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Spatial and Temporal Variability of Sea Surface Temperature and Chlorophyll-A According to the Season in Pesisir Selatan Regency Waters with Aqua-MODIS Imagery

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ABSTRACT

Fishermen's understanding of oceanographic parameters, especially sea surface temperature conditions and chlorophyll-a concentration in the process of determining fishing operations are still very low. The cause is the constraints of technology and human resources, and not widely available data and information on fisheries resources, including their parameters. Remote sensing technology is one solution that can be used to understand the spatial and temporal conditions of great waters. This research was conducted in the waters of the Pesisir Selatan Regency with the aim to : 1) measure and map the spatial and temporal variability of sea surface temperature in 2013, 2) measure and map the spatial and temporal variability of chlorophyll-a concentration in 2011-2013, 3) measure the relationship between sea surface temperature with the concentration of chlorophyll-a. This study uses a quantitative approach using analysis desk metode. The results showed that: 1) sea surface temperature mean highest monthly throughout the year occurred in the first transitional season between March and May, where sea surface temperatures reach more than 31 ^{0}C, 2) Chlorophyll-a concentration between 2011 to 2013 was highest in the east of the season and second in the transitional seasons are concentrated in the area of the waters region of Linggo Sari Baganti Regencys to Silaut Regencys, 3) Sea surface temperature is strongly influencing the concentration of chlorophyll-a, regression coefficient (r) of 0.811, Relationships sea surface temperatures mean monthly negatively correlated, with each increase of 1 ^{0}C of the sea surface temperature caused a decrease in chlorophyll-a concentration of 0.176 mg/m^3.

Keywords: oceanographic parameters, sea surface temperature, chlorophyll-a

Introduction

Pesisir Selatan Regency as one of 7 regencies / cities in West Sumatra which is located in a coastal area has great coastal and marine potential. According to the Pesisir SelatanFisheries Marine Service, the potential for sustainable capture of Pesisir Selatan Regency per year reaches 95 thousand tons.

Catch production tends to fluctuate; in 2005 fish production was around 24 thousand tons, in 2006 amounted to 26 thousand tons, in 2007 to 2009 amounted to 25 thousand tons. This production can only reach 36.5%. still far below the achievement of fisheries production in West Sumatra which reached 75.22%. This figure is clearly still far from the optimal value which is still possible to be developed in a sustainable corridor.

This potential has not been utilized optimally due to technological and human resource constraints. Another factor is because there are not enough data and information available about the potential of fish resources in Indonesia's marine waters spatially and continuously.

Information on sea surface temperature and chlorophyll-a variability is an important indicator in estimating potential zones for fishing including determining the location of upwelling, fronts, or eddies current (Lalli and Parson, 1994). Sea surface temperature plays an important role in the formation of vertical stratification of water columns that allows upwelling, as well as horizontal stratification that causes the front.

In fisheries oceanography, especially in developed countries, oceanographic satellite data has been developed to estimate potential fishing areas of fish species that have high economic value. Estimates of potential fishing areas based on analysis of oceanographic satellite data, statistical modeling and

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geographic information systems (GIS) have been developed to improve pelagic fishing efficiency, among others; albakora tuna and skipjack fish in Japanese waters.

Ocean conditions in one zone basically provide certain reflections according to the content and environmental conditions of the sea water against the remote sensing recording sensor. By interpreting the reflection given by the sea to the sensor it can be estimated the condition of the sea chlorophyll content, surface temperature, and other conditions of the recording zone. The results of this interpretation can be used to determine the zone of movement of marine biota including surface fish (plagic).

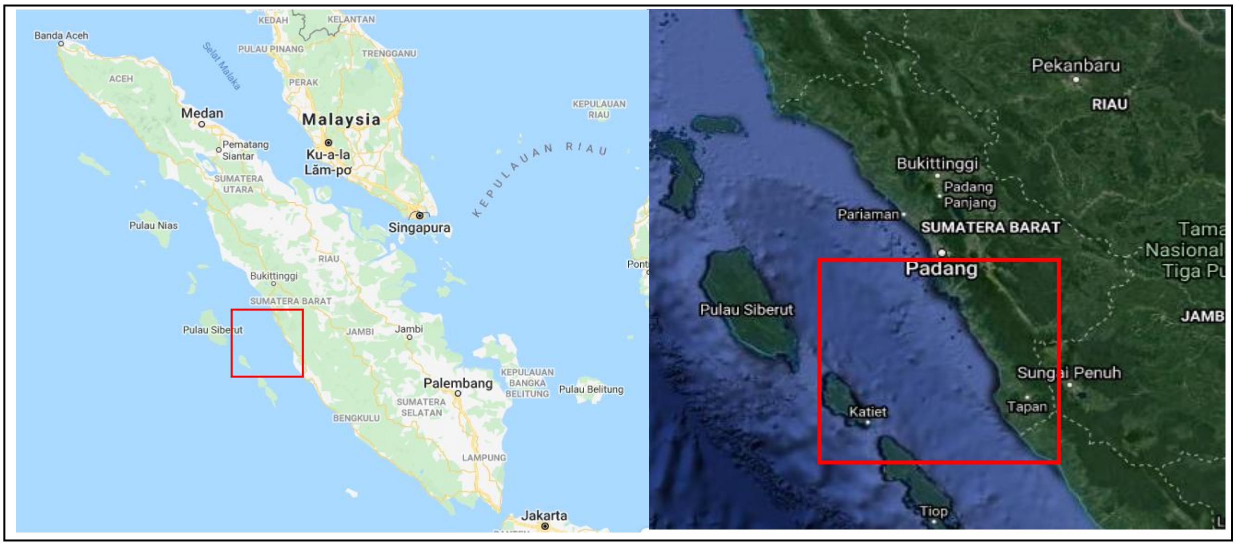
Starting from that, this paper tries to estimate spatial and temporal sea surface temperature (SST) and chlorophyll-a concentration with remote sensing and geographic information systems (GIS) aims to: (1) Measure and map the distribution of sea surface temperature (SST) in the region waters of Pesisir Selatan Regency in 2013, (2) Measuring and mapping chlorophyll-a concentrations in the waters of Pesisir Selatan Regency in 2011, 2012 and 2013. (3) Calculating the relationship of sea surface temperature parameters (SST) with chlorophyll-a concentration spatially and temporal.

