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The Effect of Chlorophyll-A on the Catches of Skipjack Tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

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Abstract. Potential areas for catching *K. pelamis* has a close relationship with environmental parameters, especially chlorophyll-a. The use of remote sensing methods to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions. Remote sensing technology helps in observing oceanographic parameters so that they can determine the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea. The purpose of this study was to analyze the relationship and effect of chlorophyll-a on the catch of *K. pelamis*. This study uses the data analysis method used, namely multiple linear regression, because it uses two independent variables, namely chlorophyll-a. Based on the results and discussions that have been described, it can be concluded that; (1) the value of the coefficient of determination (R_2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the real model by 19.6% so that the rest is explained by other factors of 80.4%. Based on the t_{test}, the t_{count} value of chlorophyll-a was 3.320, the sig value was 0.029. For the t_{table} value of 2.77. Based on the results obtained the value of $t_{count} > t_{table}$ and sig value of 0.029 <0.05. So it was found that H_o was rejected and H_1 was accepted, then there was a significant effect between chlorophyll-a and *K. pelamis*. (2) in the ANOVA table the value of R^2 = 0.779 or 77.9% the effect of chlorophyll-a on *K. pelamis*, so the remaining 22.1% is another factor. Based on the calculation of the F_{test} using SPSS 25 and manually, it is obtained that the value of F_0 = 7.030 and the value of F_{table} = 6.94. The results obtained in the ANOVA table have a sign value of 0.049 <0.05. So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or F_0 F_{table}, so there is a significant effect of chlorophyll-a on *K. pelamis*.

Keywords: Purse seine, remote sensing, Sea surface Temperature (SST), catch season.

Introduction.

The Banda Sea is one of the waters that has this wealth which has an abundant nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea (Putra et al 2017). The topography of the seabed is very complex with a basin in the west and a trough in the east (Suyarso 1999; Tapilatu 2016). This complex topographical shape also determines the mass exchange of water. The circulation of different water masses and varies between seasons is influenced by the monsoon wind pattern system.

The circulation of water mass in Indonesian waters differs between the west monsoon and the east monsoon. In the west monsoon, water masses generally flow to the east of Indonesian waters, and vice versa when the eastern monsoons develop perfectly supplying water masses originating from the upwelling areas in the Arafura and Banda Seas (Hasanudin 1998). The upwelling process that occurs in the Banda Sea results in a decrease in temperature, an increase in salinity, and a removal of nutrients, so that the availability of nutrients in the Banda Sea will affect the abundance of plankton in the waters (Baars et al 1990; Armus et al 2019).

The potential area for catching Skipjack tuna (*K. pelamis*) has a close relationship with environmental parameters, especially the optimum chlorophyll-a in the range 0.12-0.22 mg m^3 (Zainuddin 2011; Hidayat et al 2019; Wangi et al 2019). Almost all fish populations that live in marine waters have an optimum sea surface temperature range and chlorophyll-a for their life, including *K. pelamis* (Jufri et al 2014). Remote sensing technology helps in observing the oceanographic parameters of the surrounding waters in the Banda Sea so that they can determine the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea. The purpose of this study was to analyze the relationship and effect of chlorophyll-a on the catch of *K. pelamis* (Mugo et al 2010).

K. pelamis likes areas where there is a convergence of currents that mostly occur in areas that have many islands. The vertical distribution of *K. pelamis* starts from the surface to a depth of 260 m during the day, while at night it will go to the surface (diurnal migration) (Ekayana et al 2017). *K. pelamis* in the small size category tends to be caught in a more homogeneous (warm) SST, while large *K. pelamis* is caught in a wider range of SST (cold and warm)(Simbolon & Limbong 2012). *K. pelamis* congregates at low chlorophyll-a concentrations and water depths of ≥ 500 m because *K. pelamis* is a carnivorous fish with the main prey of small pelagic fish such as *Stelophorus sp.* and *Sardinella sp*. which abundant in continetal shelf and continetal slope waters (Bubun et al 2015).

Remote sensing technology is an alternative method that is very beneficial if it is used in a country with a very large area such as Indonesia (Syah 2010). Remote sensing is a technique for collecting information about objects and their environment from a distance without physical touch (Lo 1986). The use of remote sensing methods to detect osenographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions is a very appropriate alternative (Tangke 2016; Mashita & Lumban-Gaol 2019). Remote sensing technology has several advantages including cheap and easily accessible data prices, wide area coverage, high temporal resolution and digital data forms, making it a potential source of geographic information system (GIS) data. (Louhenapessy & Waas 2009).

One of the sensing satellites equipped with sensors that can detect chlorophyll-a content is the Aqua MODIS satellite (Utari 2013). The variables measured by the Aqua satellite include aeserol, plants covering land, phytoplankton and dissolved organic matter in the oceans, as well as air, land and water temperature (Putra et al 2012). The Aqua MODIS satellite has a polar sun-syncronus orbit. The satellite crosses the equator at noon approaching 13.30 local time (Karif 2014).

Changes in fishing actually occur when the seasons change. Seasonal changes directly affect the oceanographic aspects of the waters, especially sea surface temperature and chlorophyll-a, which greatly affect the presence of fish in an area which has an impact on changes in fishing grounds in that area. Both of these parameters can trigger natural events or phenomena such as upwelling and fronts (Waileruny et al 2014). The fishing season in Southeast Sulawesi waters can be found in January to April and July to September. The fishing season can be affected by the salinity which is the habitat of the caught fish species. In the eastern monsoon (June to September), high salinity water masses originating from the Flores Sea and Pacific Ocean flow through the Makassar Strait to the Java Sea. In the western season (December to March) surface currents move from the South China Sea into the Java Sea from west to east (Bubun & Mahmud 2016).

Material and Method.

The tools and materials needed in the implementation of this research include stationery, cameras, rulers, GPS, MODIS data, SeaDas, SPSS 25, and Surfer 13.

Method of collecting data

The data collection method uses primary data (carried out *in situ*) which is direct observation in the field by following the fishing operation including operating time, the number of catches and the position of the fishing area, and by using secondary data including the image of the distribution of chlorophyll-a level 3 Aqua MODIS downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov) then processed using Seadas to get the chlorophyll value and processed using Surfer 13 to get the results of the distribution of chlorophyll-a in the form of images.

The chlorophyll-a image data chosen to be processed is a standard 8-day image with 4 km resolution map with level 3 at night in November 2017 to March 2018. Chlorophyll-a data is calculated using chlorophyll-a image data that has been corrected both atmospheric and geometrically. using Seadas which will produce chlorophyll-a distribution data which will be reprocessed using a computer device, then the data is reprocessed using Surfer 13 which will find out the distribution of chlorophyll-a in the form of JPEG image format.

The catch used includes the catch weight of *K. pelamis* during November 2017 to March 2018, analyzed by calculating the weight per fishing trip so that fluctuations in the catch based on time (temporal) and fishing location (spatial) can be observed.

Data analysis method

Multiple Correlation Analysis

Multiple correlation is a number that shows the direction and strength of the relationship between two variables together or more with other variables. To be able to provide an interpretation of the correlation coefficients found to be large or small, it can be guided by the conditions listed in table 1 below (Sugiono 2007):

Table 1

Assessment of the correlation coefficient (Sugiono 2007).

Coefficient Interval	Relationship Level
0,00 – 0,199	Very low
0,20 – 0,399	Low
0,40 – 0,599	Moderate
0,60 – 0,799	Strong
0,80 – 1,00	Very strong

The double correlation formula for two variables is as follows:

$$\mathrm{R}_{\mathrm{y.\,x_1x_2}} = \sqrt{\frac{r_{yx1}^2 + r_{yx2}^2 - 2r_{yx1}r_{yx2}\,r_{x1x2}}{1 - r^2{}_{x1\,x2}}}$$

Information :

$\mathrm{R}_{\mathrm{y.\,x_1x_2}}$ = Correlation between variables X_1 and X_2 together with the variable Y

ryx_1 = Correlation between X_1 and Y

ryx_2 = Correlation between X_2 and Y

rx_1x_2 = Correlation between X_1 and X_2

Multiple Linear Regression Analysis

The data where the correlation coefficient is at a sufficient level or more than sufficient, then tested again using multiple linear regression (Sugiono 2005). The multiple linear regression formula is as follows:

$$\mathrm{Y} = \mathrm{a} + \mathrm{b}_1\mathrm{X}_1 + \mathrm{b}_2\mathrm{X}_2$$

Information :

X_1 = Variable Sea Surface Temperature

X_2 = Chlorophyll-a variable

Y = The most number of certain fish species caught

a, b_1, b_2 = Constants

Multiple Linear Statistical Test

According to Hasan (2004), multiple linear regression statistical tests are used to test the significance or not of the relationship of more than two variables through the regression coefficient. Multiple linear regression, statistical tests can be divided into two, namely as follows:

1. Concurrent Test

The test conducted in multiple linear regression uses the simultaneous test, which is a statistical test for the regression coefficient that simultaneously or jointly affects Y, this test uses the F test, namely:

$$F_o = \frac{R^2(n-k-1)}{k(1-R^2)}$$

$$F_o = \frac{\frac{R^2(\sum y^2)}{k}}{\frac{(1-R^2)(\sum y^2)}{n-k-1}}$$

Information :
n = number of subjects
k = number of independent variables
$\sum y^2$ = sum of squares of the variable Y

2. Individual Test

Individual test, namely the statistic for the regression coefficient with only one regression coefficient that affects Y. This test uses the t_{test}, namely:

$$t_o = \frac{b_1 - B_i}{S_{b1}}$$

Especially for regression involving only two independent variables, the values of S_{b1} and S_{b2} are as follows:

$$S_{b1} = \sqrt{S_e^2 \frac{\sum x_2^2}{(\sum x_1^2)(\sum x_2^2)-(\sum x_1 x_2)^2}}$$

$$S_{b2} = \sqrt{S_e^2 \frac{\sum x_1^2}{(\sum x_1^2)(\sum x_2^2)-(\sum x_1 x_2)^2}}$$

$$S_e = \sqrt{\frac{\sum e_i^2}{n-3}} = \sqrt{\frac{\sum y^2 - b_1\sum x_1 y - b_2 \sum x_2 y}{n-3}}$$

Geographical Information Systems (GIS) Analysis

Geographical information system (GIS) analysis using *Surfer 13* software was used to map the distribution of *chlorophyll-a* in November 2017 to March 2018 based on time (temporal) and fishing location (spatial) with the aim of producing information about the relationship of these variables.

