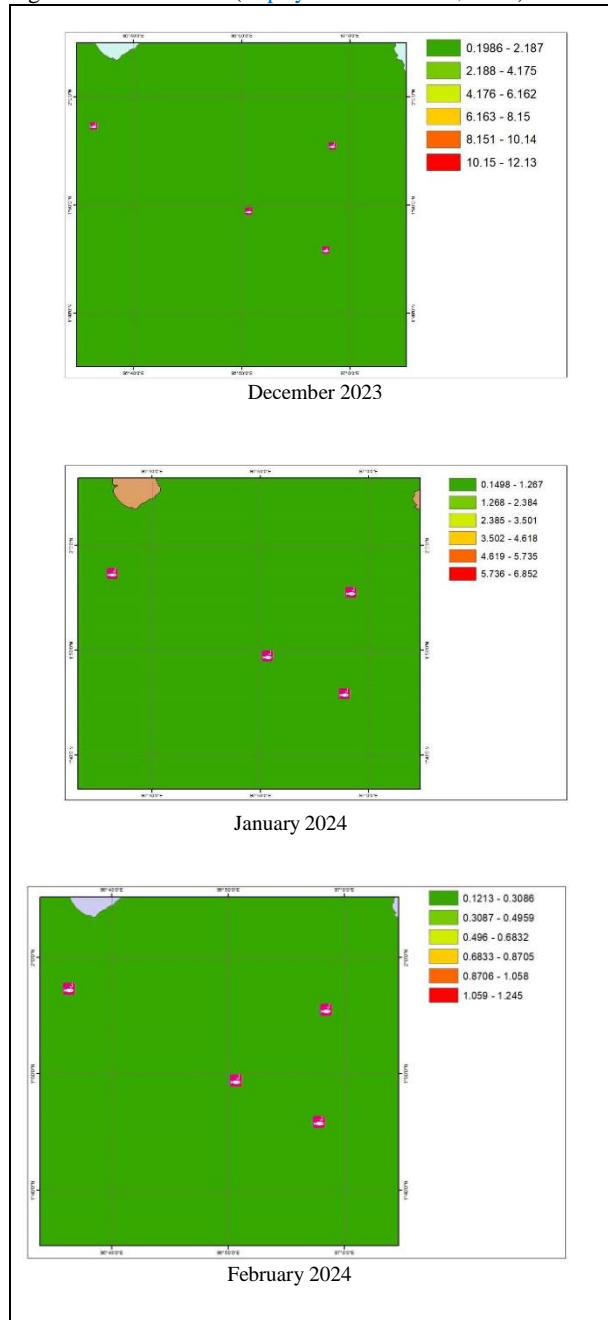


Fig 11. Spatial Distribution of Chlorophyll-a for the West Season in 2023-2024.

### 3.8 Transition II season Chlorophyll-a Distribution

The results of image data processing of the spatial distribution of chlorophyll-a in the Transition II Season can be seen in Figure 10. Distribution of chlorophyll-a in Indian Ocean waters in 2023 has the highest value in November 2023 of

0,8495 mg/m<sup>3</sup> and the lowest was in September 2023 with a value of 0,21449 mg/m<sup>3</sup>.

The phenomenon that causes chlorophyll-a to increase at transition II because this season the frequency of rainfall is sufficient. Allegedly on in these waters, nutrients increase as a result of vertical stirring at the bottom of the water towards the surface of the water so that it can increase chlorophyll-a on the sea surface. This follows the statement by Bukhari and Kurniawan (2017) which states that the increase in wind speed and rainfall in coastal areas can increase the rate of mixing of water masses from the seabed is rich in nutrients, and ultimately increases its value chlorophyll-a concentration.