Materials And Methods

Study Area

The study area is Pesisir Selatan Regency waterzone in southern of West Sumatera Province. Pesisir Selatan Regency is located between 0^0 59’ S – 2^0 28.6’ S and 100^0 19’ E – 101^0 18’ E. Pesisir Selatan Regency is one of 7 regencies / cities in West Sumatra which is located in a coastal area has great coastal and marine potential. Pesisir Selatan Regency is located in the southern part of Sumatra Barat Province, extending from north to south with a coastline length of 234 Km.

Figure.1.Study Area



Data Analysis Techniques

Satellite Imagery and Processing

The image that has been downloaded from the NASA website is then processed with the device Sea Das 7.0.2 for reprojection of data from the NetCDF (NC) format into the Geotiff format, Visualization and subsequent analysis is performed with GIS Arc GIS 10.1 software. Image processing scheme can be seen in figure 1:

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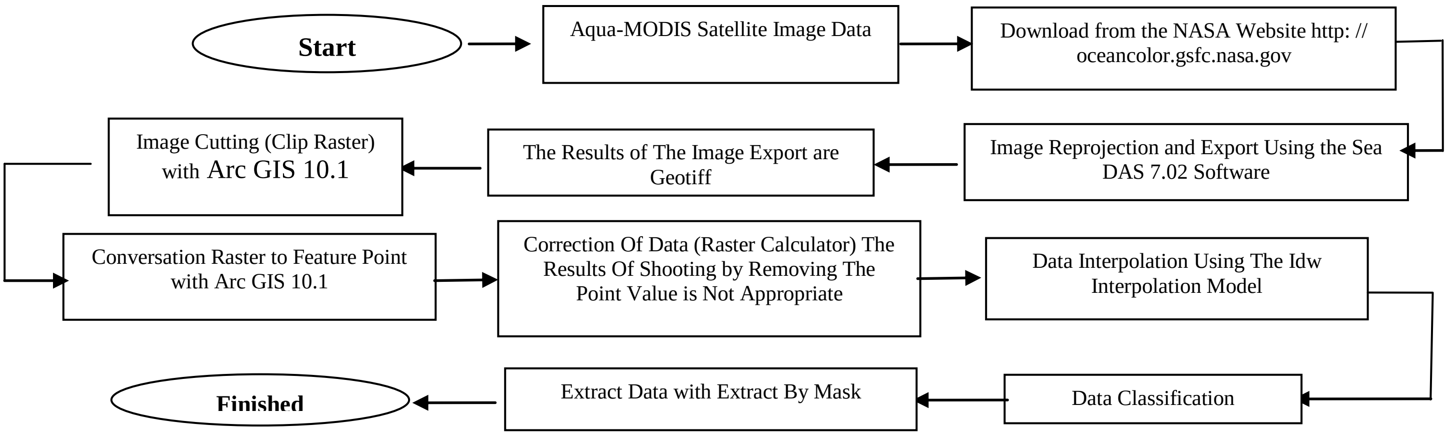
Analysis Of The Relationship of Sea Surface Temperature (SST) With Chlorophyll-a Concentration

The analysis of the relationship between sea surface temperature (SST) and chlorophyll-a concentration was carried out using statistical analysis with the simple regression equation as follows

Figure.2.Aqua-MODIS Satellite Image Processing Flow



$\hat{Y} = {}^{2}0 + {}^{2}1 X 1 i + {}^{2}2 X 2 i + - i$

Estimator equation :

$\hat{Y} = a + bX$

Y = Dependent variable

a = Constant coefficient

b = Regression coefficient

X = Dependent variable

Hypothesis : t count > t table:

there is an influence between sea surface temperature (SST) on the concentration of chlorophyll-a.

To determine the degree of relationship between variables, an analysis was performed using SPSS version 15.0. Where the range of correlation coefficient values is : $-1 \leq r \leq +1$, The relationships are stated tightly if : $r \geq 0,7$ dan $r \leq -0,6$, and the Relationships not close if : $-0,6 < r < 0,7$

Spatial Regression Analysis with Spatial Statistics

In spatial regression analysis, the causality relationship can be plotted and clearly illustrated on a map. From the results of the spatial regression analysis then a map of the spatial distribution of the coefficient of determination (R^2) and the coefficient of determination per polygon (local R^2).

Output

Expected outputs from this research are: (1) Map of sea surface temperature distribution (SST) and its fluctuations (2) Map of chlorophyll-a distribution and its fluctuations, (3) Map of distribution of regression coefficient values between Sea Surface Temperature (SST) and Chlorophyll- a, (4) Map of spatial distribution of chlorophyll-a with concentrations above 0.2 mg / m3 according to the peak season between 2011-2013.

Results

Sea Surface Temperature and Temporal Variability in 2013

The highest mean monthly sea surface temperature in 2013 occurred in March (31.23^{0}C) and the lowest occurred in November (29.83^{0}C). The range of sea surface temperature in the water columns ranges from 24.43^{0}C - 33.81^{0}C West season 2013 temperature range 24^{0}C to 33^{0}C.

The highest mean sea surface temperature throughout the year occurs in the transition season I when the sun is at the equator. Between March and May sea surface temperatures in the monthly Pesisir SelatanRegency are above mean 31^{0}C.

In the west season, the waters in the south, especially around the waters of Pancung Soal to Silaut Regencys are warmer than the surrounding waters. Whereas in the transition season sea surface temperatures in the northern part of the waters are warmer, especially around the waters of Regency XI Koto Tarusan to the waters area of Regency IV Jurai.