Result and Discussion

This research was conducted in November 2017 to May 2018 by following a fishing operation using a purse seiner in the Banda Sea, Maluku Indonesia.

Figure 1. Purse seiner

Fish Catch Results

The fishing operation is carried out in seven trips, with 34 settings. The total catch was 56,689 kg with an average of 12,558.17 kg. The number of catches on the 2nd trip (6 times the setting) was the largest with a total catch of 11,954 kg with an average of 1,992.33 kg or 21.1% of the total catch. Meanwhile, the 3rd trip (2 times setting) was the minimum catch, namely 5,522 kg with an average of 2,761 kg or 9.7% of the total catch. For more details, see table 2.

Table 2

The number of fish catch per trip

Trip to-	Number of settings	Amount (Kg)	Average (Kg)	Percentage (%)
1st	4	8,226	2,056.5	14.5
2nd	6	11,954	1,992.33	21.1
3rd	2	5,522	2,761	9.7
4th	4	7,006	1,751.5	12.4
5th	6	9,607	1,601.16	17
6th	6	7,982	1,330.33	14.1
7th	6	6,392	1,065.33	11.2
Total	34	56,689	12,558.17	100

Composition of Catch

The catch data consists of seven trips with 34 settings. The main catches are *K. pelamis*, *T. albacares*, *E. affinis* and *D. ruselli*. Based on the results obtained, the highest *T. albacares* catches were on trip 7th and the lowest was on trip 5th. *K. pelamis* catches the highest on trip 2nd and the lowest on trip 6th. The highest *T. albacares* catches were on trip 2nd and the lowest was on trip 7th, and the highest *D. ruselli* was on trip 6th and the lowest was on trip 3rd. The composition of the catch can be seen in table 3 below.

Table 3

The composition of the catch based on the type of fish

Trip to-	Total Catch (Kg)				Total
	T. albacares	*K. pelamis*	*E. affinis*	*D.ruselli*	

1st	825	3,018	2,590	1,793	8,226
2nd	230	5,676	4,430	1,618	11,954
3rd	90	4,270	497	665	5,522
4th	569	2,948	1,817	1,672	7,006
5th	0	4,467	4,290	850	9,607
6th	13	2,536	670	4,763	7,982
7th	915	4,323	0	1,154	6,392

Based on the table above, the highest catch was on the second trip as much as 11,954 kg consisting of 230 kg *T. albacares*, 5,676 kg *K. pelamis*, 4,430 kg *E. affinis*, and 1,618 kg *D. ruselli*. The lowest catch was on the 3rd trip as much as 5,522 kg consisting of 90 kg *T. albacares*, 4270 kg *K. pelamis*, 497 kg *E. affinis*, and 665 kg *D. ruselli*.

The highest catch of *T. albacares* was on the 7th trip as much as 915 kg, while the lowest was on the 5th trip with no catch. The highest catch of *K. pelamis* was on the 2nd trip as much as 5,676 kg while the lowest on the 6th trip was 2,536 kg. The highest *T. albacares* catch was on the 2nd trip as much as 4,430 kg and the lowest on the 7th trip with no catch. The highest *D. ruselli* catch was on the 6th trip as much as 4,763 kg and the lowest on the 3rd trip was 665 kg. Based on all catches, *K. pelamis* was the most dominant fish caught compared to other fish. This can be seen in Figure 2 below.

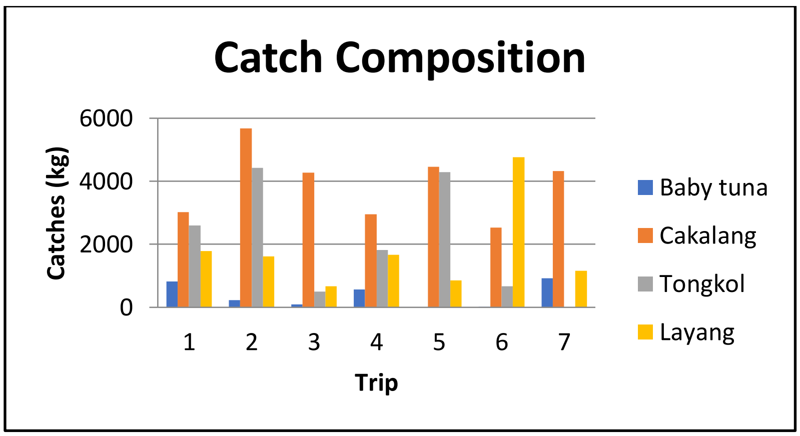


Figure 2. Composition diagram of the catch

Average *K. Pelamis* Persetting Results

The catch of *K. pelamis* is higher than that of other types. The total catch of *K. pelamis* from the 1st trip to the 7th trip was 27,238 kg. The average catch of *K. pelamis* with the highest setting on the 3rd trip was 1,495 kg while the lowest catch on the 6th trip was 422.67 kg. The catch of the 1st trip was 754.5 kg, the 2nd trip was 946 kg, the 3rd trip was 1,495 kg, the 4th trip was 737 kg, the 5th trip was 744.5 kg, the 6th trip was 422, 67 kg, the 7th trip was 720.5 kg. as shown in Figure 3 below.

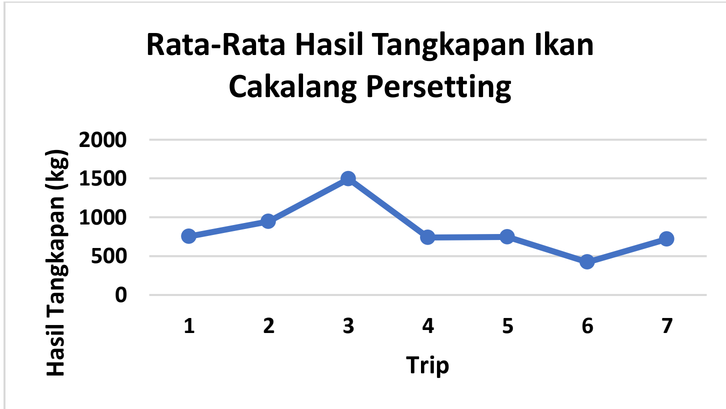
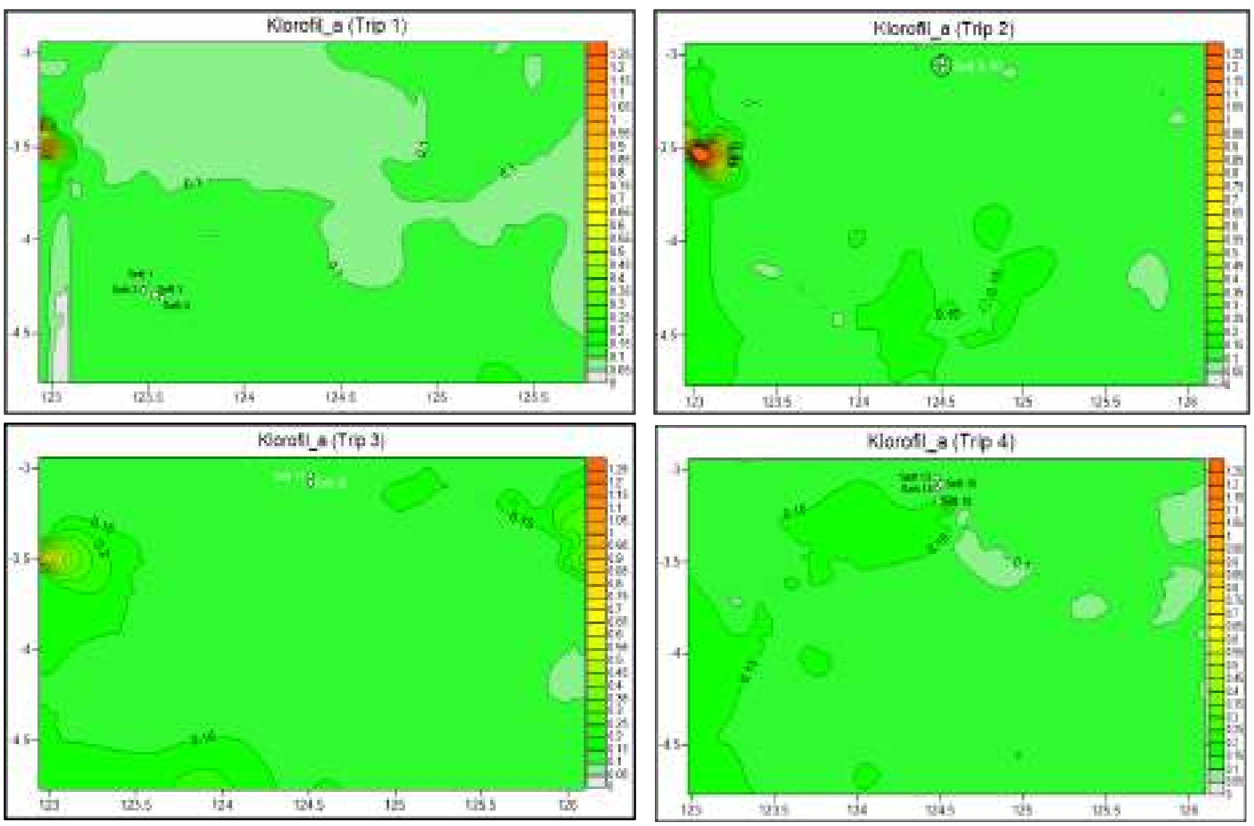


