Relationship of spatial and temporal characteristics of water conditions and *Rastreliger kanagurta* production in the Malacca Strait using satellite imagery

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**Abstract.** The eastern coast waters of North Sumatra is a fishing ground with a high level of exploitation. One of commodity catches in the eastern coast of Sumatra is mackarel (*Rastreliger kanagurta*). By understanding the parameters of oceanography, especially sea surface temperature and chlorophyll-a, it can help to predict fishing area which are used as a guide for the purpose of fishes catching or exploitation. One of the satellites that can detect sea water temperature and chlorophyll-a is Aqua (EOS PM) with a moderate resolution imaging spectro radiometer sensor (MODIS). Mackerel catch data were obtained from ocean fishing port in Belawan. Sea surface temperature eastern coast of North Sumatra based on Aqua MODIS image analysis ranged from 29.55-31.66°C, and chlorophyll-a distribution has a range of 1.56-4.65 mg/m³. Mackerel catches fluctuations every month. The highest average catch is 232.174 tons which occurred in February. While the lowest catch is 201.457 which occurred in May. The results of the correlation between catching mackerel and sea surface temperature of -0.337 have a weak and not direct relationship. Relationship of chlorophyll-a with catches obtained a positive correlation value of 0.660 which indicates that between chlorophyll-a and catches has a strong and direct relationship.

1. **Introduction**

The Malacca Strait administratively covers 4 provincial regions namely Aceh Province, North Sumatra (eastern coast), Riau and Riau Islands. The Malacca Strait waters is one of the productive waters for the utilization of small pelagic fish resources. The acoustic method analysis results obtained the estimated value of the maximum sustainable yield (MSY) of small pelagic fish of 99,865 tons per year and the total allowable catch (TAC) of 79,892 tons per year with the utilization rate category is fully exploited [1]. Small pelagic fish that have high economic value include mackerel (*Rastreliger kanagurta*).

Catching mackerel in the Malacca Strait waters especially North Sumatra (east coast) which is increasingly intensive will cause a decline in mackerel populations. So information about oceanographic environmental factors (sea surface temperature and chlorophyll-a) is needed that affect the distribution of mackerel on a space and time scale for the effectiveness of fishing and sustainable management of fisheries.

Variability of temperature and chlorophyll that changes all the time requires remote sensing technology to provide information temporally. Data captured oceanographic satellites can be used to monitor various ocean phenomena are closely related to fishery [2].
Remote sensing is a technique that can be applied for observing oceanographic oceanic parameters. Aqua moderate resolution imaging spectro radiometer (Aqua MODIS) is one of the remote sensing satellites that can detect chlorophyll-a content and sea surface temperature. Aqua MODIS satellite data can be used to determine chlorophyll-a concentrations and the distribution of sea surface temperatures associated with variations in fish catches [3]. Satellite data are very helpful in determining the optimum temperature and chlorophyll-a which is favoured by fish. Then the data can be implemented to predict fishing grounds. The development of technology in the field of remote sensing for information on fishing areas is expected to increase the certainty of the catch. Fishing ground that are always on the move make catches obtained by fishermen not optimal and require higher operational costs. Therefore, the distribution of mackerel based on sea surface temperature distribution and chlorophyll-a concentration in the waters of the east coastal of North Sumatra needs to be studied.

This study aims to analyse the correlation between sea surface temperature and the distribution of chlorophyll-a in the Malacca Strait (eastern waters of north Sumatra) to the production of mackerel fishing using Modis satellite imagery data.

2. Materials and methods

This research was conducted in May 2018 on Malacca straits (east coast of North Sumatra Province) which is geographically located at coordinates 2° 21'15" N - 4° 21'15" N and 98° 13'45" E - 101° 21'15" E. Data on mackerel catches were obtained from the Belawan ocean fishing port for 5 years (2013-2017).

2.1. Procedure

The method that was used in this study was a survey method. The survey method is an investigation conducted to obtain facts from the symptoms that exist and find out factual information [4]. Acquisition of temperature and chlorophyll-a data for the last 5 years obtained and downloaded from Aqua MODIS level 3 satellite imagery with the site http://www.oceancolour.gsfc.nasa.gov and it has a spatial resolution of 4 km. After the data is collected, it is cut according the study area. Then the unification of the Indonesian layer was carried out with the sea surface temperature and chlorophyll-a data. Secondary data in the form of daily data and monthly composite sea surface temperatures (SST) and chlorophyll-a concentrations of the Aqua MODIS satellite has a period of time which is the same as the fishing period.