Table 1. Monthly Sea Surface (^{0}C) Variability and Mean Temperature Year 2013

Month	Min.	Max.	Mean	Std Dev (Sd)
January	29,14	31,94	30,50	0,32
February	25,03	32,95	30,54	0,69
March	30,19	32,50	31,23	0,30
April	29,31	33,21	31,19	0,37
May	29,35	32,86	31,02	0,34
June	29,77	32,10	30,70	0,24
July	29,91	33,08	30,55	0,26
August	29,99	32,41	30,66	0,35
September	26,33	33,81	30,77	0,57
October	28,70	32,94	30,92	0,57
November	24,89	32,19	29,83	0,94
Desember	24,43	32,57	30,20	0,93

Source : Aqua MODIS Level 3 SST Imagery Processing

Information :
Max. = Maximum Value
Min. = Minimum Value
Mean = Mean
Sd = Standar Deviation

Overall it can be illustrated that the sea surface temperature (SST) fluctuations in the waters of Pesisir Selatan Regency are spatially or temporally not too high. The difference in the intensity of sunlight received across open tropical waters such as in the Pesisir SelatanRegency is also not much different throughout the year because it is very close to the equator. Where sea surface temperature (SST) in the east season is higher than in the west season.

While the highest sea surface temperature (SST) distribution and evenly distributed in all waters zones of the Pesisir SelatanRegency, occurred at the peak of the transition season I in April with an mean temperature reaching more than 31^{0}C and is the highest throughout the year. More details can be seen in the following tables, graphs and map images:

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Table 2. Comparison of Sea Surface Temperature (^{0}C) According to the Season 2013

Indikator	Musim Barat	Musim Peralihan I	Musim Timur	Musim Peralihan II
Suhu Permukaan Laut Terendah (Min)	29,14	29,31	29,91	28,70
Suhu Permukaan Laut Tertinggi (Maks)	31,94	33,21	33,08	32,94
Suhu Permukaan Laut Rata-Rata (Mean)	30,50	31,19	30,55	30,92

Source : Aqua MODIS Level 3 SST Imagery Processing

Figure 4. Spatial and Temporal Distribution of Sea Surface Temperature in 2013 in the Pesisir Selatan Regency

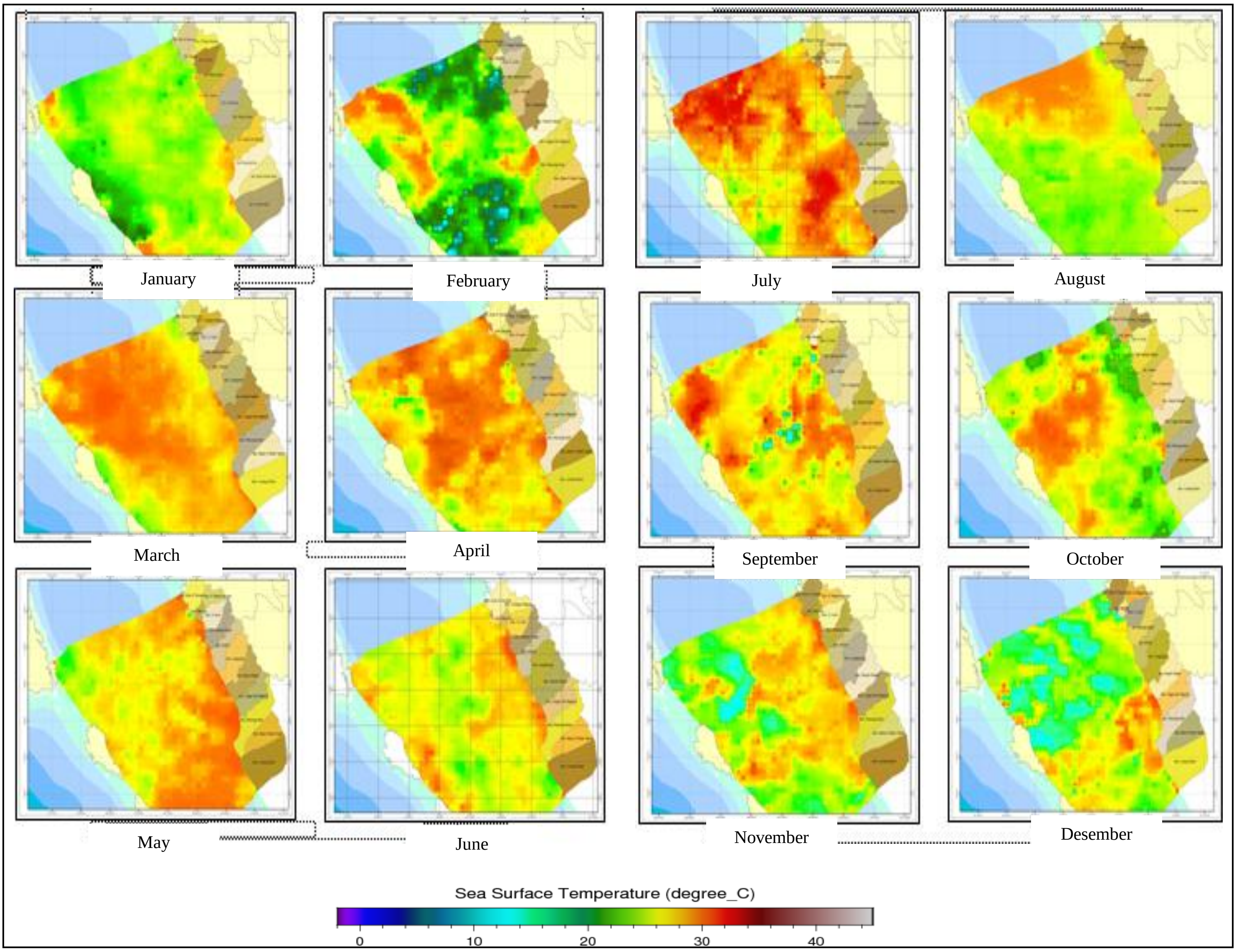
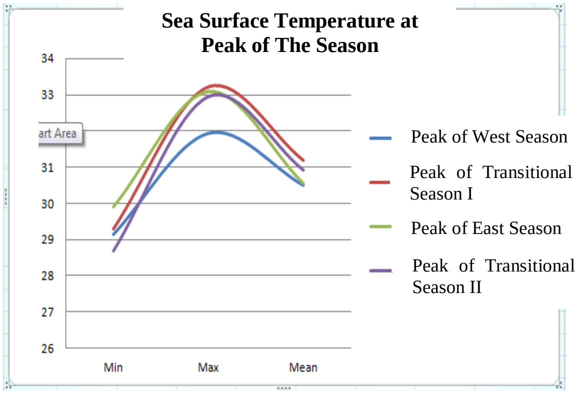