Figure 3. Diagram of the average catch of *K. pelamis*

Chlorophyll-a

Fertile waters contain high chlorophyll-a concentrations, because chlorophyll-a is an indicator of fertility in waters. The chlorophyll-a concentration is also influenced by other factors such as current. Chlorophyll-a image data were downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). The data will be processed using Seadas which will produce chlorophyll-a data which is recycled using the help of a computer device, then the data will be processed using Surfer 13 which will be processed in the form of a JPEG image format which displays the distribution of chlorophyll-a with different colors for each chlorophyll-a. The distribution of chlorophyll-a was taken based on the time and position of the capture. The following is a JPG image format of chlorophyll-a distribution in 7 trips of fishing.



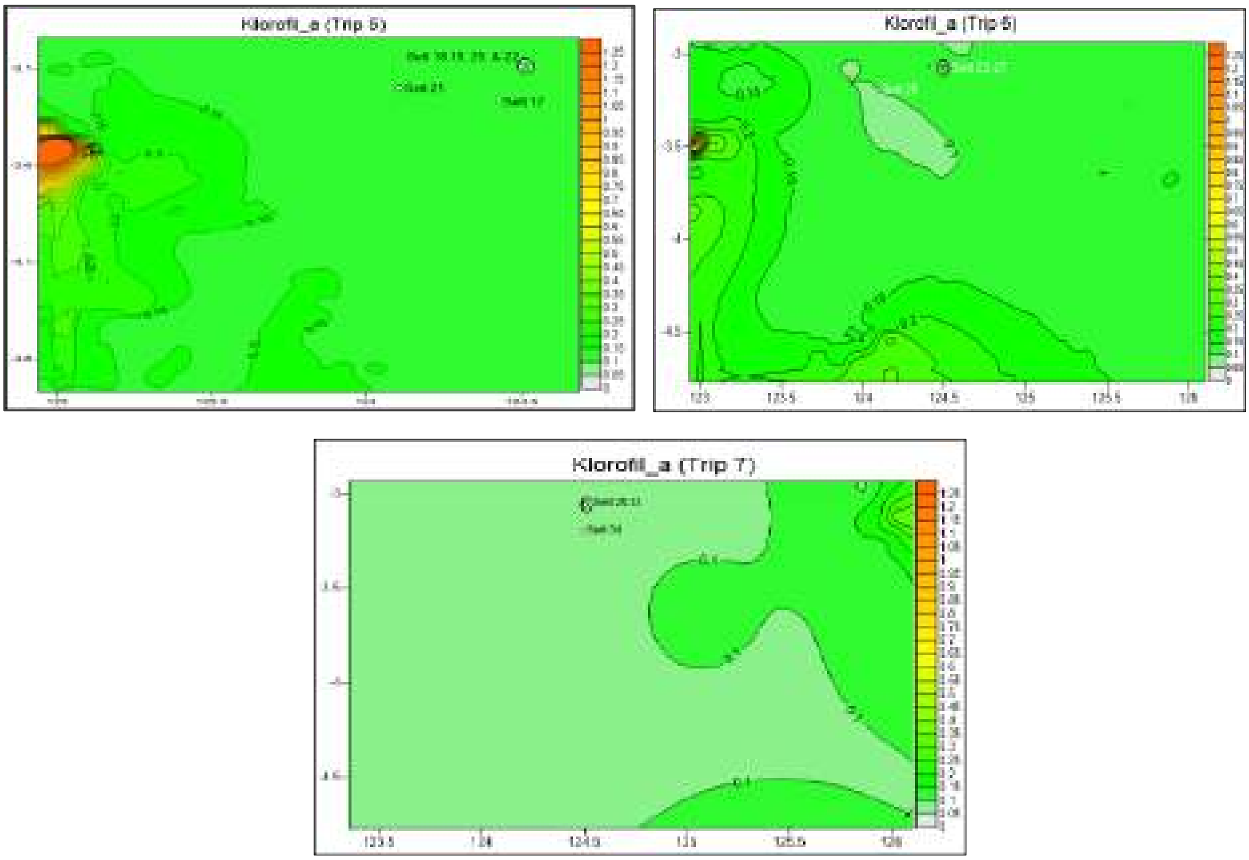


Figure 4. Distribution of chlorophyll-a in 7 trips of fishing.

Table 4

Chlorophyll-a Concentration Value

	Chlorophyll-a Concentration Value (mg m^3)						
	1st Setting	2nd Setting	3rd Setting	4th Setting	5th Setting	6th Setting	Average
Trip 1	0.1308	0.1292	0.1273	0.1268	-	-	0.1285
Trip 2	0.1176	0.1176	0.1173	0.1266	0.1176	0.1266	0.1205
Trip 3	0.1399	0.1342	-	-	-	-	0.1370
Trip 4	0.1046	0.1080	0.1077	0.1632	-	-	0.1209
Trip 5	0.1314	0.1312	0.1312	0.1314	0.1313	0.1258	0.1303
Trip 6	0.1208	0.1288	0.1287	0.1227	0.1281	0.1001	0.1215
Trip 7	0.0895	0.0903	0.0913	0.0880	0.0875	0.0894	0.0893

Information :

The distribution of the highest chlorophyll-a concentrations

The distribution of the lowest chlorophyll-a concentrations

The chlorophyll-a concentration value on the 7th trip decreased significantly, which was the lowest concentration value compared to the other trips. The higher the chlorophyll-a concentration value in the waters, the more fertile the waters will be and conversely the lower the concentration of the waters, the less fertile the waters will be.

Average chlorophyll-a

The average chlorophyll-a can be seen in Figure 5, where the concentration of the 7th trip decreased the concentration of chlorophyll-a which was greatly decreased compared to the concentration on the other trips. The chlorophyll-a concentration can be seen in the image below which shows a decrease and an increase in the chlorophyll-a concentration. The average chlorophyll-a concentration was the highest in trip three and the lowest in trip 7. The difference between the highest and lowest concentrations is 0.0477 mg m^3.

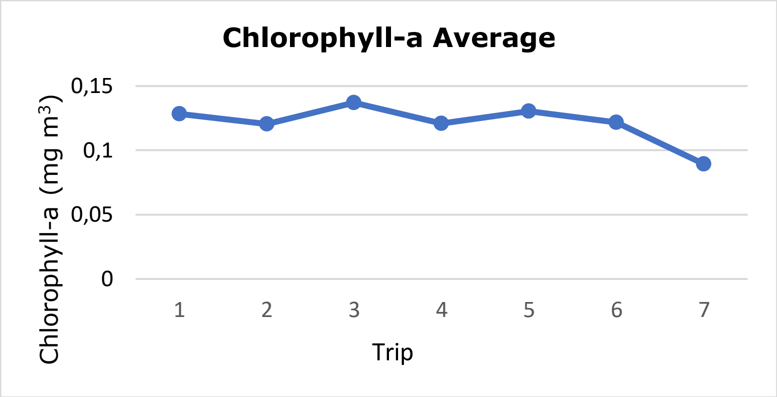


Figure 5. Diagram of average chlorophyll-a for 7 trips

The Relationship between Average Chlorophyll-a against *K. pelamis*

The relationship of chlorophyll-a to the catch of *K. pelamis* was calculated using a multiple correlation test. Multiple correlation estimator level of chlorophyll-a relationship to *K. pelamis* catch. Manual multiple correlation test using SPSS 25.

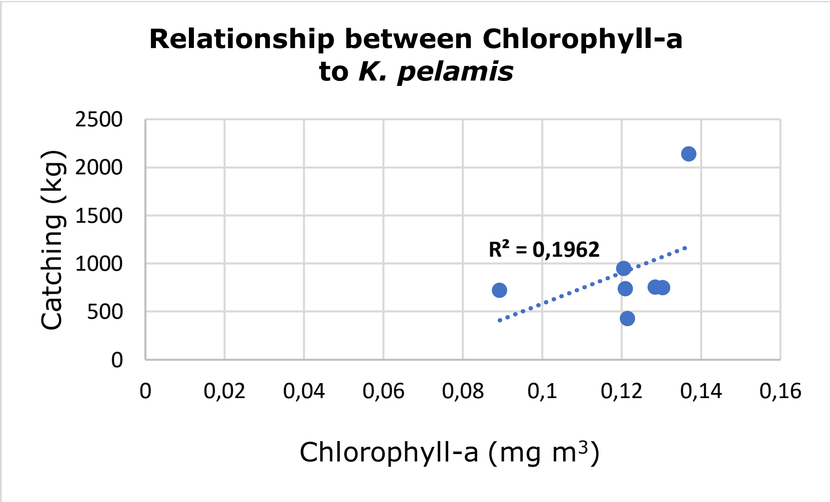


Figure 6. Graph of chlorophyll-a relationship to *K. pelamis*

Based on graph 6 above, the coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6% so that the remaining 80.4% is explained by other factors such as salinity, currents and others.