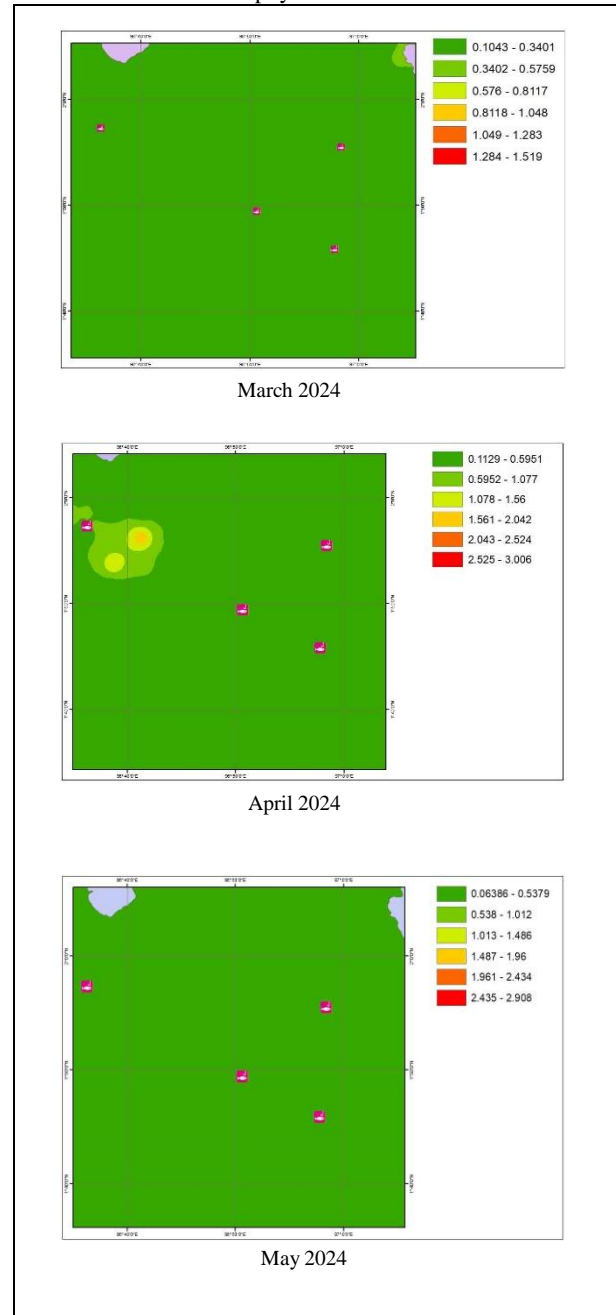


Fig 12. Spatial Chlorophyll-a Distribution in Transition I Season 2024.

### 3.9 West Season Chlorophyll-a Distribution

Based on the results of image data processing of the chlorophyll-a spatial distribution of the west season can be seen in Figure 11. Chlorophyll-a distribution in Indian Ocean waters in 2023-2024 had the highest value in December 2023 of 1,1928

mg/m<sup>3</sup> and the lowest value was in February 2024 of 0,21495 mg/m<sup>3</sup>.

In the west season, chlorophyll-a distribution tends to be the most abundant in areas near land, this occurs due to rivers flow that carry it nutrients and flows to the sea edge and causes the chlorophyll-a distribution increase. Intensive rain also affects the chlorophyll-a distribution during this season. In accordance with Sihombing, *et al.*, (2013) states that the high and low chlorophyll-a content is closely related to the nutrients supply which originates from land through rivers flow that empty into the waters.

### 3.10 Distribution of Chlorophyll-a for Transition I season

Based on the image data processing results of the chlorophyll-a distribution transition I season can be seen in Figure 12. Chlorophyll-a distribution in Indian Ocean waters in 2024 has the highest value in April 2024 was 0,354 mg/m<sup>3</sup> and the lowest was in March 2024 with a value in 0,2222 mg/m<sup>3</sup>.

In the transition I season, it is still influenced by the west season, however, the rainfall intensity begins to weaken resulting in the chlorophyll-a spread decreases in coastal areas and starts to increase in open waters (Rosmasita, *et al.*, 2016). According to the chlorophyll-a distribution map in May 2024, chlorophyll-a began to spread to open sea waters.