Figure 3. Graphic Comparison of Sea Surface Temperature According to the Peak of Season 2013



Spatial Variability and Temporal Chlorophyll-A Concentration (mg/m3) in 2011, 2012 and 2013

Based on the exposure of chlorophyll-a concentration data from 2011 to 2013 above, several conclusions can be drawn. Overall, the lowest mean chlorophyll-a concentration occurs in the west and transition season I. While high concentrations occur in the east and transition season II, with the transition season II being the peak of abundance of marine nutrients throughout the year. The following is the comparison of chlorophyll-a concentration according to year and season.

Table 4. Mean of Chlorophyll-A Concentration (mg/m^3) Monthly
Year 2012

Month	Min.	Max.	Mean	Std Dev. (Sd)
January	0,12	0,71	0,17	0,05
February	0,10	1,51	0,18	0,14
March	0,08	0,65	0,15	0,06
April	0,09	0,79	0,16	0,07
May	0,12	0,70	0,18	0,07
June	0,14	1,93	0,21	0,15
July	0,09	2,77	0,23	0,26
August	0,13	2,13	0,21	0,13
September	0,12	4,22	0,55	0,67
October	0,10	0,77	0,16	0,05
November	0,09	4,94	0,42	0,02
Desember	0,11	1,31	0,20	0,14

Source: Aqua MODIS Level 3 Imagery Processing Chlorofil-a

Table 5. Mean of Chlorophyll-A Concentration (mg/m^3) Monthly
Year 2013

Month	Min.	Max.	Mean	Std Dev. (Sd)
January	0,09	2,62	0,21	0,20
February	0,09	1,70	0,22	0,14
March	0,09	1,19	0,18	0,09
April	0,05	3,89	0,20	0,20
May	0,09	1,10	0,18	0,11
June	0,06	1,05	0,16	0,09

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July	0,11	4,41	0,20	0,21
August	0,07	2,88	0,24	0,23
September	0,10	2,94	0,27	0,27
October	0,08	0,94	0,17	0,11
November	0,12	3,99	0,47	0,02
Desember	0,11	5,05	0,32	0,44

Source: Aqua MODIS Level 3 Imagery Processing Chlorofil-a

Information :

Max. = Maximum Value

Min. = Minimum Value

Mean = Mean

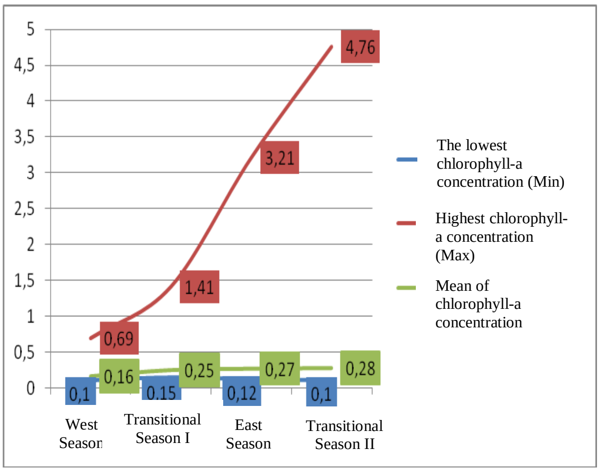
Sd = Standar Deviation

Table 6. Comparison of Mean Chlorophyll-a Concentration according to Season 2011, 2012 and 2013 (Mg/m^3)

Year	West Season	Transition Season I	East Season	Transition Season II
2011	0,16	0,25	0,27	0,27
2012	0,21	0,16	0,22	0,38
2013	0,21	0,19	0,20	0,30

Source: Aqua MODIS Level 3 Imagery Processing Chlorofil-a

Figure 5. Graphic Comparison of Chlorophyll-a Concentration according to Season 2011



Spatially, it can be concluded that the shallow waters near the coast in a zone of less than 17 nautical miles from the coast, especially around the Linggo Sari Baganti Regencys to the Lunang Regencys and the Silaut Regencys in the astronomical zone between 1^0 45’ S - 2^0 32’ S dan 101^0 35’ E – 101^0 E is the waters with the highest concentration of chlorophyll-a throughout the year. While the water area deeper than 100 m and far from the coast has a chlorophyll-a concentration between 0,1 mg/m^3 – 0,2 mg/m^3.Figure 6. Spatial and Temporal Distribution of Chlorophyll-A 2011 in the Pesisir Selatan Regency Waterzone