The value of the correlation coefficient using SPSS 25 can be seen in table 4. The correlation coefficient value was obtained at 0.443, which means that the positive relationship between chlorophyll-a and the catch of *K. pelamis* is moderate, because the correlation coefficient value is in the correlation interval 0.40-0.599. This relationship is stated as positive, if the value of one variable is increased, it will increase the value of the other variables and vice versa (Sugiono 2007). So the positive relationship between chlorophyll-a and the catch of *K. pelamis*, this means that if the chlorophyll-a is higher it will increase the catch, and vice versa if the chlorophyll-a is lower it will decrease the catch of *K. pelamis*.

Hypothesis testing is used to determine whether the hypothesis is accepted or rejected, then the t test is used. This hypothesis uses the help of the Coefficients table (Table 7). Based on this table, the t_{count} value of chlorophyll-a is 3,320 and a sig value of 0.029. Based on the results obtained, the value $t_{count} > t_{table}$ = 3,320 > 2.77 and the value of sig. 0.029 < 0.05. Obtained H_o is rejected and H_1 is accepted, so there is a significant effect between chlorophyll-a and the catch of *K. pelamis*, this is in accordance with previous research conducted by Demena et al (2017) which states that chlorophyll-a and the number of catches *K. pelamis* has a unidirectional relationship, and the chlorophyll-a concentration affects the presence of *K. pelamis*.

The Effect of Chlorophyll-a on the Catch of *K. pelamis*

chlorophyll-a is an indicator that greatly influences the presence of fish in the waters, especially *K. pelamis*, because *K. pelamis* is a fish that likes to immigrate its life. Knowing the effect of chlorophyll-a on the catch of K. pelamis is calculated using multiple linear regression with the help of SPSS 25 and manual calculations using a computer device.

Table 5

Model summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.882[a]	.779	.668	320.54745
a. Predictors: (Constant), Chlorophyll-a				

Based on the results obtained in table 5 above the coefficient of determination (R^2) = 0.779 or 77.9%. This shows that 77.9% influence chlorophyll-a on the catch of *K. pelamis*, so that the remaining 22.1% is influenced by other factors such as currents, salinity, and others. The correlation coefficient (R) in the model summary table above is 0.882. Based on table 5, the relationship level of the correlation coefficient (R) is included in the interval at 0.80-1.00, which means that the level of chlorophyll-a relationship to the catch of *K. pelamis* is very strong.

Table 6

ANOVA[a]

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1444657.089	2	722328.544	7.030	.049[b]
	Residual	411002.672	4	102750.668		
	Total	1855659.760	6			
a. Dependent Variable: *K. pelamis*						
b. Predictors: (Constant), Chlorophyll-a, Sea Surface Temperature (SST)						

Hypothesis test used is the F_{test}, this test is conducted to test the effect of chlorophyll-a (independent) together on the catch of *K. pelamis* (dependent) which will know the results of the hypothesis are accepted or rejected. The results obtained in the ANOVA table sign value 0.049 < 0.05 So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or $F_o \geq F_{table}$. If H_o is rejected and H_1 is accepted, then there is a significant effect between SST and chlorophyll-a on the catch of *K. pelamis*, this is based on previous research conducted by Demena et al (2017) which states that sea surface temperature and chlorophyll-a are two indicators. which greatly affects the presence of fish in the waters, especially *K. pelamis*.

Based on the output of SPSS 25 in the coefficientsa table and manual calculations using the help of a computer device, the results of the multiple linear regression equation are as follows:

$$Y = -21557.333 + 642.160\ X_1 + 33535.607X_2$$

Based on the multiple linear regression equation above, it can be interpreted as follows:

a = -21557.333 means that if the variables X_1 (SST) and X_2 (chlorophyll-a) have a value of 0, then the variable Y is -21557.33 kg.

b_1 = 642,160 means that if the variable X_1 (SST) increases by 1ºC and the other variables are constant, then the variable Y will increase by 642,160 kg.

b_2 = 33535,607 means that if the X_2 variable (chlorophyll-a) increases by 1 mg m^3 and the other variables are constant, then the Y variable will increase by 33535,607 kg.

Distribution of Chlorophyll-a against *K. pelamis* Catch

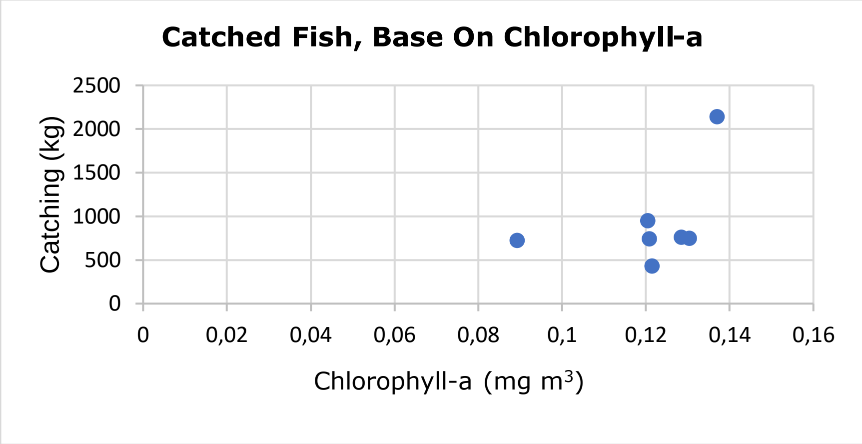


Figure 7. Catch fish based on chlorophyll-a

Based on the picture above, the highest catch is at a concentration of 0.137 mg m^3. Based on the graph of the relationship between chlorophyll-a and the catch of *K. pelamis*, it shows that the concentration of chlorophyll-a and the catch of *K. pelamis* has a unidirectional relationship, which means that the catch of *K. pelamis* increases, so the concentration in these waters increases, and vice versa. The results showed that the potential area for *K. pelamis* based on the optimum concentration for chlorophyll-a was 0.13 mg m^3. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to environmental parameters, especially optimum chlorophyll-a in the range 0.12-0.22 mg m^3.

Conclusion.

Based on the results and discussion that has been described, it can be concluded as follows:

1. The coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the real model of 19.6%, so the rest is explained by other factors of 80.4%. Based on the t_{test}, the t_{count} value of chlorophyll-a was 3,320, the sig value was 0.029. For the t_{table} value of 2.77. Based on the results, the value of $t_{count} > t_{table}$ and sig value is $0.029 < 0.05$. So it is obtained that H_o is rejected and H_1 is accepted, so there is a significant effect between chlorophyll-a and *K. pelamis.*
2. The results obtained in the ANOVA table, the value of $R^2 = 0.779$ or 77.9% is the effect of chlorophyll on *K. pelamis,* so that the remaining 22.1% is another factor. Based on the calculation of the F_{test} using SPSS 25 and manually, the value of $F_o = 7.030$ and the value of $F_{table} = 6.94$ is obtained. The results obtained in the ANOVA table sign value 0.049 <0.05 So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or $F_o \geq F_{table}$, so there is a significant effect of chlorophyll-a on *K. pelamis.*

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Submission letter

Article title:

The Effect of Chlorophyll-A on the Catches of Skipjack Tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

Hereby I would like to submit the manuscript entitled "**The Effect of Chlorophyll-A on the Catches of Skipjack Tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia**" to Aquaculture, Aquarium, Conservation & Legislation - International Journal of the Bioflux Society.

This manuscript was not submitted or published to any other journal. The authors declare that the manuscript is an original paper and contain no plagiarised text. All authors declare that they are not currently affiliated or sponsored by any organization with a direct economic interest in subject of the article. My co-authors have all contributed to this manuscript and approve of this submission.

Name of the authors:

Adnal Yeka   Defra Monika   Ratih M. Rahmani

Deni Sarianto   Yulia Fitri   Eli Nurlaela

Bongbongan Kusmedy   Erick Nugraha

September 15, 2021

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Authors:
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We would like to inform you that after the preliminary evaluation your paper is qualified for processing (reviewing).