### 3.11 Skipjack Tuna Catch Results

The results used are Sibolga Archipelago Fishing Harbor (PPN) statistical data starting from June 2023 to May 2024 in Indian Ocean waters. The volume of catches landed at Sibolga Archipelago Fishing Harbor (PPN), especially for skipjack tuna commodities is presented in Figure 13. Skipjack tuna is one commodity landed at Sibolga Archipelago Fishing Harbor (PPN).

Table 4. Skipjack Catch Results in June 2023-May 2024.

SKIPJACK TUNA CATCH RESULTS JUNE 2023 - MAY 2024			
SEASON	MONTH	Number of Catches (Kg)	A/S
EAST	JUNE	12,678	907429
	JULY	1,437,724	
	AUGUST	1,271,886	
TRANSITION II	SEPTEMBER	940,845	1430161
	OCTOBER	1,920,006	
	NOVEMBER	1,429,632	
WEST	DECEMBER	2,023,543	1712355
	JANUARY	1,883,915	
	FEBRUARY	1,229,607	
TRANSITION I	MARCH	1,572,387	1595589
	APRIL	1,942,229	
	MAY	1,272,150	

Information: \*A/S = Average per Season.

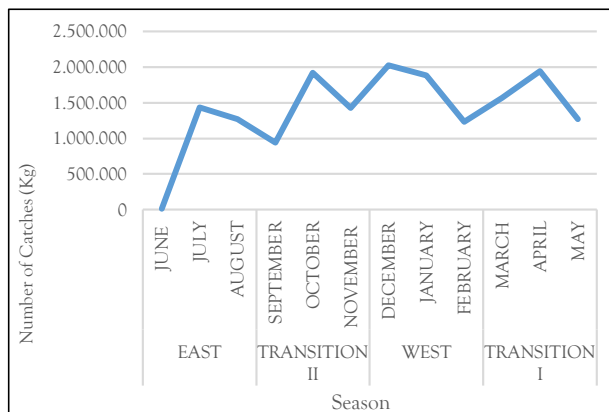


Fig 13. Fluctuations in the Number of Skipjack Tuna Catches.

The highest skipjack tuna occurred in December 2023 with a catch total was 2,023,543 kg, and the lowest in June 2023 with a value of 12,678 kg. The highest average number of seasonal catches in the west season an average value of 1,712,355 kg and the lowest in the east season with a value of 9,074,29 kg.

Changes in oceanographic factors can indicate distribution patterns of fish resources are uneven and also cause uncertainty in the numbers caught (Tangke, 2012). These oceanographic factors include plankton abundance, temperature, currents, salinity, and so on. According to the statement by Sahidi, *et al.*, (2015), utilization of oceanographic parameters such as temperature, salinity, and management of fish resources, especially in fishing efforts.

### 3.12 Relationship between SST with Chlorophyll-a and the number of Skipjack catches

To express the relationship between skipjack tuna catches with SST, a linear regression analysis was used, namely temperature (X) is the independent variable (Independent), while the skipjack catch (Y) is a variable bound (dependent).

Table 5. Relationship Between SST with Catch Results for June 2023-May 2024

Relationship Between SST and Catch Results for June 2023 - May 2024			
SEASON	MONTH	Number of Catches (Kg)	SST (°C)
EAST	JUNE	12,678	31.73
	JULY	1,437,724	30.71
	AUGUST	1,271,886	30.86
TRANSITION II	SEPTEMBER	940,845	29.59
	OCTOBER	1,920,006	29.50
	NOVEMBER	1,429,632	28.37
WEST	DECEMBER	2,023,543	29.87
	JANUARY	1,883,915	30.96
	FEBRUARY	1,229,607	31.43
TRANSITION I	MARCH	1,572,387	31.92
	APRIL	1,942,229	31.32
	MAY	1,272,150	31.68

