Asian Journal of Aquatic Sciences, April 2024. Vol 7, Issue (1) 8-18

e-issn: 2716-4608
p-issn: 2655-366X

ANALYSIS OF CHLOROPHYLL-α AND SEA SURFACE TEMPERATURE DISTRIBUTION USING SATELITE IMAGE TO ESTIMATE OF FISHING ZONES FOR YELLOWFIN TUNA (*Thunnus albacares*) IN WEST SUMATERA PROVINCE WATERS

Fandi Handika Arta[1], Mubarak[2], Syafruddin Nasution[2]
[1]Fisheries Resource Utilization Study Program, Sekolah Tinggi Perikanan Sibolga, Sibolga, 22531 Indonesia
[2]Department of Marine Science, Faculty of Fisheries and Marine, Universitas Riau, Pekanbaru, 28293 Indonesia
*fandi.arta@gmail.com

ABSTRACT

The potential of tuna in the waters of West Sumatra reaches 300,000 tons per year, and only 25% of its existing potential has been exploited. The existence of these fish can be determined by measuring the concentration of chlorophyll-α as an indicator of food sources in the waters and measuring sea surface temperature as an indicator of the fish environment, which can be done using remote sensing technology. This research was conducted from August 05 to September 29, 2022, using Aqua MODIS satellite imagery data. The results obtained during the study showed that the concentration of chlorophyll-α had an average of 2.01 mg/m^3. The highest concentration occurred in the period 13-20 August 2022 with an average value of 3.17 mg/m^3, and the lowest occurred in the period 06-13 September 2022 with an average value of 0.85 mg/m^3. Sea surface temperature has a relatively similar value, which ranges from 29.5–30.8^{o}C with an average of 30.5^{o}C. Determination of the alleged fishing area for yellowfin tuna was carried out using the overlay technique by shading the area from chlorophyll-a criteria >0.1 mg/m^3 with the sea surface temperature criteria of 29-30^{o}C. The accuracy level of the yellowfin tuna fishing area estimation has an average accuracy of 28.7%. The highest accuracy value occurs from August 29 to September 05 2022, with a percentage of 69.8%, and the lowest occurs from August 13 to 20, 2022, with a rate of 3.9%.

Keywords: Chlorophyll-α, Sea surface temperature, Fishing zones, Satelite image

1. INTRODUCTION

Tuna is a large pelagic fish with relatively high economic value and is one of Indonesia's export commodities, especially in the West Sumatra Province. Data from the West Sumatra Province Maritime and Fisheries Service (DKP) notes that the potential for tuna fish in West Sumatra Sea waters reaches 300,000 tons annually. However, only around 25% or 75 tons of this amount are harvested by local fishermen. Among the tuna caught, two types of tuna have great potential, namely yellowfin tuna (*Thunnus albacares*), reaching 43.3 tons per year, and big eye tuna (*T.obesus*), having a catch potential of 31.7 tons per year.

One type of tuna mainly caught in West Sumatra's seawater is yellowfin tuna. This fish is a type of large pelagic fish that lives at the sea surface up to the upper limit of the thermocline layer and is an economically important type of fish better known as yellowfin fish[1].

The existence of yellowfin tuna is dynamic, constantly changing or moving according to changes in environmental conditions, which naturally means the fish chooses fertile water conditions characterized by the abundance of food

Received : 15 January 2024
Accepted : 2 March 2024

sources from this fish. This food source is characterized by high phytoplankton biomass in a water area. The existence of phytoplankton can be used as a source of information in knowing fishing areas because phytoplankton have an essential role in the food chain cycle. Phytoplankton biomass can be calculated by estimating the concentration of chlorophyll-α[2]. Chlorophyll-α is a green pigment that absorbs the most sunlight. This sunlight is used in photosynthesis reactions as reaction activation energy.

Variations strongly influence the distribution and abundance of yellowfin tuna in temperature parameters and water depth. In general, yellowfin tuna likes waters above the thermocline layer. High-temperature changes can cause yellowfin tuna to leave this layer[1]. Sea surface temperature in waters is one of the external factors in the distribution of yellowfin tuna. Yellowfin tuna is generally distributed in waters with a temperature range between 21– 31^{o}C[3].

Generally, fishermen in West Sumatra still use traditional methods in determining fishing areas, namely looking for signs from nature, such as the occurrence of ripples in the water and the gathering of birds on the surface of the water, so that when fishing, fishermen must look for fishing areas. Based on signs from nature. This causes uncertainty in catch results, ineffective time spent during the fishing process, and high operational costs that must be incurred during the fishing process.