However, the manuscript does not respect the AACL formatting requirements. Please find the model on our website and replace each section with your text, **leaving the footer exactly as it is, including the page numbering.**

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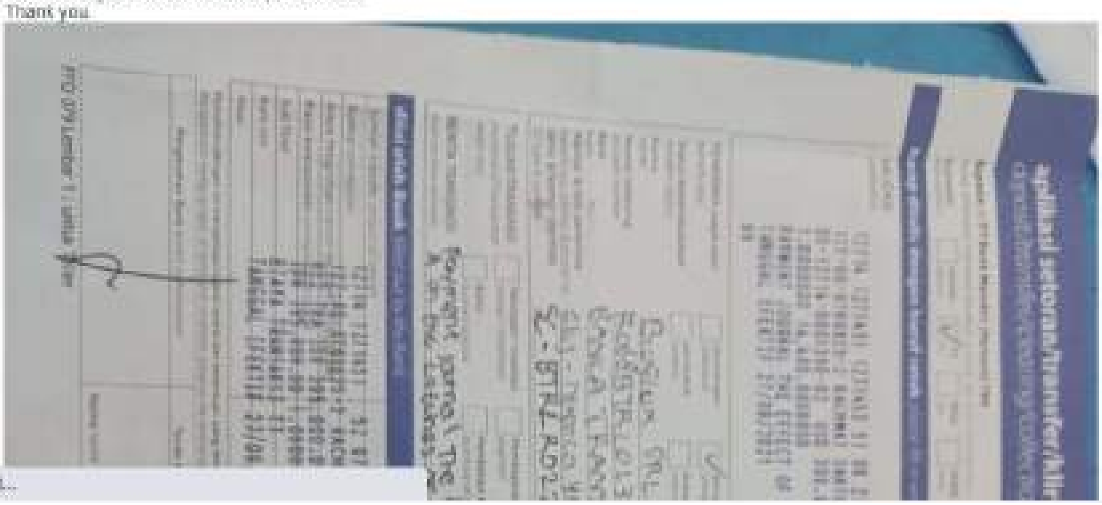

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Regarding your manuscript submitted to AACL Bioflux, the editorial team has some requests prior to acceptance (please see the attachment).

Please note: Always operate corrections/additions (or deletions) in the manuscript we are sending you, by **highlighting with a bright color** (for an easy identification). We never work on the manuscript you send back, just identify the corrections and operate them on our document (to avoid any undesirable accidental operations like changed page set up, otherwise the editors have to start all the work from the beginning, and we cannot ask them to re-check every manuscript word by word to identify unmarked modifications).

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The effect of chlorophyll-a on the catches of skipjack tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

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Abstract. The Banda Sea owes its abundance to a high nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea. The potential area for catching skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ranges from 0.12 to 0.22 mg m^{-3}. Based on the results of the study, it is known that (1) the value of the coefficient of determination (R_2) is 0.196 or 19.6%. it means that the chlorophyll-a factor can only explain the real model by 19.6% so that the rest is provided by other factors of 80.4%. Based on the t-$_{test}$, the $t_{\_count}$ value of chlorophyll-a is 3.320, the sig value is 0.029. For the $t_{\_table}$ value of 2.77. the results are based on the value of $t_{\_count}$ > $t_{\_table}$ and the value of sig 0.029 < 0.05. So that the H_o obtained is rejected and $H_{\_1}$ is accepted, then there is a significant effect between chlorophyll-a and *K. pelamis*. (2) in the ANOVA table the value of R^2 = 0.779 or 77.9% the effect of chlorophyll on *K. pelamis*, so the remaining 22.1% is another factor. Based on the calculation of F with SPSS 25 and manually obtained the value of F_o = 7.030 and the value of $F_{\_table}$ = 6.94. The results obtained in the ANOVA table have a sig value of 0.049 <0.05. So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or F_0 F_{table}, so there is a significant effect of chlorophyll-a on *K. pelamis*.

~~Potential areas for catching *Katsuwonus pelamis* have a close relationship with environmental parameters, especially chlorophyll-a. Remote sensing methods are used to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions. On this purpose, the multiple linear regression method was used to analyze their relationship. Based on the results of the study, it is known that (1) the value of the coefficient of determination (R_2) is 0.196 or 19.6%. it means that the chlorophyll-a factor can only explain the real model by 19.6% so that the rest is provided by other factors of 80.4%. Based on the t-$_{test}$, the $t_{\_count}$ value of chlorophyll-a is 3.320, the sig value is 0.029. For the $t_{\_table}$ value of 2.77. the results are based on the value of $t_{\_count}$ > $t_{\_table}$ and the value of sig 0.029 < 0.05. So that the H_o obtained is rejected and $H_{\_1}$ is accepted, then there is a significant effect between chlorophyll-a and *K. pelamis*. (2) in the ANOVA table the value of R^2 = 0.779 or 77.9% the effect of chlorophyll on *K. pelamis*, so the remaining 22.1% is another factor. Based on the calculation of F with SPSS 25 and manually obtained the value of F_o = 7.030 and the value of $F_{\_table}$ = 6.94.~~

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Commented [WU1]: Please rewrite the Abstract:

Please summarize the major aspects of you paper in a sequence that includes:
1) A short introductory phase of the research – the context
2) the overall purpose of the study
3) the methodology used in the study
4) your main findings, results of your analysis
5) the significance of your study

Key Words: purse seine, remote sensing, sea surface temperature (SST), catch season.

Introduction. The Banda Sea owes its abundance to a high nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea (Putra et al 2017). The topography of the seabed is very complex, with a basin in the west and a trough in the east (Suyarso 1999; Tapilatu 2016). This complex topographical shape also determines the mass exchange of water. The circulation of different water massesvaries between seasons and is influenced by the monsoon system's wind pattern.

The circulation of water mass in Indonesian waters differs between the west monsoon and the east monsoon. In the west monsoon, water masses generally flow to the east of Indonesian waters. The eastern monsoons develop perfectly, supplying water masses originating from the upwelling areas in the Arafura and Banda Seas (Hasanudin 1998). The upwelling process that occurs in the Banda Sea results in a decrease of temperatures, an increase of salinity and the removal of nutrients, so that their availability will affect the abundance of plankton in the waters (Baars et al 1990; Armus et al 2019).

The potential area for catching skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ranges from 0.12 to 0.22 mg m^{-3} (Zainuddin 2011; Hidayat et al 2019; Wangi et al 2019). Almost all fish populations that live in marine waters, including *K. pelamis*, require optimal sea surface temperature (SST) range and chlorophyll-a values for their survival (Jufri et al 2014). Remote sensing technology helps observing the oceanographic parameters of the surrounding waters in the Banda Sea, so that it can determine the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea.

K. pelamis likes areas where there is a convergence of currents that mostly occur in areas with many islands. The vertical distribution of *K. pelamis* starts from the surface to a depth of 260 m during the day, while at night it will go to the surface (diurnal migration) (Ekayana et al 2017). *K. pelamis* specimens from the small size category tend to be caught at a more homogeneous (warm) SST, while large *K. pelamis* are caught in a wider range of SST (cold and warm) (Simbolon & Limbong 2012). *K. pelamis* congregate at low chlorophyll-a concentrations and water depths of ≥ 500 m, because *K. pelamis* is a carnivorous fish with the main prey of small pelagic fish such as *Stelophorus sp.* and *Sardinella sp*., which are abundant in the continetal shelf and sloping waters (Bubun et al 2015).

Remote sensing technology is an alternative method that is very beneficial if it is used in a country with a very large area such as Indonesia (Syah 2010). Remote sensing is a technique for collecting information about objects and their environment from a distance without physical touch (Lo 1986). The use of remote sensing methods to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions is a very appropriate alternative (Tangke 2016; Mashita & Lumban-Gaol 2019). Remote sensing technology has several advantages including cheap and easily accessible data prices, wide area coverage, high temporal resolution and digitalized data supply, making it a potential source for the geographic information system (GIS) data (Louhenapessy & Waas 2009).

One of the sensing satellites equipped with sensors that can detect the chlorophyll-a content is the Aqua MODIS satellite (Utari 2013). The variables measured by the Aqua satellite include the aerosols, land-covering plants, phytoplankton and dissolved organic matter in the oceans, as well as the air, land and water temperature (Putra et al 2012). The Aqua MODIS satellite has a polar sun-synchronous orbit. The satellite crosses the equator at noon, approaching at 13.30 local time (Karif 2011).

Changes in fishing actually occur when the seasons' change. Seasonal changes directly affect the oceanographic aspects of the waters, especially sea surface temperature and chlorophyll-a, which greatly influence the presence of fish in an area, determining the fishing grounds in that area. Both of these parameters can trigger natural events or phenomena such as upwelling and fronts (Waileruny & Wiyono 2014). The fishing season in Southeast Sulawesi waters can be found in January to April and from July to September, and it can affect the salinity of the habitat of the caught fish species. In the eastern monsoon (June to September), high salinity water masses originating from the Flores Sea and Pacific Ocean flow through the Makassar Strait to the Java Sea. In the western season (December to March) surface currents move from the South China Sea into the Java Sea from west to east (Bubun & Mahmud 2016). ~~The purpose of this study was to analyze the relationship and effect of chlorophyll-a on the catch of *K. pelamis* (Mugo et al 2010).~~

This research aims to analyzed how much influence chlorophyll-a had on the number of skipjack tuna (*Katsuwonus pelamis*), knowing distribution of chlorophyll-a concentrations in the Banda Sea, Maluku. So that fishermen can be more effective again in determining the area and time of catch.

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Material and Method. The tools and materials needed in the implementation of this research include: stationery, cameras, rulers, GPS, MODIS data and the softwares SeaDas, SPSS Statistics 25 and Surfer 13.0.

Method of collecting data. The data collection method uses primary data, carried out *in situ* by direct observation of the fishing operation including operating time, the number of catches and the position of the fishing area, and by using secondary data including the image of the distribution of chlorophyll-a, from the level 3 of the Aqua MODIS, downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). Data were processed using the Seadas to get the chlorophyll value and the Surfer 13 to get the distribution of chlorophyll-a in the form of images.