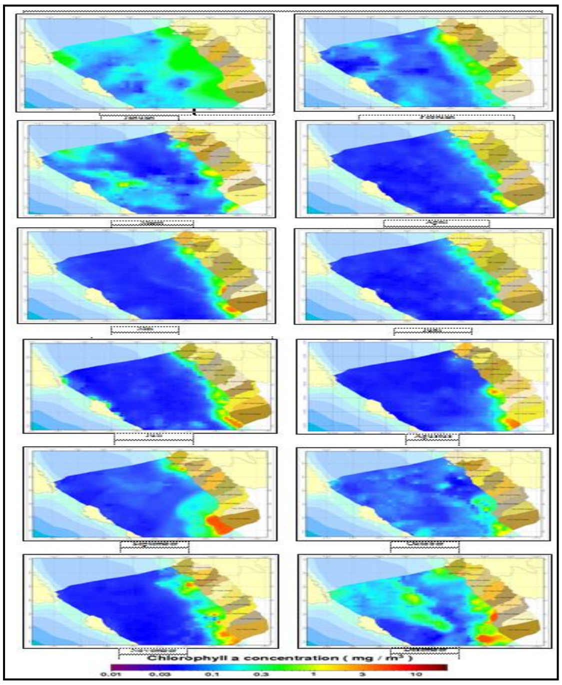


Figure 7. Spatial and Temporal Distribution of Chlorophyll-A 2012 in the Pesisir Selatan Regency Waterzone

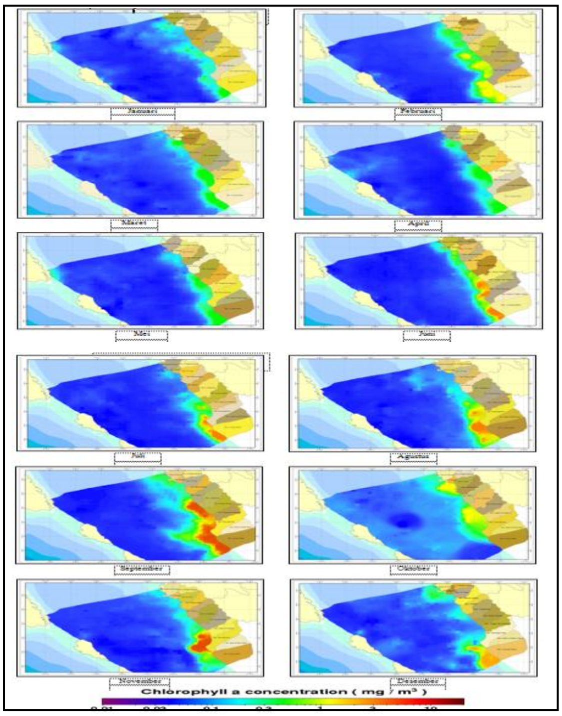


Figure 8. Spatial and Temporal Distribution of Chlorophyll-A 2011 in the Pesisir Selatan Regency Waterzone

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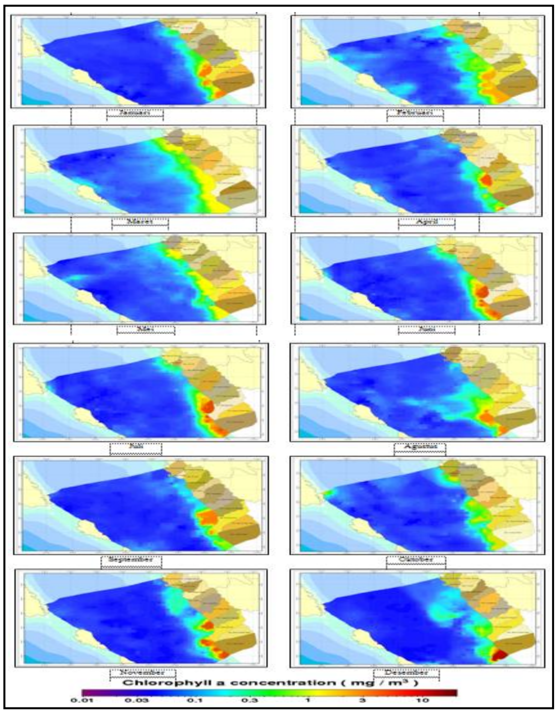


Relationship Between Sea Surface Temperature (X) and Chlorophyll-a Concentration (Y)

Tabel 10. Rata-Rata Bulanan Konsentrasi Klorofil-a dan Rata-Rata Suhu Permukaan Laut Tahun 2013

Bulan	Konsentrasi Klorofil-a Rata-Rata Bulan (Mg/m^3)	Suhu Permukaan Laut Rata-Rata Bulanan (^{0}C)
Januari	0,21	30,50
Februari	0,22	30,54
Maret	0,18	31,23
April	0,20	31,19
Mei	0,18	31,02
Juni	0,16	30,70
Juli	0,20	30,55
Agustus	0,24	30,66
September	0,27	30,77
Oktober	0,17	30,92
November	0,47	29,83
Desember	0,32	30,20

Source: Aqua MODIS Level 3 Imagery Processing Chlorofil-a

There is a strong influence of sea surface temperature on the concentration of chlorophyll-a, the regression coefficient (R) of 0.811. While the determinant coefficient (R2) of 0.657 or 65.7%, meaning that 65.7% chlorophyll-a concentration in the waters of the Pesisir SelatanRegency is affected by temperature changes, while the remaining 34.3% is influenced by other variables.

Model Summary(b)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,811(a)	,657	,623	,05330

a Predictors: (Constant), Suhu Permukaan Laut
b Dependent Variable: Konsentrasi Klorofil-a

The price of t arithmetic was -4.380 and the significance of 0.001 <0.05, then the sea surface temperature variable had a significant influence on the concentration of chlorophyll-a. The following table shows the constant value (a) is 5,623 and the value is X = -0,176. The line of regression equation is as follows :

$Y = a + bx = 5{,}623 + (-0{,}176)\ X = 5{,}623 - 0{,}176\ X$

That is, if there is no monthly mean value of sea surface temperature, the value of chlorophyll-a concentration is 5.623. Whereas if an mean monthly sea surface temperature increases of 1 0C causes a decrease in the monthly mean chlorophyll-a concentration of 0.176 mg / m3 in the waters of the Pesisir Selatan Regency.

Regresi Spasial

The effect of sea surface temperature (X) on the concentration of chlorophyll-a (Y) in 2013 strengthened at the peak of the east season (July) and the transition season II (October). At the peak of the west season (January) the coefficient of determination (R^2) is 0.1913 or 19.13% with waters in the south having a coefficient of determination stronger than the waters in the north.