Using Geographical and Information Systems (GIS) technology is the right way in the fishing process because it will make the fishing process more effective and increase fishermen's catches. One method that can be used is remote sensing. Remote sensing is a science that studies how to obtain information from remote measurements without direct contact with the object. Remote sensing can analyze the chlorophyll-α concentration and sea surface temperature in a body of water without touching the object directly.

2. RESEARCH METHOD

Time and Place

This research was carried out from August 05 to September 29 2022. The research study area covers the entire sea area of West Sumatra.

Tools and Materials

The tools used during the research were a laptop, plankton net, thermometer, GPS, vacuum pump, centrifuge tube, spectrophotometer, millipore paper, refrigerator and grinder. Meanwhile, the materials used in this research were chlorophyll-α and SPL image data, Seadas software, ArcMap software, 90% acetone, and magnesium carbonate.

Method

The method used in this research is a survey method. The analysis used in this research uses descriptive analysis.

Chlorophyll-α Image Data and Sea Surface Temperature

Data was used for analysing chlorophyll-α concentration and sea surface temperature from Aqua MODIS imagery with a spatial resolution of 1km and a temporal resolution of 8 days from August 05 to September 29 2022. Data was downloaded via the Ocean Color website. Other data used is 2019 Indonesian digital map data from the Geospatial Information Agency as a base map.

Water Sampling for Chlorophyll-α Measurement

Determination of stations was carried out by purposive sampling. Sampling was carried out to validate previous chlorophyll-a image data. Sampling was carried out at 5 station points with three repetitions. Water samples were taken to carry out laboratory scale chlorophyll-a measurements, which were carried out by filtering seawater using 1L plankton. Then, the water samples are put into an ice box for further analysis at the Marine Chemistry Laboratory.

In Situ Sea Surface Temperature Measurement

Sea surface temperature is measured directly using a thermometer. Measurements were carried out at 5 station points with three repetitions. The measurement results obtained are used to validate the analysis of sea surface temperature image data that has been analyzed previously.

Fish Catch Data

Yellowfin tuna catch data was obtained from the Directorate General of Capture Fisheries, Sub. Fish Resources Management, Ministry of Maritime Affairs and Fisheries. This includes logbook data for catching yellowfin tuna in the WPP 572 fishing area.

Data Analysis

Processing of Chlorophyll-α Values and Sea Surface Temperature

Data on chlorophyll-α image values and sea surface temperature that have been filtered are then input into the ArcMAP 10.3 application. After inputting the data, the next step is to create a distribution map by selecting the 3D Analyst Tool menu and then selecting Raster Interpolation. Furthermore, the data on chlorophyll-a values and sea surface temperature is presented in map form and displays the distribution of chlorophyll-α and sea surface temperature.

Determination of Yellowfin Tuna Fishing Areas

Determining fishing areas for yellowfin tuna is carried out using an overlay technique by combining maps from analysis of the distribution of chlorophyll-a and sea surface temperature, then shading the area with the provisions of chlorophyll-a >0.1 mg/m^3 and sea surface temperature of 29-30^{o}C as criteria, yellowfin tuna fishing area. The results of this shading are used as information to estimate yellowfin tuna fishing areas.

Accuracy Testing of Yellowfin Tuna Fishing Areas

After obtaining data on suspected yellowfin tuna fishing areas, the accuracy of the data was then tested by combining previously analyzed tuna fishing area data with data on yellowfin tuna fishing location points obtained from the logbook of the Ministry of Maritime Affairs and Fisheries in the WPP 572 area. Next, calculate the number of fishing points included in the shaded yellowfin tuna fishing area, divide it by the total existing fishing point data, and put it as a percentage.

Chlorophyll-α Sample Analysis

The water samples that have been taken are then analyzed for chlorophyll-a concentration using the spectrophotometric method referring to Boyd[4] as follows:

Chlorophyll-α content: (mg/L)

$$11.9\ C\frac{v}{L}\ x\ \frac{1000}{s}$$

Where:

C = Reading value spectrophotometer (665-750 nm)

V = Extraction acetone used (mL)

L = Cuvette diameter (cm)

S = The volume of a filtered sample (mL)

Validate Image Data with Laboratory and Insitu Data

Data validation is used to determine whether there are differences between image data and data from laboratory analysis (chlorophyll-α) and in situ measurements (sea surface temperature). The test carried out is using the T Test.

3. RESULT AND DISCUSSION

Distribution of Chlorophyll-α

Fertile waters contain high concentrations of chlorophyll-α because chlorophyll-a indicates fertility in waters. Chlorophyll-α concentrations are also strongly influenced by currents in these waters. Using satellite image data, namely

e-issn: 2716-4608
p-issn: 2655-366X

chlorophyll-α and sea surface temperature, is essential because it has proven to be a productive fishing area[5].