The chlorophyll-a image data chosen to be processed is a standard 8-day image with a 4 km resolution map of level 3, at night, from November 2017 to March 2018. Chlorophyll-a data was calculated using chlorophyll-a image data that has been adjusted with both atmospheric and geometrical corrections. Seadas produced the chlorophyll-a distribution data which was reprocessed using a computer device, then using the Surfer 13, which will produced the distribution data of chlorophyll-a in the JPEG image format.

The catch used includes the catch weight of *K. pelamis* analyzed by calculating the weight per fishing trip, so that fluctuations in the catch based on time (temporal) and fishing location (spatial) can be observed.

Multiple correlation analysis. The multiple correlations showed the direction and strength of the relationship between the studied variables. To be able to provide an interpretation of the correlation coefficients found, reference values are listed in Table 1 below (Sugiono 2007).

Table 1

Assessment of the correlation coefficient (Sugiono 2007)

Coefficient interval	*Relationship level*
0.00–0.199	Very low
0.20–0.399	Low
0.40–0.599	Moderate
0.60–0.799	Strong
0.80–1.00	Very strong

The double correlation formula for two variables is (Sugiono 2007):

$$R_{y.x_1x_2} = \sqrt{\frac{r^2_{yx1} + r^2_{yx2} - 2r_{yx1}r_{yx2}\ r_{x1x2}}{1 - r^2_{x1\,x2}}}$$

Where:

$R_{y.x_1x_2}$ - correlation of the variables X_1 and X_2 with the variable Y;

ryx_1 - correlation between X_1 and Y;

ryx_2 - correlation between X_2 and Y;

rx_1x_2 - correlation between X_1 and X_2.

Multiple linear regression analysis. When the correlation coefficient is sufficiently high, a multiple linear regression was used to examine the variables relationship (Sugiono 2005), as follows:

$$Y = a + b_1X_1 + b_2X_2$$

Where:

X_1 - variable sea surface temperature;

X_2 - chlorophyll-a variable;

Y - the maximum quantity of certain fish species caught;
a, b_1, b_2 - constants.

Multiple linear statistical test. According to Hasan (2004), multiple linear regression statistical tests are used to test the significance of the relationship of more than two variables through the regression coefficient. The multiple linear regression statistical tests can be divided into two categories, namely:
1. Concurrent test
The test is carried out in multiple linear regression using the F test, a statistical test for the regression coefficient that together affects Y, namely:

$$F_o = \frac{R^2(n-k-1)}{k(1-R^2)}$$

Where:
n - number of fish caught;
k - number of independent variables;
R^2 – determination coefficient.

1. Individual test
Individual test, namely the regression statistic with only one regression coefficient affecting Y, using the t_{test}:

$$t_o = \frac{b_1 - B_i}{S_{b1}}$$

$$t_0 = \frac{b_1 - \beta_1}{S_{b1}}$$

Where:
b_1 – ......
B_i – ......
S_{bi} – ......
b_1 = regression slope coefficient;
β_1 = hypothesized slope;
S_{b1} = standard deviation of slope.

When the regression formula involves only two independent variables, the values of S_{b1} and S_{b2} are as follows (....):

$$S_{b1} = \sqrt{S_e^2 \frac{\sum x_2^2}{(\sum x_1^2)(\sum x_2^2)-(\sum x_1 x_2)^2}}$$

$$S_{b2} = \sqrt{S_e^2 \frac{\sum x_1^2}{(\sum x_1^2)(\sum x_2^2)-(\sum x_1 x_2)^2}}$$

$$S_e = \sqrt{\frac{\sum e_i^2}{n-3}} = \sqrt{\frac{\sum y^2 - b_1\sum x_1 y - b_2 \sum x_2 y}{n-3}}$$

Where:
S_{bk} – standard error of estimator bk, k=1, 2;
e – confounding error (values of other variables not included in the equation).

Geographical information analysis. The Surfer 13 software was used to map the distribution of *chlorophyll-a* from November 2017 to March 2018, based on time (temporal) and fishing location (spatial), with the aim of producing information about the relationship of these variables.

Results and Discussion

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This research was conducted from November 2017 to May 2018 by following a fishing operation using a purse seiner in the Banda Sea, Maluku Indonesia.

Figure 1. Purse seiner (original photo).

Fish catch results. The fishing operation was carried out in seven trips, with the total catch was 56,689 kg with an average of 12,558.17 kg per 34 time operation. The number of catches on the 2nd trip (6 time operations) was the largest, with a total catch of 11,954 kg (an average of 1,992.33 kg per operation) or 21.1% of the total catch. Meanwhile, the 3rd trip (2 operations) recorded the smallest total catch, namely 5,522 kg or 9.7% of the total catch, but with the highest average per operation, of 2,761 kg (Table 2).

Commented [A2]: Elementary mistake: this is the sum of the averages (total per trip per number of operations); it has no signification; the authors either calculate the average of the averages or the overall total per total number or operations

Commented [WU3]: Please clarify if 12,558.17 kg represents an average/trip or an average per setting?
Please calculate the average per trip and the average per setting and based on the total catch of 56,689 give the results.
The 12,558.17 value represents the total of the averages per trip and IT DOES NOT REPRESENT AN AVERAGE.

Table 2

The number of fish catch per trip

Trip	*Number of operations*	*Amount (Kg)*	*Average (Kg)*	*Percentage (%)*
1st	4	8,226	2,056.5	14.5
2nd	6	11,954	1,992.33	21.1
3rd	2	5,522	2,761	9.7
4th	4	7,006	1,751.5	12.4
5th	6	9,607	1,601.16	17
6th	6	7,982	1,330.33	14.1
7th	6	6,392	1,065.33	11.2
Total	34	56,689	12,558.17	100

Catch composition. The catch data consists of seven trips with 34 operations. The main catches are *K. pelamis*, *T. albacares*, *E. affinis* and *D. ruselli*. Based on the results obtained, the highest *T. albacares* catches were on the 7th trip and the lowest was on the 5th trip. *K. pelamis* catches reached the highest value on the 2nd trip and the lowest on the 6th trip. The highest *T. albacares* catches were on the 2nd trip and the lowest was on the 7th trip, and the highest *D. ruselli* was on the 6th trip and the lowest was on the 3rd trip. The composition of the catch can be seen in Table 3 below.

Table 3

The composition of the catch based on the type of fish

Trip to-	*Total catch (Kg)*				*Total*
	T. albacares	*K. pelamis*	*E. affinis*	*D. ruselli*	
1st	825	3,018	2,590	1,793	8,226
2nd	230	5,676	4,430	1,618	11,954
3rd	90	4,270	497	665	5,522
4th	569	2,948	1,817	1,672	7,006
5th	0	4,467	4,290	850	9,607
6th	13	2,536	670	4,763	7,982
7th	915	4,323	0	1,154	6,392

Based on the data mentioned above, the highest catch was on the second trip, and the lowest catch was on the 3rd trip. The highest catch of *T. albacares* was on the 7th trip, as much as 915 kg, while the lowest was on the 5th trip, with no catch. The highest catch of *K. pelamis* was on the 2nd trip, as much as 5,676 kg, while the lowest was on the 6th trip, with 2,536 kg. The highest *E. affinis* catch was on the 2nd trip, as much as 4,430 kg, and the lowest on the 7th trip, with no catch. The highest *D. ruselli* catch was on the 6th trip, as much as 4,763 kg, and the lowest was on the 3rd trip, with 665 kg. Based on all catches, *K. pelamis* was the most dominant fish caught compared to other fish (Figure 2).

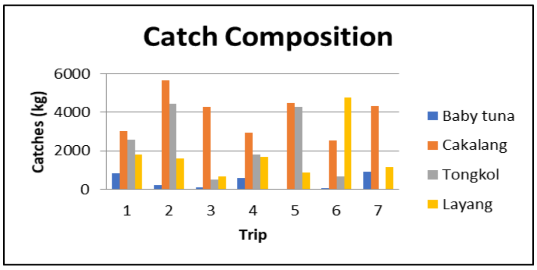

Figure 2. Composition diagram of the catch.

Average K. pelamis per operation. The catch of *K. pelamis* is higher than that of other types. The total catch of *K. pelamis* from the 1st trip to the 7th trip was 27,238 kg. The average highest catch per operation of *K. pelamis* was recorded on the 3rd trip, with 1,495 kg, while the lowest catch per operation was recorded on the 6th trip, with 422.67 kg. The catch of the 1st trip was 3,018 kg, the 2nd trip was 5,676 kg, the 3rd trip was 4,270 kg, the 4th trip was 2,948 kg, the 5th trip was 4,467 kg, the 6th trip was 2,536 kg, the 7th trip was 4,323 kg (Figure 3).