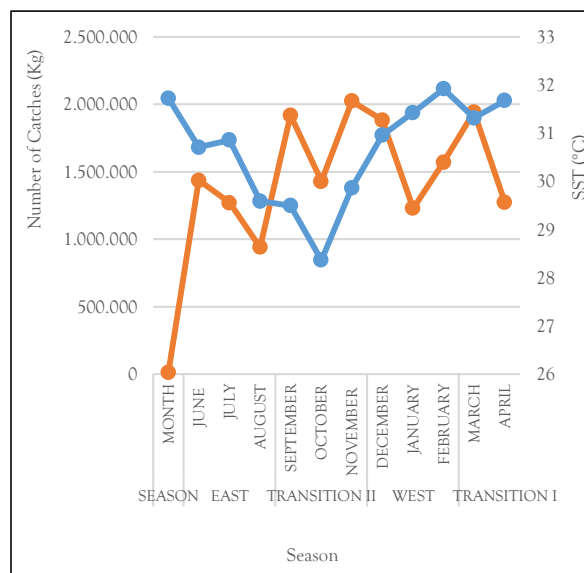


Fig 14. Fluctuations between SST with Number of Catches in 2023-2024.

In this research, the highest monthly average of skipjack tuna caught was temperature 30,71-31,92 °C (Figure 14).

### 3.13 Relationship between SST with Catch Results in East Season

SST

East Season

	df	SS	MS	F	Significance F
Regression	1	1.21353E+12	1.21353E+12	1110.0998	0.02
Residual	1	1093170070	1093170070		
Total	2	1.21462E+12			

In the linear regression analysis, the relationship between SST with skipjack tuna catches in the east season received a significance (F) value of 0,02, where SST affected skipjack tuna catches.

### 3.14 Relationship between SST with Catch Results in Transition II Season

SST

Transition II Season

	df	SS	MS	F	Significance F
Regression	1	2041276206	2041276206	0.0042764	1.0
Residual	1	4.77337E+11	4.77337E+11		
Total	2	4.79379E+11			

In the linear regression analysis, the relationship between SST with skipjack tuna catches in transition II season received a significance (F) value of 1,0, where SST affected skipjack tuna catches.

### 3.15 Relationship between SST with Catch Results in West Season

SST

West Season

	df	SS	MS	F	Significance F
Regression	1	2.50185E+11	2.50185E+11	2.2925173	0.4
Residual	1	1.09131E+11	1.09131E+11		
Total	2	3.59316E+11			

In the linear regression analysis, the relationship between SST with skipjack tuna catches in the West Season received a significance (F) value of 0,4, where SST did not affect skipjack tuna catches.

### 3.16 Relationship Between SST with Catch Results in Transition I Season

SST

Transition I Season

	df	SS	MS	F	Significance F
Regression	1	93165833463	93165833463	0.7050296	0.6
Residual	1	1.32145E+11	1.32145E+11		
Total	2	2.2531E+11			

In the linear regression analysis, the relationship between SST with skipjack tuna catches in transition I season received a significance (F) value of 0,6, where SST affected skipjack tuna catches.

The high correlation between SST and the number of skipjack tuna catches in the west-east season is thought to be because the skipjack tuna distribution in a water area is not only influenced by one particular oceanographic factor. It is possible that the fish distribution in one place on predominantly influenced by SST, but in other areas the influenced distribution is influenced by other oceanographic factors (Gaol, *et al.*, 2014). The low correlation between SST and the number of skipjack tuna catches in the East season is thought to be due to the temperature in that season being optimum for skipjack tuna bodies, where the results from satellite imagery for the

transition II season, SST is 28,37-29,59 °C. This is confirmed by Mulyadi, *et al.*, (2017) who stated that the water temperature preferred by skipjack tuna is around 18-31 °C and skipjack tuna spawn, as stated by Bramantya, *et al.*, (2021) that, skipjack tuna spawn in July-November in tropical and subtropical water spread across three oceans, namely the Atlantic, Pacific, and Indian Oceans.