The chlorophyll-α distribution in West Sumatra's sea waters was analyzed using satellite image data. The distribution of chlorophyll-α was analysed using Ocean Color Aqua MODIS level-3 data at a spatial resolution of 4km for eight days from August 05 to September 29 2022. The results of image data processing are presented in Figures 1 – 7.

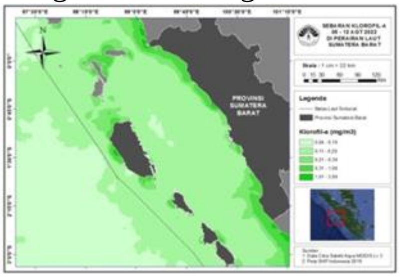
Figure 1. 05-12 August 2022

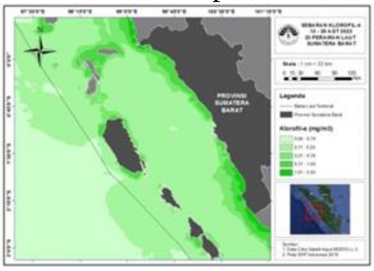
Figure 2. 13-20 August 2022

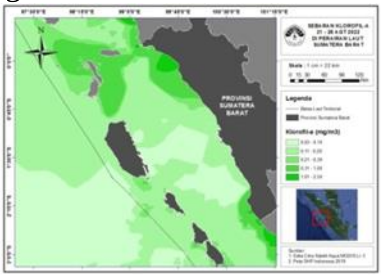
Figure 3. 21-28 August 2022

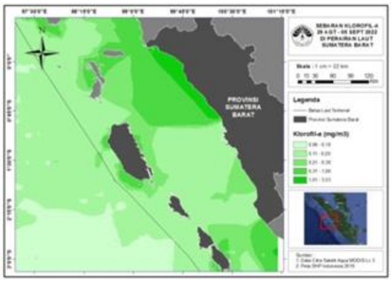
Figure 4. August 29 – September 05, 2022

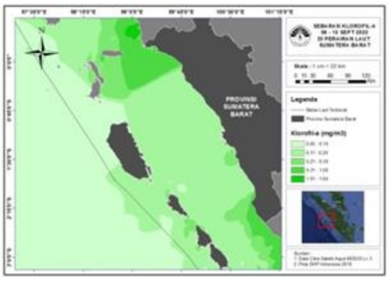
Figure 5. 06-13 September 2022

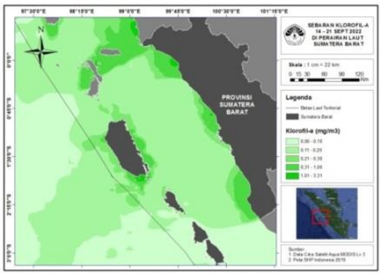
Figure 6. 14-21 September 2022

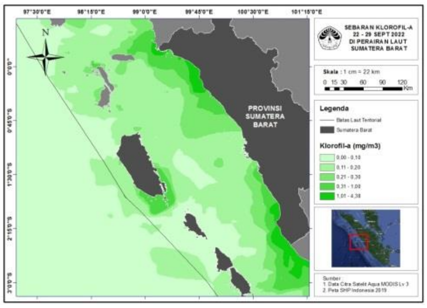
Figure 7. 22-29 September 2022

The image analysis results show that chlorophyll-α found in the sea waters of West Sumatra have different distributions in each region. Distribution with high concentrations is found in the coastal waters of West Pasaman Regency, Pesisir Selatan Regency and the waters of Siberut Island. In contrast, concentrations tend to be lower in open sea areas than in coastal areas. This is suspected to be the supply of nutrients carried through rivers such as the Batang Tomok River in West Pasaman Regency, the Rumbai River on the Pesisir Selatan or Bengkulu Border and Muara Siberut on Siberut Selatan Island. According to Nybakken[6,] the concentration of chlorophyll-α in coastal waters is higher due to the supply of nutrients through river run-off from land, while the low concentration of chlorophyll-α in offshore waters is due to the absence of a direct supply of nutrients from land. Direct. The chlorophyll-α concentration value from the results of satellite image analysis can be seen in Table 1.