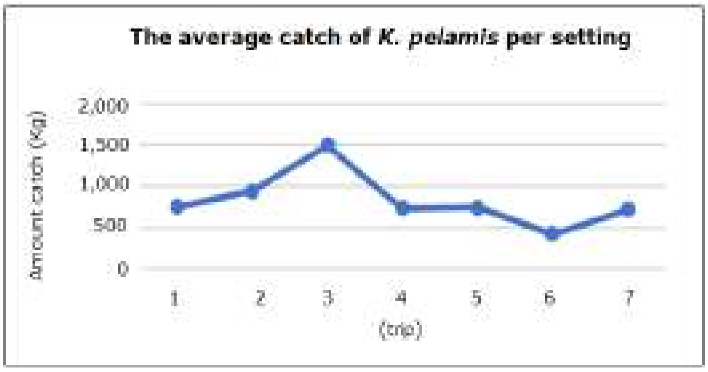

Figure 3. Diagram of the average catch of *Katsuwonus pelamis.*

Chlorophyll-a. Because fertile waters contain high chlorophyll-a concentrations, the chlorophyll-a is eligible as an indicator of fertility in waters. The chlorophyll-a concentration is also influenced by other factors such as currents. Chlorophyll-a image data were downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). The research data was processed using Seadas to produce chlorophyll-a data. Furthermore, the data was processed using Surfer 13 into JPEG format images that display the distribution of chlorophyll-a with different colors. The distribution of chlorophyll-a was taken based on the time and position of the capture operation. Figure 4 shows the chlorophyll-a distribution over the 7 fishing trips.

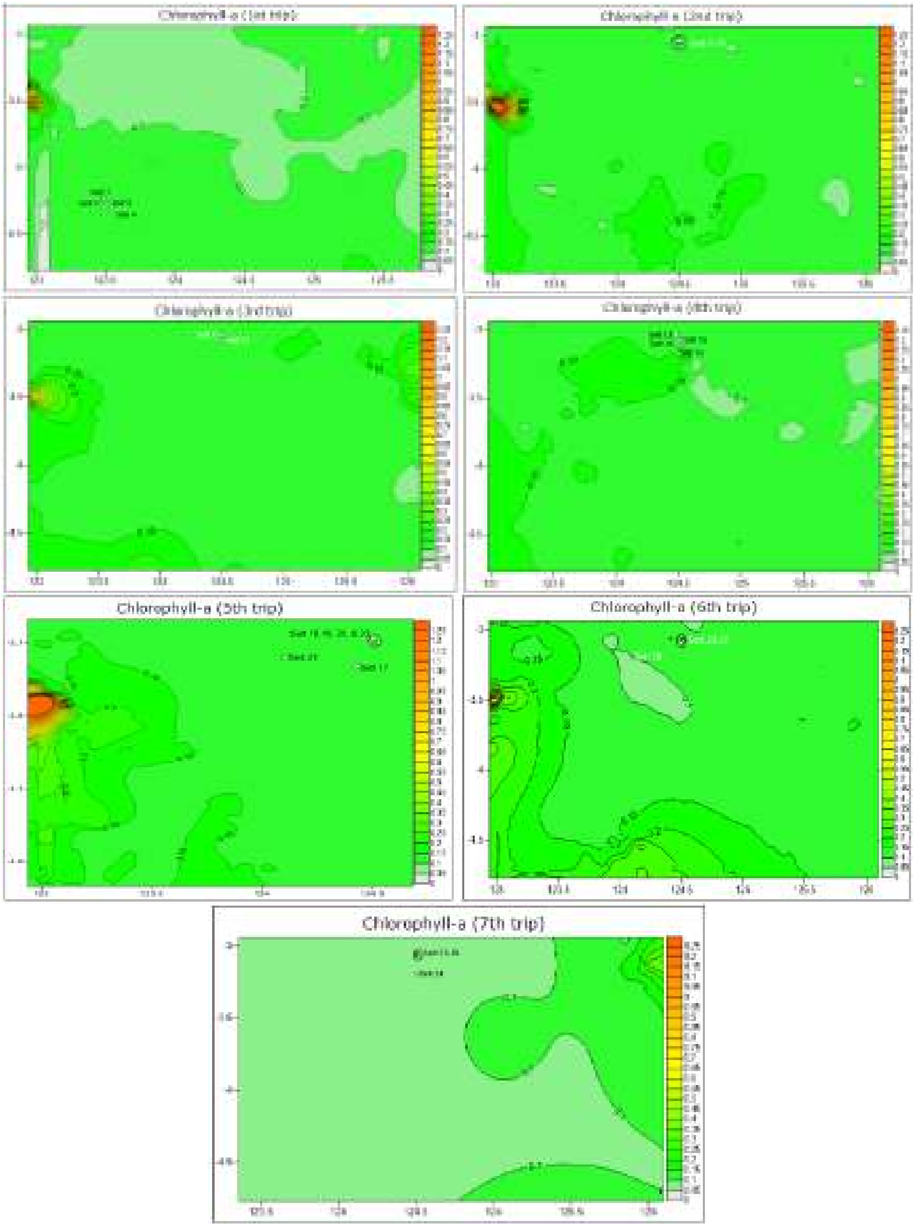

Figure 4. Distribution of chlorophyll-a over the 7 fishing trips.

chlorophyll-a concentration values can also be seen in table 4 below:

Table 4

Chlorophyll-a concentration values

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Trips	Chlorophyll-a concentration value (mg m^{-3})						Average
	1st operation	2nd operation	3rd operation	4th operation	5th operation	6th operation	
Trip 1	0.1308[a]	0.1292	0.1273	0.1268[b]	-	-	0.1285
Trip 2	0.1176	0.1176	0.1173[b]	0.1266	0.1176	0.1266[a]	0.1205
Trip 3	0.1399[a]	0.1342[b]	-	-	-	-	0.1370
Trip 4	0.1046[b]	0.1080	0.1077	0.1632[a]	-	-	0.1209
Trip 5	0.1314	0.1312	0.1312	0.1314[a]	0.1313	0.1258[b]	0.1303
Trip 6	0.1208	0.1288[a]	0.1287	0.1227	0.1281	0.1001[b]	0.1215
Trip 7	0.0895	0.0903	0.0913[a]	0.0880	0.0875[b]	0.0894	0.0893

[a] the distribution of the highest chlorophyll-a concentrations; [b] the distribution of the lowest chlorophyll-a concentrations.

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The chlorophyll-a concentration value on the 7th trip decreased significantly, compared to the other trips. The higher the chlorophyll-a concentration value in the waters, the more fertile the waters.

Average chlorophyll-a. The average chlorophyll-a can be seen in Figure 5, where the concentration of the 7th trip decreased, compared to the other trips. The average chlorophyll-a concentration was the highest on trip 3 and the lowest on trip 7. The difference between the highest and lowest concentrations is 0.0477 mg m^{-3}.

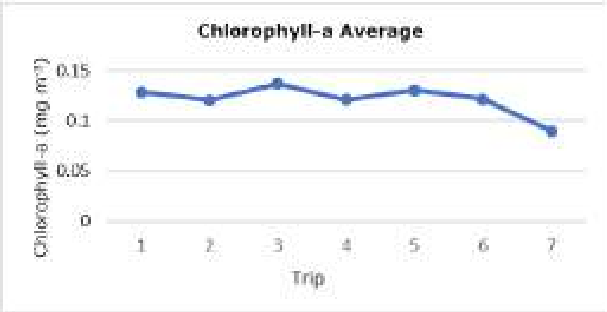

Figure 5. Diagram of average chlorophyll-a for 7 trips.

The relationship between average chlorophyll-a against K. pelamis. The relationship of chlorophyll-a to the catch of *K. pelamis* was calculated using a multiple correlation test. The multiple correlation estimator for the level of chlorophyll-a relationship to *K. pelamis* catch was determined by using SPSS 25.

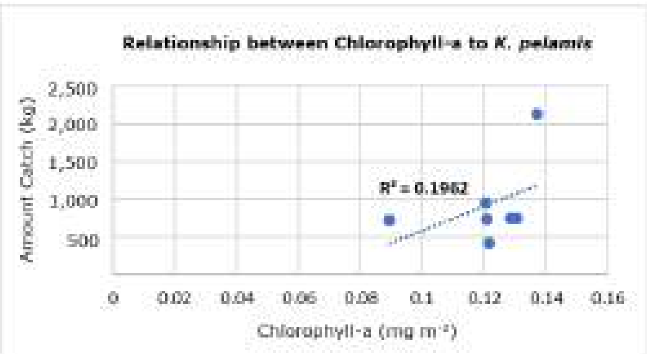

Figure 6. Graph of chlorophyll-a relationship to *Katsuwonus pelamis.*

Based on Figure 6 above, the coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents.

The value of the correlation coefficient using SPSS 25 can be seen in table 4. The correlation coefficient value was obtained at 0.443, which means that the positive relationship between chlorophyll-a and the catch of *K. pelamis* is moderate, because the correlation coefficient value is in the correlation interval 0.40-0.599. This relationship is positive: if the value of one variable is increased, it will increase the value of the other variables and vice versa (Sugiono 2007), while if the chlorophyll-a decreases, it will decrease the catch of *K. pelamis*.

Hypothesis testing via the t test is used to determine whether the hypothesis is accepted or rejected, based on the coefficients table (Table 7). Based on this table, the t_{count} value of chlorophyll-a is 3,320, $t_{count} > t_{table}$ (3,320>2.77, respectively) and the sig value of 0.029 (<0.05), therefore the null hypothesis is rejected, due to the significant effect of chlorophyll-a on the catch of *K. pelamis*, in accordance with a previous research conducted by Demena et al (2017), which states that chlorophyll-a and the number of catches *K. pelamis* have a unidirectional relationship and the chlorophyll-a concentration affects the presence of *K. pelamis*.

The effect of chlorophyll-a on the catch of K. pelamis. Chlorophyll-a is an indicator that greatly influences the presence of fish in the waters, especially *K. pelamis*, a migratory species. The effect of chlorophyll-a on the catch of K. pelamis is calculated using the multiple linear regression, with the SPSS 25, and manual calculations were performed using a computer device.