At the height of the transition season II (April) the effect of sea surface temperature on chlorophyll-a concentrations was stronger, the coefficient of determination (R^2) increased to 0.2975 or 29.75%. The Magnitude of the determination coeficient value (local R^2) is more evenly distributed.

At the peak of the east monsoon (July) the effect of sea surface temperature on chlorophyll-a concentrations increases again. The coefficient of determination is 0.4363 or 43.63%. The coefficient of determination per polygon (local R^2) in the northern waters is stronger than the southern waters.

The strongest influence of sea surface temperature occurs at the peak of the transition season II (October), the coefficient of determination is 0.5258 or 52.58%. The waters in the north have a higher determination coefficient (local R^2) than the waters in the south. reach 31 ^{0}C. This is due to the large intensity of sunlight falling in waters close to the equator the highest sea water temperature occur in areas close to the equator, Indonesia. Unlike the temperature variability on land, the range of temperature differences in the relative waters is not too far away. Especially in the waters of the Pesisir Selatan Regency the sea surface temperature ranges between 25^{0}C – 31^{0}C.

The intensity of sunlight received throughout the Indonesian territorial waters is relatively the same because it is in the equatorial zone, this causes the difference in relative temperatures not too different in the Indonesian water columns, especially at sea level. Temperature variations in water areas, especially sea surface temperature is strongly influenced by the size of the intensity of sunlight (King, 1963).

Aqua-Modis satellite imagery also shows that sea surface temperatures in the Pesisir Selatan waters also tend to be high sea temperature itself ranges from 28 - 31^{0}C (Weyl, 1967 in Manuhutu and Hutagalung, 2010).

The mean concentration of chlorophyll-a in Indonesian waters is 0.19 mg/m^3 throughout the year with 0.24 mg/m^3 in the east season and 0.16 mg/m^3 in the west season. The magnitude of this concentration is strongly influenced by up welling activities in the water columns in Indonesia (Nontji, 2002). Aqua-MODIS image processing results to the average monthly concentration showed in the west season between 2011 and 2013 the range of chlorophyll-a concentration was at 0.16 mg/m^3 to 0.21 mg/m^3.

In the east season the monthly average chlorophyll-a concentration is also higher between 0.20 mg/m^3 - 0.27 mg/m^3. The highest range throughout the year in the waters of Pesisir Selatan Regency actually occurs in the transition season II, from 2011-2013 the monthly average of chlorophyll-a is in the range of 0.27 mg/m^3 - 0.38 mg/m^3.

The chlorophyll-a concentration in the shallow water zone near the coast is less than 17 nautical miles from the shoreline is a zone of waters with higher nutrient abundance throughout the year. Especially shallow waters close to the coast around Linggo Sari Baganti SubRegency to Silaut SubRegency have higher nutrient levels compared to other waters in the Pesisir Selatan Regency to the eastern waters of the Kepulaun Mentawai Regency. Seawater masses in shallow waters near the coast have higher levels of chlorophyll-a compared to offshore waters due to the direct entry of runoff from land directly through rivers (Hatta, 2002).

The chlorophyll-a concentration in the east season which is higher than in the west season also illustrates that the mass of water in the waters of the Pesisir Selatan Regency is partly influenced by the mass of water from the waters in the east. This mass of water moves following the flow of currents and winds from mainland Australia (high pressure center) to mainland Asia (low pressure center) between June and August, and is still influential in the transition season II.

North East Indian Ocean waters covering the west coast of Sumatra and South Java - Sumbawa, throughout the year are supplied by water masses and Southern Equatorial Currents and Equatorial Currents, whereas equatorial and Monsoon Currents (AM) are only in the months certain month (Wyrtki,1961 and Tchernia,1980).

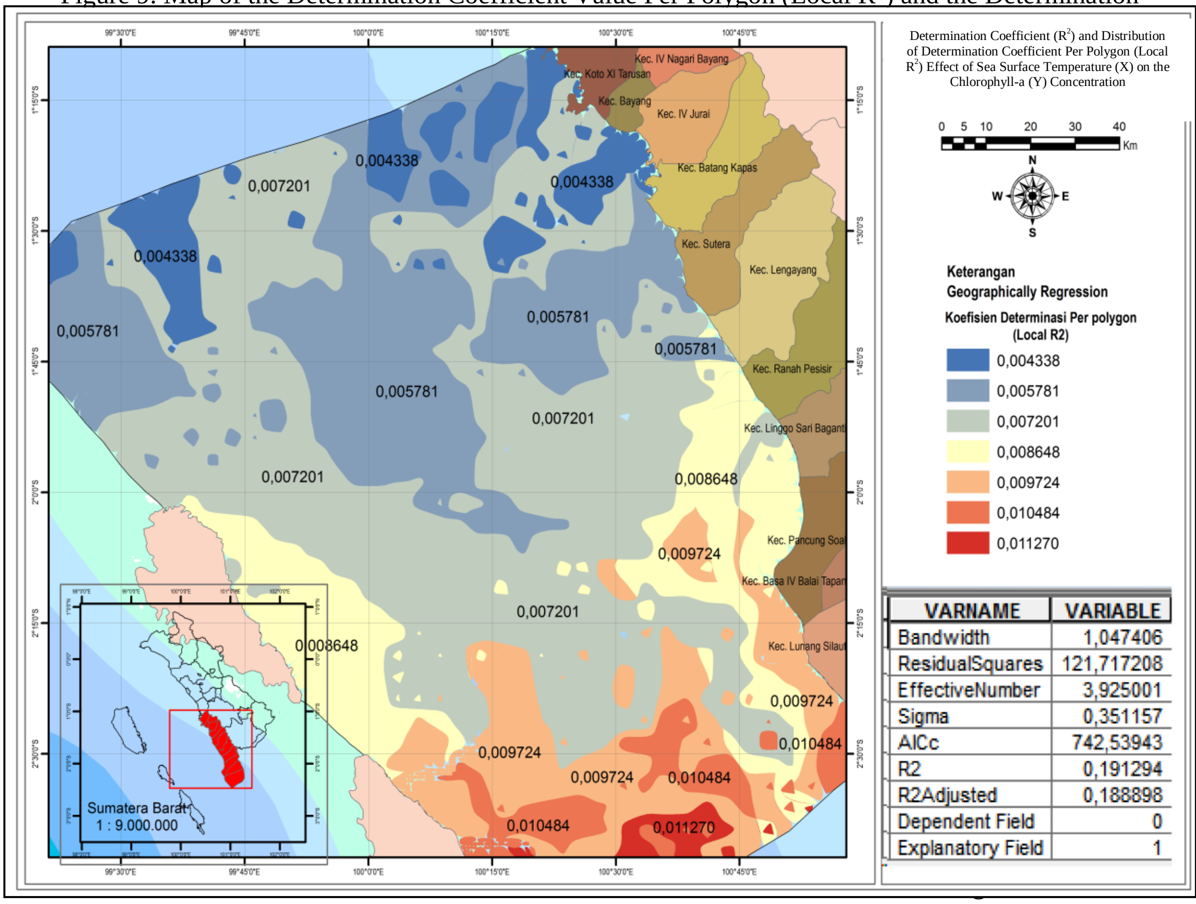
This waters zone are affected by water masses originating from the Timor Sea, Lombok Strait, Sawu Strait, and Sunda Strait. Changes in the pattern of currents and mass supply of water cause the water mass characteristics of water always differ based on the prevailing monsoon (Wyrtki,1961)