Table 1. Temporal Chlorophyll-α Concentration Values

No.	Time (2023)	Chlorophyll-α concentration (mg/m^3)		
		Min	Maks	Average
1	05-12 Aug	0.03	4.68	2.35
2	Aug. 13-20	0.03	6.32	3.17
3	Aug. 21-28	0.03	3.76	1.89
4	August 29 – September 05	0.05	3.53	1.79
5	Sept. 6-13	0.05	1.64	0.85
6	Sept. 14-21	0.03	3.31	1.67
7	Sept. 22-29	0.05	4.57	2.31

Source: Ocean Color Satellite Image Data

Chlorophyll-α concentrations from August 05 to September 29 2022, fluctuated each period. The highest concentration occurred from 13 to August 20 with an average value of 3.17 mg/m^3, and the lowest occurred from 06 to September 13 with an average of 0.85 mg/m^3. The distribution of chlorophyll-α concentrations tends to be inhomogeneous and has different values for each pixel. This is thought to be due to environmental influences such as temperature, currents and the amount of nutrients entering the waters, which cause the concentration of chlorophyll-α to fluctuate.

Nontji[7] said that temperature can affect photosynthesis either directly or indirectly. The direct effect is due to enzymatic chemical reactions that play a role in photosynthesis. Indirect influence because temperature will determine the hydrological structure of waters where phytoplankton reside. Furthermore, Nontji[8] said that phytoplankton can develop optimally in the temperature range of 20 °C to 30 °C, or on average at 25 °C. The distribution of sea surface temperature is influenced by the amount of heat received from sunlight, where the water area that gets the most sunlight is the water area close to 0 latitude, which will influence the life of chlorophyll-α in the water.

Siagian[9] said that the distribution of phytoplankton and chlorophyll-α differs in each ocean and place, and it is greatly influenced by season, geographical location, and temperature. Coastal areas are rich in phytoplankton compared to the open ocean due to the mixing process in coastal waters and regions.

Validation of Image Data with Laboratory Analysis

The chlorophyll-α concentration value obtained from the image analysis results is then tested for the accuracy of the value by comparing the value contained in the image with the value resulting from laboratory analysis. Sampling was carried out at 5 station points with a total of three repetitions, and the station points were determined to represent the study area. The results of the image data accuracy test with laboratory analysis results can be seen in Table 2.

Table 2. Chlorophyll-α Values from Satellite Images and Laboratory Analysis

Station	Location	Coordinate		Satellite Imagery (mg/m^3)	Laboratory (mg/m^3)
		Longitude	Latitude		
1	Teluk Bayur Harbor	100.358282	-1.010630	0.4469	0.3821
2	Teluk Buo PLTU	100.348764	-1.076303	0.3747	0.3610
3	PPS Bungus	100.394449	-1.051557	0.4287	0.4254
4	High seas	100.345432	-1.152446	0.2954	0.3150
5	Residential Beach	100.380458	-1.153779	0.3210	0.3317
Average				0.3733	0.3630

After image analysis and laboratory analysis, a T-test was carried out to see whether there were differences between satellite image data and laboratory analysis data. If the Sig value is > 0.05, the results are no different, and if the Sig value is < 0.05, the results are different.

The results of the T-test showed a significant value of 0.524. It can be concluded that there is no difference between the chlorophyll-a values from satellite images and the results of laboratory analysis, so satellite image data can be used as a reference to determine the chlorophyll-a values in the field with quite good results

Distribution of Sea Surface Temperature

Solar radiation occurs yearly, and the sun's position constantly changes. This change in the sun's position influences temperature changes in Indonesian waters. The difference in air pressure on the Asian and Australian Continents also influences temperature changes in Indonesian waters between the two continents[10]. The image analysis results can be seen in Figure 8-14.