Sea surface temperature significantly contributes to fish growth, mobility, and activity, migration, distribution, abundance, maturation, egg fecundity, and hatching and fish larva survival ability (Tadjuddah, 2005). Sea surface temperature is taken as an indicator to predict organism presence in the water body, mainly fishes since most organisms are poikilothermic (Fajrianti and Musbir, 2016).

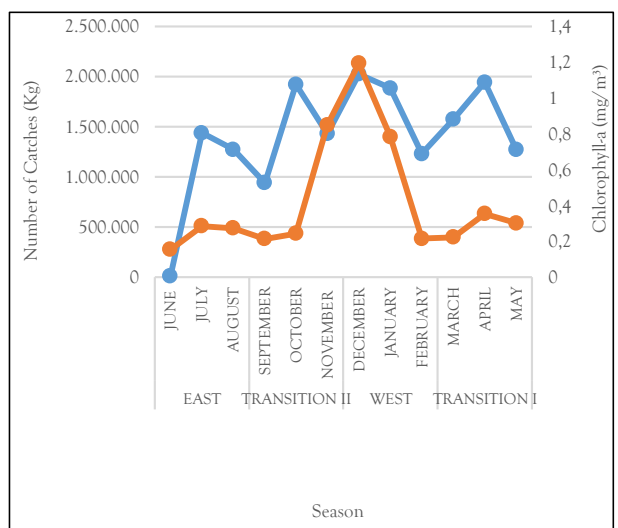
Besides being an indicator of climate change phenomena, the temperature is also an oceanographic factor that plays an essential role in organisms' lives by influencing their metabolic activity and also plays a role in sea organisms' development. Sea surface temperature also characterizes the mass of seawater and its relation to seawater layer condition, which is used to analyze any existing phenomena in the sea (Cahya and Surinati, 2016 in Tangke, *et al.*, 2019).

### 3.17 Relationship Between Chlorophyll-a and the number of Skipjack Tuna Catches

To express the relationship between skipjack tuna catches with chlorophyll-a, a linear regression analysis was used, namely chlorophyll-a (X) is the independent variable (Independent), while the skipjack catch (Y) is a variable bound (dependent).

Table 6. Relationship Between Chlorophyll-a and Catch Results for June 2023-May 2024.

SEASON	MONTH	Number of Catches (Kg)	Chlorophyll-a (mg/m <sup>3</sup> )
EAST	JUNE	12,678	0.15415
	JULY	1,437,724	0.28479
	AUGUST	1,271,886	0.2735
TRANSITION II	SEPTEMBER	940,845	0.21449
	OCTOBER	1,920,006	0.24415
	NOVEMBER	1,429,632	0.8495
WEST	DECEMBER	2,023,543	1.1928
	JANUARY	1,883,915	0.784
	FEBRUARY	1,229,607	0.21495
TRANSITION I	MARCH	1,572,387	0.2222
	APRIL	1,942,229	0.354



MAY	1,272,150	0.30088
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Fig 15. Fluctuations between Chlorophyll-a and Catch Results in 2023-2024.

Figure 15 and Table 6 show monthly fluctuations in the chlorophyll-a distribution with results of catches of skipjack tuna in the Indian Ocean waters in 2023-2024. Analysis results show a change, where the highest concentration distribution is in December 2023 with a value of 1,1928 mg/m<sup>3</sup> followed by the yield value catch of 2,023,543 kg while the lowest concentration was in June 2023 with a value of 0,15415 mg/m<sup>3</sup> followed by a catch of 12,678 kg.