November is a month of high nutrient abundance. Optimal sea surface temperature zones of Skipjack fish are formed. This is actually in line with the theory of Wyrtki (1961) that in the east monsoon zone there is a divergence zone at 200°S as a result of moving south of the equator to the north at high speed and south at a low speed. The zone will move south until it disappears in February when the equatorial turn curved, so the divergence zone turned into a convergence where Southern Equatorial Currents again increased in strength. Meanwhile, according to Clarke and Liu (1993) different conditions occur during the transition season, especially in October and November, where the mass that flows along the west coast of Sumatra causes downwelling.

The strong influence of sea surface temperature on the concentration of chlorophyll-a indicates the possibility of movement of vertical currents that causes the concentration of chlorophyll-a to increase, on the other hand a certain temperature range is a living zone for phytoplankton. In the waters of the Pesisir Selatan Regency in the western season the waters in the southern part have a higher relationship between sea surface temperature and chlorophyll-a. Warmer surface temperatures in the south cause vertical currents to move nutrients from the layers below to the layers below. While the waters in the north are supplied by the mass of water from the waters in the west and the South Equatorial Current.

Conversely, in the east monsoon, the influence of sea surface temperature which is stronger in the north shows that the waters

Figure 9. Map of the Determination Coefficient Value Per Polygon (Local R^2) and the Determination



VARNAME	VARIABLE
Bandwidth	1,047406
ResidualSquares	121,717208
EffectiveNumber	3,925001
Sigma	0,351157
AICc	742,53943
R2	0,191294
R2Adjusted	0,188898
Dependent Field	0
Explanatory Field	1

Sawu and the South Equator Current.

Temperature directly or indirectly influences primary productivity in the sea (Tomascik et. Al., 1997). Directly, temperature plays a role in controlling enzymatic chemical reactions in photosynthesis. While indirectly, temperature plays a role in forming the stratification of water columns which can affect the vertical distribution of phytoplankton.

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Figure 10. Map of Determination Coefficient Value Per Polygon (Local R^2) and Determination Coefficient Value (R^2) at Peak Transition I (April) 2013