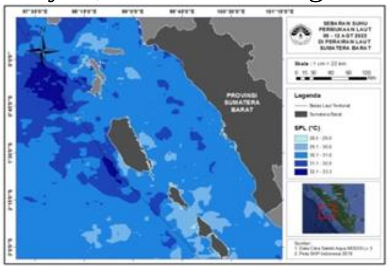

Figure 8. Period 05-12 August 2022

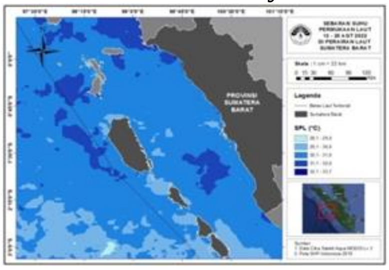

Figure 9. Period 13-20 August 2022

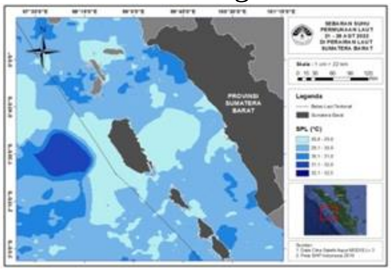

Figure 10. Period 21-28 August 2022

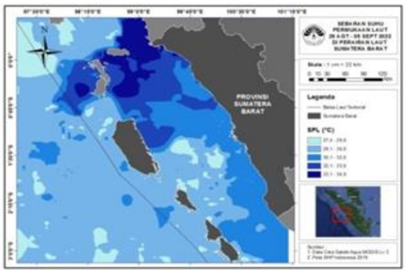

Figure 11. Period August 29 – September 05, 2022

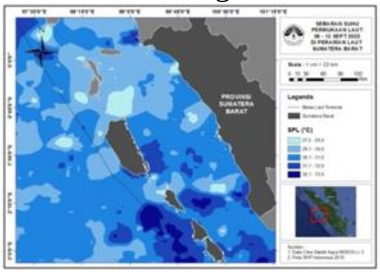

Figure 12. Period 06-13 Sept 2022

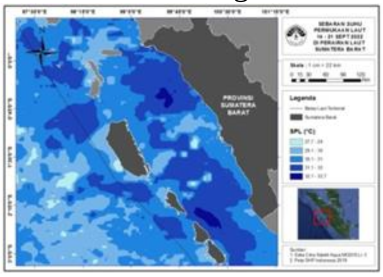

Figure 13. Period 14-21 Sept 2022

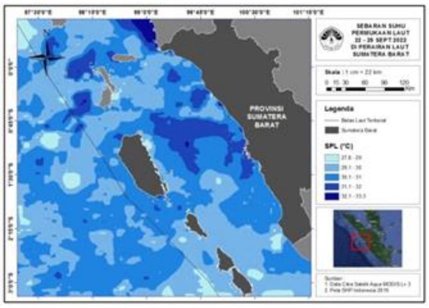

Figure 14. Period 22-29 Sept 2022

The image analysis results show that the distribution of sea surface temperatures in the sea waters of West Sumatra is uneven. The movement of water masses has a significant influence in determining the distribution of sea surface temperatures. Sea surface temperature values can be seen in Table 3.

Based on the analysis results, sea surface temperatures range between 26.6–34.9^{o}C. The highest sea surface temperature was in August 29– September 05 2022, with a value of 31.1^{o}C, while the lowest was in the period 21-28 August 2022, with a value of 29.5°C. The average sea surface temperature during the research period, August 05 to September 29 2022, is 30.5°C.

Table 3. Temporal Sea Surface Temperature Concentration Values

No	Time (2023)	Sea surface temperature (°C)		
		Min	Max	Average
1	05-12 Aug	28.4	33.3	30.8
2	Aug. 13-20	28.0	33.7	30.8
3	Aug. 21-28	26.6	32.5	29.5
4	August 29 – September 05	27.3	34.9	31.1
5	Sept. 6-13	27.3	33.8	30.5
6	Sept. 14-21	27.6	33.0	30.3
7	Sept. 22-29	27.7	33.3	30.5
Average				30.5

Source: Ocean Color Image Data

The sea waters of West Sumatra have a reasonably high sea surface temperature value, namely 30.5°C. This is because West Sumatra is located on the equator line, where the area on this route receives the most sunlight, which makes the sea surface temperature in this area relatively higher. Tjasyono[11] said that the amount of solar radiation received per unit area (insolation) in tropical regions is more significant than in other areas.

In Figure 11-17, it can be seen that the distribution of sea surface temperatures tends to be higher in waters close to land. This is thought to be due to the influence of land, which can absorb heat better than water carried through transport flows. According to Prianto et al.[12] temperature changes slowly from coastal areas towards the open sea. Generally, the temperature at the coast is higher than in sea areas because land absorbs solar heat more efficiently than sea waters.

Nontji[7] said that sea surface temperature (SST) can be used to estimate the presence of organisms in waters, especially fish. This is because most organisms are poikilothermic. The direct influence of temperature on life in the sea is the rate of photosynthesis in plants and animal physiological processes, especially the degree of metabolism and reproductive cycles.

The high and low-temperature variations are an essential factor in determining the migration of a type of fish, especially yellowfin tuna, because, in general, this fish does not like high-temperature changes.

Validation of Image Data with Insitu Data

The sea surface temperature value obtained from the results of image analysis is then tested for the accuracy of the value by comparing the value contained in the image with the value resulting from in situ measurements. Data collection was carried out at 5 station points with three repetitions, and the station points were determined to represent the study area. The results of testing the accuracy of image data using in-situ measurements can be seen in Table 4.

After in-situ image analysis and measurements, a T-test was conducted to see whether there were differences between satellite image data and laboratory analysis data. If the Sig value is > 0.05, the results are no different, and if the Sig value is < 0.05, the results are different.