2.2. Data analysis

The catch data is then analysed descriptively and presented in Tables or Graphs. Catches fluctuations based on time (temporal) and location of capture (spatial)

Aqua MODIS level-3 satellite data is in the form of compressed digital data in the Hierarchical Data Format (HDF) format which has been corrected radiometrically and atmospherically. Data processing is continued by using the SeaWIFS Data Analysis System (SeaDAS) 7.2 software with the windows operating system. At this stage cropping is carried out based on the study area. The output from the image cropping is converted into the form of American Standard Code for Information Interchange (ASCII) data, which includes the variables of longitude, latitude, estimated value of chlorophyll-a concentration and sea temperature.

Furthermore, display the spatial distribution of sea surface temperature and chlorophyll-a using Surfer 8 and ArcGIS software. The form of the spatial distribution of temperature and chlorophyll-a concentration is image display with the extension of the joint photographic group (JPG).

Monthly composite data is used to find out the pattern of interaction and correlation between temperature and chlorophyll-a relation to the amount of mackerel catches in Belawan ocean fishing port. Correlation analysis using the Pearson test.
3. Result and discussion

3.1. Sea surface temperature distribution in the east coastal of North Sumatra.

The distribution of sea surface temperature in the waters of the North Sumatra coastal based on Aqua MODIS image analysis in 2013 - 2017 is relatively constant in the range of 30°C. The average sea surface temperature (SST) distribution pattern in February 2013 - 2017 has a value of 29.89°C, where the water mass is predominantly yellow in the east coast of North Sumatra.

Figure 1 describe the average SST distribution pattern, in February showed the lowest temperature value compared to the highest temperature value in other months.

![Figure 1](image)

**Figure 1.** Sea surface temperature distribution averaged in 2013 – 2017 (a) February (b) May

In May, distribution of sea surface temperature (SST) average was the highest at 31.12°C, marked by the mass of water that dominated the red colour. Monthly averages of spatial distribution of sea surface temperature of the Malacca Strait according to MODIS satellite imagery ranges from 29.55°C-31.66 °C.

This due to May including in the west transition season which resulted in temperatures broadcast hot trowths. This in accordance with [5], which states that (March, April, May) sea surface temperatures tend to form warm waters. In general, within a period of 5 years the trend of SST changes occurs every month, starting to increase in January and peaks in April and May, then slowly decreases until December.

3.2. Chlorophyll-a concentration distribution in the eastern coast of North Sumatera

The observation of MODIS aqua satellite imagery of the concentration of chlorophyll-a shows the distribution value of chlorophyll-a in the east coast of North Sumatra in year 2013-2017 has a range of 1.56 - 4.65 mg/m³. The chlorophyll-a concentration changes every month, the colour of the mass of water that is getting green indicates that the concentration of chlorophyll-a of eastern water of North Sumatra is getting higher.

Chlorophyll-a concentration in the east coastal of North Sumatra for 5 years (2013-2017) according to Aqua MODIS satellite image analysis showed an average of 3.15 mg/m³. Compared to the month, May has the lowest concentration with an average value of 2.01 mg/m³. This is indicated by the small mass of water that is green. It can be seen below (Figure 2).
In February the concentration of chlorophyll-a on the east coastal of North Sumatra had a very high value with an average value of 3.63 mg/m$^3$. It is characterized by a mass of water that is dominated by green. This result is not much different from [6] where the chlorophyll-a obtained ranged between 1.5-2.5 mg/m$^3$. The high concentration of chlorophyll-a is closely related to the upwelling process which is indicated by a mass of colder water with higher salinity and high abundance of plankton or chlorophyll [7].

3.3. Mackerel production on the east coastal of North Sumatra
The catch used is Belawan PPS statistical data starting from January 2013 - December 2017 in the North Sumatera East Coast fishing area. Mackerel (*Rastrelliger kanagurta*) is one of the many pelagic fishes landed at Belawan ocean fishing port. Its presence in the sea which does not depend on the season makes fish one of the dominant fish in this area. Mackerel is usually caught using gillnet fishing gear. Mackerel production fluctuates every month, the highest production reaching 232.174 tons which occurred in February. The lowest production of mackerel is 201.457 which occurred in May.

3.4. Relationship between sea surface temperature and catches of mackerel
In general, the increase in production volume of mackerel in the eastern coast of North Sumatra occurs when the temperature decreases. The high catch of fish when the lowest temperature is found in February. On the contrary, at the time of the highest SST the fish catch decreased which occurred in May. The comparison between SST and mackerel production can be seen in Figure 3.