### 3.18 Relationship between Chlorophyll-a and the Number of East Season Catches

Chlorophyll-a  
East Season

	df	SS	MS	F	Significance F
Regression	1	1.21363E+12	1.21363E+12	1227.038	0.02
Residual	1	989074080.5	989074080.5		
Total	2	1.21462E+12			

In the linear regression analysis, the relationship between chlorophyll-a with skipjack tuna catches in the east season received a significance (F) value of 0,02, where chlorophyll-a affected skipjack tuna catches.

### 3.19 Relationship between Chlorophyll-a with Catch Results in Transition II Season

Chlorophyll-a  
Transition II Season

	df	SS	MS	F	Significance F
Regression	1	784246519.3	784246519.3	0.001639	1.0
Residual	1	4.78594E+11	4.78594E+11		
Total	2	4.79379E+11			

In the linear regression analysis, the relationship between chlorophyll-a with skipjack tuna catches in the east season received a significance (F) value of 1,0, where chlorophyll-a affected skipjack tuna catches.

### 3.20 Relationship between Chlorophyll-a and the Number of West Season Catches

Chlorophyll-a  
West Season

	df	SS	MS	F	Significance F
Regression	1	3.34886E+11	3.34886E+11	13.70783	0.2
Residual	1	24430285402	24430285402		
Total	2	3.59316E+11			

In the linear regression analysis, the relationship between chlorophyll-a with skipjack tuna catches in the east season received a significance (F) value of 0,2, where chlorophyll-a affected skipjack tuna catches.

### 3.21 Relationship Between Chlorophyll-a with Catch Results in Transition I Season

Chlorophyll-a  
Transition I Season

	df	SS	MS	F	Significance F
Regression	1	46576672429	46576672429	0.260593	0.7
Residual	1	1.78734E+11	1.78734E+11		
Total	2	2.2531E+11			

In the linear regression analysis, the relationship between chlorophyll-a with skipjack tuna catches in the east season received a significance (F) value of 0,7, where chlorophyll-a affected skipjack tuna catches.

The oceanographic indicators may correspond well with the potential feeding ground for skipjack tuna (Zainuddin, et al., 2013 in Putri and Zainuddin, 2019).

Sea surface temperature and chlorophyll-a can have a very large impact on determining potential fishing zones (Hidayat, et al., 2019; Hidayat, et al., 2019). This can be attributed to food availability and the resilience of fish to environmental temperatures. Many other factors also influence the distribution of fish in marine waters. Associated with the distribution of FADs, water depth can be a very influential factor (Cayre, 1991 in Hidayat, et al., 2019).

Ramlah, et al., (2020) in Nurani, et al., (2022) added that CPUE differences could occur due to several factors such as the fishing gear used, variations in fishing gear, fishing grounds, fishing time, recording and reporting of catches, and natural factors such as seasons and oceanographic conditions.

Fish life patterns are influenced by oceanographic parameters such as temperature, salinity, currents, and chlorophyll-a concentration. Each type of fish has a habitat with different oceanographic conditions to support optimal life. Oceanographic conditions, especially sea surface temperature and chlorophyll-a content, affect fish distribution in their habitat and are an indicator for potential fishing grounds and fishing season (Karman, et al., 2016).

## 4. Conclusion

Spatially and temporally, the distribution of sea surface temperature in Indian Ocean waters in 2023-2024 between 29,15-31,64 °C on June 2023-May 2024 experiences a significant decrease in temperature from 31,10-29,15 °C due to east monsoon winds and distribution chlorophyll-a ranges from 0,24-0,73 mg/m<sup>3</sup> with the highest average distribution in west season. The phenomenon causes chlorophyll-a to increase in the western season due to the frequency of rainfall in this season sufficient rain causes nutrients to increase as a result of vertical stirring so that it can increase chlorophyll-a in sea level.

The relationship between sea surface temperature and the number of skipjack tuna catches is in the transition II season with a strong correlation value and a significance (F) value of 1,0. The chlorophyll-a relationship with the number of skipjack tuna catches in each season is non-existent this significant influence is thought to be a time lag event food chain.

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