The results of the T-test showed a significant value of 0.518. It can be concluded that there is no difference between the chlorophyll-α values from satellite images and the results of laboratory analysis, so satellite image data can be used as a reference to determine the chlorophyll-α values in the field with quite good results.

e-issn: 2716-4608
p-issn: 2655-366X

Table 4. Sea Surface Temperature Values from Satellite Images and Insitu Measurements

Station	Location	Coordinate		Satellite imagery (^oC)	Insitu (^oC)
		Longitude	Latitude		
1	Teluk Bayur Harbor	100.358282	-1.010630	31.29	31.4
2	Teluk Buo PLTU	100.348764	-1.076303	32.06	31.9
3	PPS Bungus	100.394449	-1.051557	31.76	31.7
4	Open Sea	100.345432	-1.152446	30.26	30.1
5	Near Tourist Beach	100.380458	-1.153779	31.43	31.5
Average				31.36	31.3

Analysis of Alleged Yellowfin Tuna Fishing Areas Based on Chlorophyll-α Distribution and Sea Surface Temperature

Chlorophyll-α and sea surface temperature are oceanographic parameters that can be used as indicators to determine the presence of a type of fish. Cahya et al.[13] stated that sea surface temperature and chlorophyll-α are the factors that most influence fish distribution. However, there are several other parameters depending on the condition of the waters.

Yellowfin tuna is an oceanic species found below and above the thermocline at temperatures of 18-31^{0}C. Their vertical distribution is influenced by the thermal structure of the water column, such as the correlation between the ease of catching fish by fishing gear, the depth of the swimming layer, and the strength of the temperature gradient at the thermocline. Generally, this fish is found at the top of the thermocline layer in the water column with sufficient oxygen. This fast-swimming fish is rarely seen at the bottom of the thermocline layer because the oxygen content could be higher[14]. Therefore, the spread of tuna fish in the water is a response to changes in temperature.

Adnan[15] said that high concentrations of chlorophyll-α are closely related to the availability of food for fish. As is known, small and large fish will move to look for fertile areas to get food. The relationship between chlorophyll-α and fish in waters is a prey-predator relationship in the form of a food chain. This relationship does not occur directly, but there is a time lag where herbivorous organism structures first consume the chlorophyll concentration found in the water area, for example, zooplankton or small crustaceans (juveniles), and then consumed by the trophic level above.

Analysis of suspected yellowfin tuna fishing areas using an overlay technique by determining areas with chlorophyll-α concentration levels and sea surface temperatures that match the fishing area criteria, then shaded and obtained a map of suspected yellowfin tuna fishing areas. Tangke et al.[1] stated that, generally, yellowfin tuna is caught in the chlorophyll-α range of 0.1-0.35 mg/m^3.

Table 5. Assessment of Fishing Areas Based on Chlorophyll-α Indicators

Chlorophyll-α category	Criteria (mg/m^3)	DPI category
Lots	> 0.2	Potential
Currently	0.1– 0.2	Currently
A little	< 0.1	Less potential

Table 6. Assessment of Fishing Areas Based on Sea Surface Temperature Indicators

SPL category	Criteria	DPI category
Optimum	29^{o}C – 30^{o}C	Potential
Not optimal	<29^{o}C	Less Potential

Next, the results of the analysis of suspected yellowfin tuna fishing areas were tested for accuracy by combining fishing point data from the tuna fishing logbook obtained from the Directorate General of Capture Fisheries, Fish Resources Management sub, Ministry of Maritime Affairs and Fisheries. The results of the analysis of suspected yellowfin tuna fishing areas can be seen in Figure 15-21.