The catch of mackerel which is carried out on the East Coast of North Sumatra shows different results every month. This can be caused by SST value which is also different where the increase in SST value is followed by a decrease in catch. In May, SST had the highest value of 31.12°C followed by a low fish catch of 201.457 tons while the lowest SST was in February of 29.89°C with a high catch of fish which reached 232.174 tons. This is suspected because mackerel has the ability to adapt to the range of sea surface temperature. According to [7], SST fluctuations affect the concentration of fish groups. [8] indicating that mackerel, either by using the simulation model and data collection in the field (insitu) has a central concentration at the same temperature range, 28.5-29.5°C. This is in line with research by [9], that mackerel in waters has a high catch number in the temperature range of 29-30°C.
Figure 3. Comparison between sea surface temperature and catch of mackerel

3.5. Relationship between chlorophyll-a and catches of mackerel

Generally increasing fish production is in line with the increase in the concentration of chlorophyll-a in the waters. The higher the chlorophyll value, the higher the catch production and vice versa. The highest catch was obtained in February in line with the high concentration of chlorophyll-a in the waters of the East Coast of North Sumatra. The lowest catch was obtained in May in line with the decreased concentration of chlorophyll-a in the waters. The relationship of chlorophyll-a in waters with mackerel production can be seen in Figure 4.

Figure 4. Comparison between chlorophyll-a and catch of mackerel

The relationship between chlorophyll-a and catch of mackerel in Figure 4 shows that high chlorophyll-a is followed by high catch and vice versa, low chlorophyll-a is followed by low catch. This is because the high chlorophyll indicates the high abundance of phytoplankton which is a food source for pelagic fish. According to [10], the number of pelagic fish is thought to be due to the large availability of food in a waters. As a primary producer of phytoplankton that has a relationship with aquatic productivity, it is food for small pelagic fish so as to create a food chain that supports the productivity
of fish in the waters. This is also supported by research by [9], where the high chlorophyll-a levels in December, January, February are followed by the high catches of Mackerel in that month.

3.6. Correlation between catching mackerel with SST and Chlorophyll-a based on Pearson Correlation

Based on Table 4, the results of the correlation between the production of Mackerel and SST show a negative relationship or an inverse correlation with the correlation mark of -0.365. This imply when SST increases, the catch of mackerel fish decreases and if the SST decreases the fish catch tends to increase. Nutrient availability can also be impacted abundance of phytoplankton which it affected population of fishes grow up [11].

Table 1. Relationship of mackerel catches with SST and chlorophyll-a based on pearson correlation

|                         | Mackerel Fish Production | Sea Surface Temperature (SST) | Chlorophyll-a |
|-------------------------|--------------------------|------------------------------|---------------|
| Mackerel Production     | Pearson correlation      | -0.365                       | 0.66          |
|                         | sig. (2-tailed)          | 0.635                        | 0.34          |
|                         | N                        | 4                            | 4             |
| Sea Surface Temperature (SPL) | Pearson Correlation | -0.365                       | 1             |
|                         | sig. (2-tailed)          | 0.635                        | 0.063         |
|                         | N                        | 4                            | 4             |
| Chlorophyll-a           | Pearson Correlation      | 0.66                         | -0.937        |
|                         | sig. (2-tailed)          | 0.34                         | 1             |
|                         | N                        | 4                            | 4             |

The relevancy between chlorophyll-a and catches got the positive correlation value of 0.660 which indicates that chlorophyll-a and catches have a strong and direct relationship. This means that if the chlorophyll-a content in the water mount, the catch of the Mackerel fish will increase also, likewise if the chlorophyll-a in the sea water decline, then the catch of the mackerel will decrease. [12] stated that primary productivity and temperature mainly influenced population of Indian mackerel.

4. Conclusion

Sea surface temperature distribution in the east coastal of North Sumatra in years 2013-2017 from satellite imagery Aqua MODIS ranging from 29.55°C to 31.66°C. The highest SST distribution in May was 31.12°C and the lowest was in February with an average value of 29.8°C. Chlorophyll-a concentrations in the waters of the East Coast of North Sumatra in 2013-2017 ranged from 1.56 to 4.65 mg/m³, the lowest chlorophyll-a monthly average occurred in May at 2.01 mg/m³ and the highest in February at 3.63 mg/m³. Sea surface temperature is negatively correlated with mackerel production with a mark of correlation of -0.365. The correlation between chlorophyll-a and catch results got by a positive correlation value of 0.660.