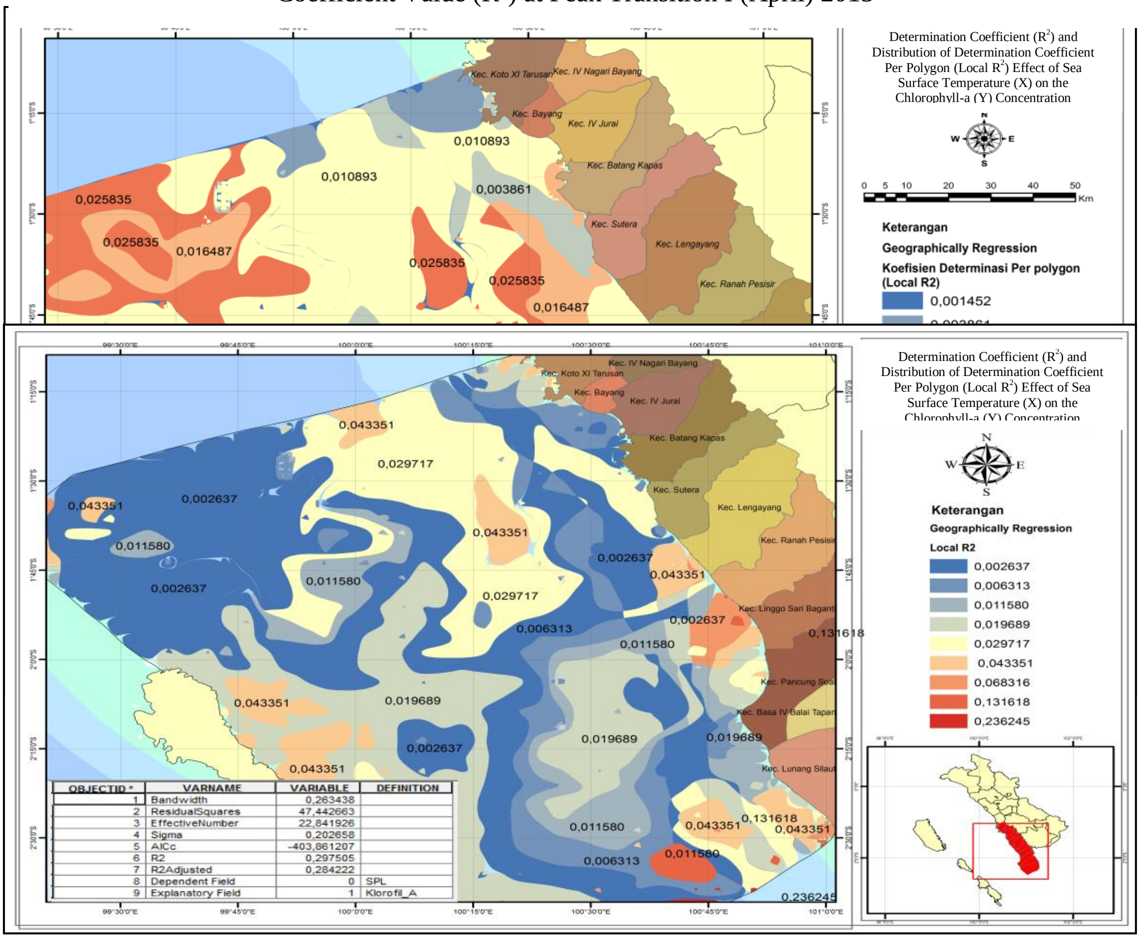
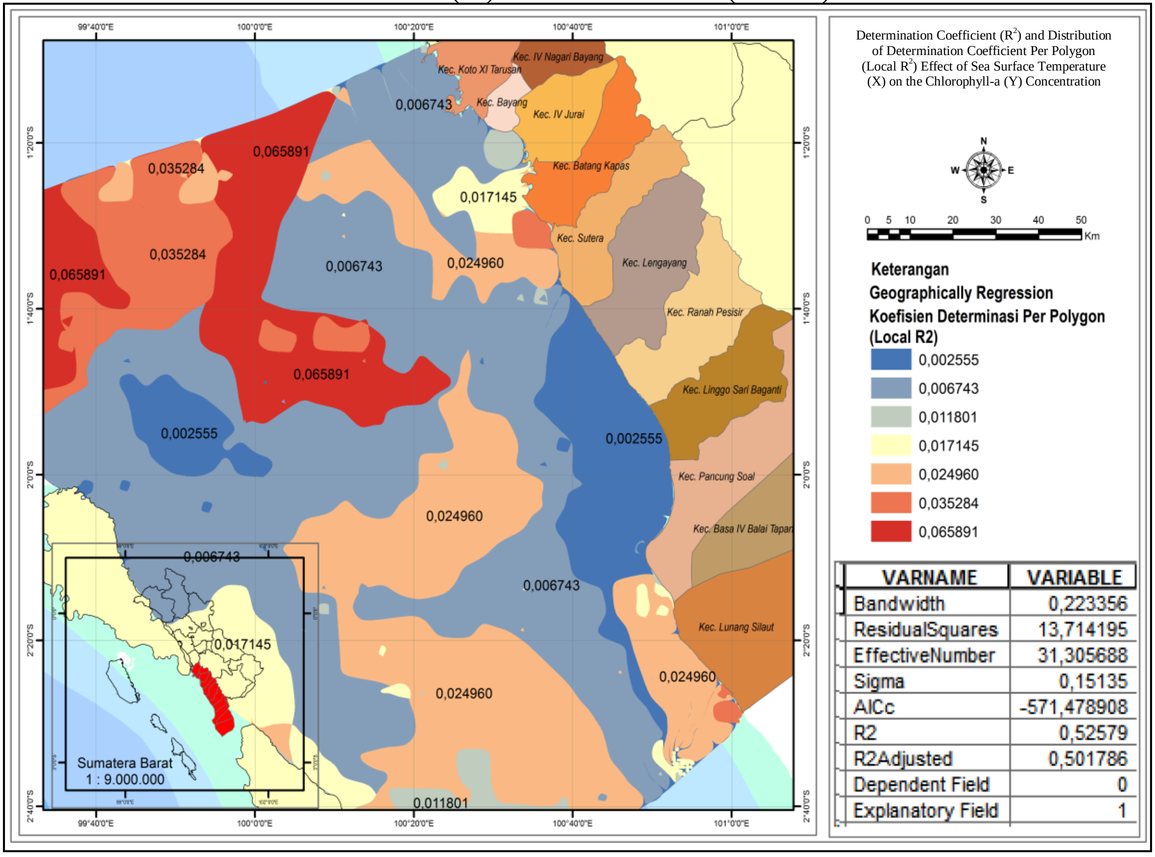


Figure 12. Map of the Determination Coefficient Value Per Polygon (Local R^2) and the Determination Coefficient Value (R^2) at Peak Transition II (October) 2013



Conclusion And Outlook

The difference in sea surface temperature between deep water zones and shallow water is not very far, ranging from 25^0C - 33^0C. Temporally, the monthly average sea surface temperature in all water columns throughout 2013 ranged from 29.83^0C - 31.23^0C. The maximum spatial temperature range peaks in July and September.

Chlorophyll-a concentrations in the shallow water zone (<100 m) near the coast are less than 17 nautical miles from the shoreline tend to be higher than deep waters (> 100 m) more than 17 nautical miles. In shallow waters, especially around the waters of Linggo Sari Baganti SubRegency to Silaut SubRegency ($100^0$35 'E - 101^0 00' E and 1^0 50 'S - 2^0 00' S) are water zones with high chlorophyll-a concentrations throughout the year. In this water zone the concentration of chlorophyll-a reaches more than 4.41 mg/m3. The highest chlorophyll-a concentration occurs during the east season until the transition season II.

The mean monthly sea level temperature also affects the monthly average chlorophyll-a concentration, a regression coefficient of R = 0.811, indicating a strong influence. The relationship of monthly mean sea surface temperature is negatively correlated, where each increase of 1^0C sea surface temperature causes a decrease in chlorophyll-a concentration of 0.176 mg/m3.

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