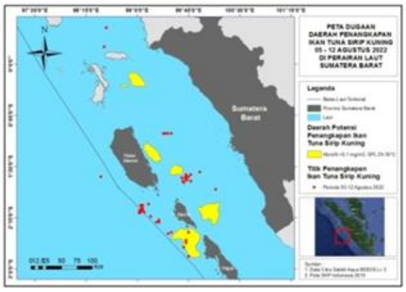

Figure 15. 05-12 August 2022

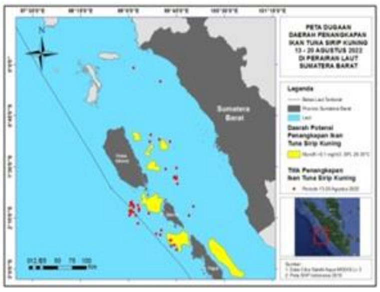

Figure 16. August 13-20, 2022

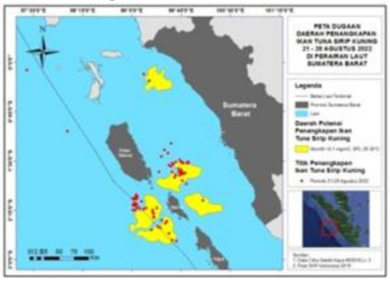

Figure 17. August 21-28, 2022

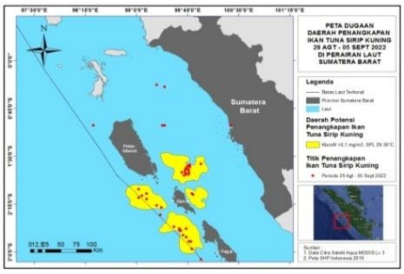

Figure 18. August 29 – September 05, 2022

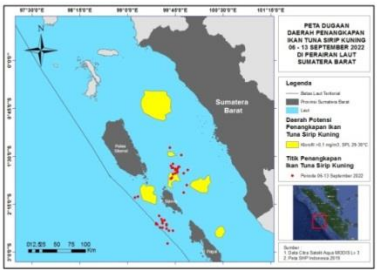

Figure 19. September 6-13, 2022

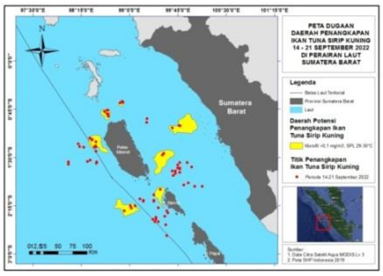

Figure 20. September 14-21, 2022

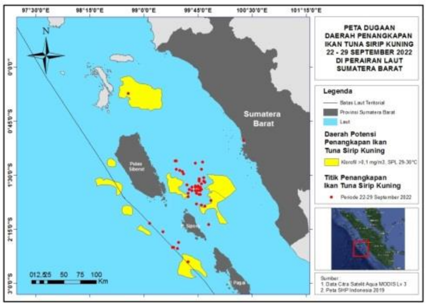

Figure 21. September 22-29, 2022

The accuracy value of the estimated yellowfin tuna fishing area can be seen in Table 7.

The analysis of suspected yellowfin tuna fishing areas shows that fishing points from August 05 to September 29 2022, had an average accuracy percentage of 28.7%. The suspected fishing area with the highest accuracy level occurred on August 29 – September 05, 2022, with an accuracy value of 69.8%, while the lowest suspected fishing occurred on 13-20 August 2022, with an accuracy value of 3.9%.

This research shows that yellowfin tuna fishing locations are not always in suspected areas with high chlorophyll-α concentration values and suitable sea surface temperatures but are also found in regions around suspected fishing areas. This is alleged to be the influence of ocean currents, which influence the distribution of chlorophyll-a as the primary source of the food chain cycle, which will affect the existence of yellowfin tuna.

This is also confirmed by the opinion of Simbolon & Girsang in Prayoga et al.[16], who state that the concentration of chlorophyll-α found in a water area does not directly affect the availability of fish in that water area. Still, there is a time leg where the concentration of chlorophyll-a found in a water area is first eaten by juvenile-sized zooplankton or crustacean organisms and then eaten at the trophic level above. Fitriah & Nahib[17] found that the lag time can last 1 to 2 months, representing the food chain in marine ecosystems where yellowfin tuna is a predatory fish.

Table 7. Accuracy Value of Estimated Yellowfin Tuna Fishing Areas

No	Arrest time (2023)	Capture point		Percentage
		Conjecture	Total	
1	August 5-12	5	51	9.8%
2	August 13-20	2	51	3.9%
3	August 21-28	50	116	43.1%
4	August 29 – September 05	37	53	69.8%
5	September 6-13	3	39	7.6%
6	September 14-21	25	73	34.2%
7	September 22-29	4	56	7.1%
Total		126	439	28.7%

Maulina et al.[18] stated that besides these two oceanographic factors, several other factors influence catch results: water depth, currents, and water salinity.

4. CONCLUSION

The chlorophyll-α value during the study period averaged 2.01 mg/m^3. The highest concentration occurred in the period 13-20 August 2022 with an average value of 3.17 mg/m^3, and the lowest occurred in the period 06-13 September 2022 with an average value of 0.85 mg/m^3. This value can be used as an indicator in determining yellowfin tuna fishing areas. Sea surface temperature has almost the same value, ranging from 29.5–30.8^{o}C to an average of 30.5^{o}C. This temperature is suitable for the yellowfin tuna environment and can be used as an indicator in determining yellowfin tuna fishing areas. The level of accuracy of yellowfin tuna fishing areas based on the distribution of chlorophyll-α and sea surface temperature during the study period had an average accuracy of 28.7%. The highest accuracy value occurred from August 29 to September 05 2022, with a percentage of 69.8%, and the lowest occurred from 13 to August 20 2022, with a percentage of 3.9%.