References

[1] Suman A, Satria F, Nugraha B, Priatna A, Amri K, Mahiswara M 2016 Status Stok Sumber Daya Ikan Tahun 2016 di Wilayah Pengelolaan Perikanan Negara Republik Indonesia (WPP NRI) dan Alternatif Pengelolaannya [The Stock status of fish resources in 2016 at fisheries management area of Indonesian Republic (FMAs) and Its Management Alternative] Jurnal Kebijakan Perikanan Indonesia 10 pp 107-128
[2] Robinson, IS 2010 Discovering the Ocean from Space The Unique Applications of Satellite Oceanography Berlin Heidelberg: Springer-Verlag
[3] Putra E, Gaol J L, Siregar V P 2012 Relationship of Chlorophyll -a Concentration and Sea Surface Temperature with Main Pelagic Fish Catches in Java Sea Waters from Modis Satellite Imagery Journal Fisheries and Marine Technology 3 2087 – 4871
[4] Nazir M 2003 *Metode Penelitian [Research Method]* Ghalia Indonesia Jakarta
[5] Tangke U, Karuwal J C, Zainuddin M, Mallawa A 2015 Sebaran Suhu Permukaan Laut dan Klorofil-A Pengaruhnya Terhadap Hasil Tangkapan Yellowfin Tuna (*Thunnus albacares*) di Perairan Laut Halmahera Bagian Selatan [Distribution of Sea Surface Temperature and Chlorophyll-a Effect on the Catches of Yellowfin Tuna (*Thunnus albacares*) in the Southern Halmahera Sea Waters] *Jurnal Iptek PSP* 2 3 pp 248 – 60
[6] Siregar S, Barus T A, Harahap Z A 2016 Analisis Konsentrasi Klorofil-A dan Suhu Permukaan Laut Menggunakan Data Satelit Aqua Modis Serta Hubungannya dengan Hasil Tangkapan Ikan Tongkol di Selat Malaka [Analysis of Chlorophyll-a concentration and Sea Surface Temperature Using Aqua Modis Satellite Data and Its Relationship with Capture of Tuna (*Euthynnus sp.*) In the Malacca Strait] *Jurnal Aquacoastmarine* 4 1
[7] Susilo E 2015 Variabilitas factor lingkungan pada habitat ikan lemuru di Selat Bali menggunakan data satelit oceanografi dan pengukuran insitu [Variability of environmental factors of Bali sardinella in Bali Strait using oceanography satellite data and insitu measurement] *Jurnal Omni-Akuatika* 14 pp 13-22
[8] Effendi R, Palloan P and Ihsan N 2012 Analisis Konsentrasi Klorofil-a di Perairan Sekitar Kota Makassar Menggunakan Data Satelit Topex/Poseidon [Analysis of Chlorophyll - a Concentration in Waters Around Makassar City Using Topex/Poseidon Satellite Data] *Jurnal Sains dan Pendidikan Fisika* 8 3 pp 279-280
[9] Jamil S, Marsoedi, Soemarno, Sukoso 2010 Determination of Concentration Areas for Indian Mackerel (*Rastrelliger kanagurta*) Using Kinesis Model in the West Coast Waters of South Sulawesi *Jurnal Pembangunan dan Alam Lestari* 1 1-8
[10] Halim M A R, Kunarso, Marwoto J 2017 Identifikasi Faktor Oseanografi yang Berpengaruh Terhadap Hasil Tangkapan Ikan Kembung di Perairan Kabupaten Pati [Identification of Oceanographic Factors that Influence the Capture of Mackerel in Pati Regency Waters] *Journal of Oceanography* 6 3 pp 500-15
[11] Akhlak M A, Supriharyono, Hartoko A 2015 Relationship between Sea Surface Temperature, Chlorophyll-A and Purse Seine Captains Landing on TPI Bajomulyo Juwana, Pati *Journal of Maquaires* 4 pp 128-35
[12] Philips E J, Badylak S, Grosskopf T 2002 Factors Affecting the Abundance of Phytoplankton in a Restricted Subtropical Lagoon, the Indian River Lagoon, Florida, USA *J Estuarine Coastal and Shelf Science* 55 3 pp 385-402
[13] Pratyush D, Mishra R K, Bhargava A K, Singh P, Mishra S, Sinha M K, Mohanty P K 2016 Abundance and Distribution of Indian Mackerel (*Rastrelliger kanagurta*) along the South-West Coast of India in Respect to the Hydro-Biological Changes *Thalassas: An International Journal of Marine Sciences* 32