REFERENCES

1. Tangke, U., Karuwal, J.C., Zainuddin., Mallawa, A. Sebaran Suhu Permukaan Laut dan Klorofil-A Pengaruhnya terhadap Hasil Tangkapan Yellowfin Tuna (*Thunnus Albacares*) di Perairan Laut Halmahera Bagian Selatan. *Jurnal IPTEKS PSP*, 2015; 2(3): 248-260.
2. Hutabarat, S., Evans, S.M. *Pengantar Oseanografi*. Jakarta: UI Press, 2000.
3. Hartoko, A., Purwanti, F., Latumeten, G.A. Analisis Hubungan Suhu Permukaan Laut, Klorofil-α Data Satelit Modis dan Sub-Surface Temperature Data Argo Float terhadap Hasil Tangkapan Tuna di Samudera Hindia. *Management of Aquatic Resources Journal*, 2013; 2(2): 1-8.
4. Boyd, R.B. *General Microbiology*. C.V. Mosby Company. St. Louis, 1984.
5. Pailin, J.B. Daerah Penangkapan Potensi Tuna Madidihang *Thunnus albacares*, Bonnaterre, 1788 (*Teleostei; Scombridae*) di Laut Seram. *Jurnal Kelautan Tropis*, 2020; 23(2): 207-216.
6. Nybakken, J.W. *Biologi Laut. Suatu Pendekatan Ekologis*. PT. Gramedia. Jakarta, 1992.

7. Nontji, A. *Tiada Kehidupan di Bumi Tanpa Keberadaan Plankton*. Lembaga Ilmu Pengetahuan Indonesia (Pusat Penelitian Oseanografi). Jakarta, 2006.
8. Nontji, A. *Plankton Laut.* Lembaga Ilmu Pengetahuan Indonesia (LIPI) Press. Jakarta, 2008.
9. Siagian. M. *Penuntun Praktikum Ekologi Perairan.* Fakultas Perikanan dan Ilmu Kelautan. Universitas Riau. Pekanbaru. p 94, 2004.
10. Nontji, A. *Laut Nusantara*. Djambatan. Jakarta, 2005.
11. Tjasyono, B. *Ilmu Kebumian dan Antariksa*. Remaja Rosdakarya. Bandung. p152, 2009
12. Prianto, T.Z., Ulqodry, U., Aryawati, R. Pola Sebaran Konsentrasi Klorofil-α di Selat Bangka dengan Menggunakan Citra Aqua-Modis. *Jurnal Maspari*, 2013; 5(1): 22-33.
13. Cahya, C.N., Setyohadi, D., Surinati, D. Pengaruh Parameter Oseanografi terhadap Distribusi Ikan. *Oseana*, 2016; 41(4): 1–14
14. Kantun, W., Mallawa, A. Respon Tuna Madidihang (*Thunnus albacares*) terhadap Umpan dan Kedalaman pada Perikanan Handline di Selat Makassar. *Journal of Fisheries Sciences*, 2015; 17(1): 1–9.
15. Adnan. Analisis Suhu Permukaan Laut dan Klorofil-α Data Inderaja Hubungannya dengan Hasil Tangkapan Ikan Tongkol (*Euthynnus affinis*) di Perairan Kalimatan Timur. *Jurnal "Amanisal" PSP FPIK Unpatti- Ambon*, 2010; 1(1): 1–12.
16. Prayoga, I.M.S., Putra, I.D.N.N., Dirgayusa, I.G.N.P. Pengaruh Sebaran Konsentrasi Chl-α berdasarkan Citra Satelit terhadap Hasil Tangkapan Ikan Tongkol (*Euthynnus* sp) di Perairan Selat Bali. *J. of Maritime and Aquatic Science*, 2017; 3(1): 30-46.
17. Fitriah, N., Nahib, I. Aplikasi Data Inderaja Multi Spektral untuk Estimasi Kondisi Perairan dan Hasil Tangkapan Ikan Pelagis di Selatan Jawa Barat. *Ilmiah Geomatika*, 2009; 15(14).
18. Maulina, D., Fauzisar, A.S., Hernawati, D., Septya, L. The Feasibility of Investment Installation using SWRO in Seribu Island, Indonesia. *Biological Environment and Pollution*, 2021; 1(2): 89-100.