Table 5

Model summary

Model	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*
1	.882[a]	.779	.668	320.54745

[a]Predictors: (Constant), Chlorophyll-a.

Based on the results obtained in table 5 above the coefficient of determination (R^2)=0.779 or 77.9%. This shows an influence of 77.9% of the chlorophyll-a on the catch of *K. pelamis*, so that the remaining 22.1% are influenced by other factors such as currents and salinity. The correlation coefficient (R) in the model summary table above is 0.882. Based on table 5, the relationship level, given by the correlation coefficient (R), is included in the interval at 0.80-1.00, which means that the level of chlorophyll-a relationship to the catch of *K. pelamis* is very strong.

Table 6

ANOVA regression table

Model		*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*
1	Regression	1,444,657.089	2	722,328.544	7.030	.049[b]
	Residual	411,002.672	4	102,750.668		
	Total	1,855,659.760	6			

[a] Dependent Variable: *K. pelamis*; [b] Predictors: (Constant), Chlorophyll-a, Sea Surface Temperature (SST).

A F_{test} was conducted to check the influence of chlorophyll-a together with the SST (independent variables) on the catch of *K. pelamis* (dependent variable), demonstrating a significant effect (in the ANOVA regression table, the significance level is 0.049<0.05 or $F_o \geq F_{table}$). A previous research, conducted by Demena et al (2017), stated that sea surface temperature and chlorophyll-a are two predictors of the presence of fish in the waters, especially concerning *K. pelamis*.

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Based on the output of SPSS 25 (the coefficients matrix), the multiple linear regression equation could be expressed as follows:

$$Y = -21,557.333 + 642.160 X_1 + 33,535.607 X_2$$

The multiple linear regression equation above can be interpreted as follows:

- if the variables X_1 (SST) and X_2 (chlorophyll-a) have a value of 0, then the variable Y is -21,557.33 kg (intercept).
- if the variable X_1 (SST) increases by 1ºC and the other variables are constant, then the variable Y will increase by 642,160 kg.
- if the X_2 variable (chlorophyll-a) increases by 1 mg m^{-3} and the other variables are constant, then the Y variable will increase by 33,535,.607 kg.

Distribution of chlorophyll-a with K. pelamis catch.

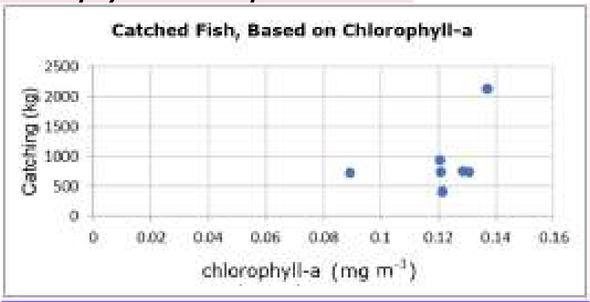

Figure 7. Catch based on chlorophyll-a.

In the figure above, the highest catch occurs at a concentration of 0.137 mg m^{-3}. The graph of the relationship between chlorophyll-a and the catch of *K. pelamis*, shows that the concentration of chlorophyll-a and the catch of *K. pelamis* have a unidirectional relationship. The results showed that the *K. pelamis* maximum fishing potential occurs for an optimal chlorophyll-a concentration of 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a chlorophyll-a in the optimal range of 0.12-0.22 mg m^{-3}.

Conclusions.

1. Based on the results obtained a value of > and a sig value of 0.029 < 0.05. So it was found that H_o was rejected and accepted, then 19.6% of the effect of chlorophyll-a on skipjack catches and 80.4% was influenced by other factors.
2. In the ANOVA table the value of R^2 = 0.779 or 77.9% the effect of chlorophyll-a on skipjack catches, so the remaining 22.1% is another factor. Based on the calculation of the F_{test} using SPSS 25 and manually, a sign value of 0.049 < 0.05 was obtained. So it can be concluded that H_o is rejected and accepted because the sign value is <0.05 or F_o then chlorophyll-a has a significant effect on (*K. pelamis)* catches.

~~Based on the results and discussion that has been described, it can be concluded as follows:~~

~~1. The value of the coefficient of determination (R_2) is 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%. Based on the t test, the SST value was 3.243, the sig value was 0.032. For a value of 2.77. Based on the results obtained the value > and sig value 0.032 <0.05. So, if H_o is accepted and rejected, then there is a significant effect between SST and *K. pelamis* catch.~~

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2. The coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the real model of 19.6%, so the rest is explained by other factors of 80.4%. Based on the t_{test}, the t_{count} value of chlorophyll-a was 3,320, the sig value was 0.029. A significant effect between chlorophyll-a and *K. pelamis* was demonstrated For the t_{table} value of 2.77. Based on the results, the value of $t_{count} > t_{table}$ and sig value is 0.029 <0.05. *So that obtained H_o is accepted and rejected, then there is a significant effect between SST and skipjack catch.*

The results obtained in the ANOVA table, the value of R^2 = 0.779 or 77.9% is the effect of chlorophyll on *K. pelamis,* so that the remaining 22.1% is another factor. Based on the calculation of the F_{test} using SPSS 25 and manually, the value of F_o = 7.030 and the value of F_{table} = 6.94 is obtained. The results obtained in the ANOVA table sign value 0.049 <0.05 So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or $F_o \geq F_{table}$, so there is a significant effect of chlorophyll-a on *K. pelamis*..

Conflict of interest. The authors declare no conflict of interest.

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The effect of chlorophyll-a on the catches of skipjack tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

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Abstract. The Banda Sea owes its abundance to a high nutrient load, the distribution of these nutrients can be seen by the upwelling phenomenon. The potential area for catching skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a. Remote sensing methods are used to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions. On this purpose, the multiple linear regression method was used to analyze their relationship. Based on the results of the study, it is known that the value of the coefficient of determination (R_2) is 0.196 or 19.6%, meaning that the chlorophyll-a factor can only explain the real model by 19.6%, so that the rest is provided by other factors of 80.4%. Based on the t_{-test}, the $t_{\_count}$ value of chlorophyll-a is 3.320, the sig value is 0.029. For the $t_{\_table}$ value of 2.77. the results are based on the value of $t_{\_count}>t_{\_table}$ and the value of sig 0.029<0.05. The H_o obtained is rejected and $H_{\_1}$ is accepted, showing a significant effect between chlorophyll-a and *K. pelamis*. The results obtained in the ANOVA table have a sig value of 0.049 <0.05. So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or F_0 F_{table}, so there is a significant effect of chlorophyll-a on *K. pelamis*.

Key Words: purse seine, remote sensing, sea surface temperature (SST), catch season.

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Introduction. The Banda Sea owes its abundance to a high nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea (Putra et al 2017). The topography of the seabed is very complex, with a basin in the west and a trough in the east (Suyarso 1999; Tapilatu 2016). This complex topographical shape also determines the mass exchange of water. The circulation of different water massesvaries between seasons and is influenced by the monsoon system's wind pattern.

The circulation of water mass in Indonesian waters differs between the west monsoon and the east monsoon. In the west monsoon, water masses generally flow to the east of Indonesian waters. The eastern monsoons develop perfectly, supplying water masses originating from the upwelling areas in the Arafura and Banda Seas (Hasanudin 1998). The upwelling process that occurs in the Banda Sea results in a decrease of temperatures, an increase of salinity and the removal of nutrients, so that their availability will affect the abundance of plankton in the waters (Baars et al 1990; Armus et al 2019).

The potential area for catching skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ranges from 0.12 to 0.22 mg m^3 (Zainuddin 2011; Hidayat et al 2019; Wangi et al 2019). Almost all fish populations that live in marine waters, including *K. pelamis*, require optimal sea surface temperature (SST) range and chlorophyll-a values for their survival (Jufri et al 2014). Remote sensing technology helps observing the oceanographic parameters of the surrounding waters in the Banda Sea, so that it can determine the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea.

K. pelamis likes areas where there is a convergence of currents that mostly occur in areas with many islands. The vertical distribution of *K. pelamis* starts from the surface to a depth of 260 m during the day, while at night it will go to the surface (diurnal migration) (Ekayana et al 2017). *K. pelamis* specimens from the small size category tend to be caught at a more homogeneous (warm) SST, while large *K. pelamis* are caught in a wider range of SST (cold and warm) (Simbolon & Limbong 2012). *K. pelamis* congregate at low chlorophyll-a concentrations and water depths of ≥500 m, because *K. pelamis* is a carnivorous fish with the main prey of small pelagic fish such as *Stelophorus sp.* and *Sardinella sp*., which are abundant in the continetal shelf and sloping waters (Bubun et al 2015).

Remote sensing technology is an alternative method that is very beneficial if it is used in a country with a very large area such as Indonesia (Syah 2010). Remote sensing is a technique for collecting information about objects and their environment from a distance without physical touch (Lo 1986). The use of remote sensing methods to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions is a very appropriate alternative (Tangke 2016; Mashita & Lumban-Gaol 2019). Remote sensing technology has several advantages including cheap and easily accessible data prices, wide area coverage, high temporal resolution and digitalized data supply, making it a potential source for the geographic information system (GIS) data (Louhenapessy & Waas 2009).

One of the sensing satellites equipped with sensors that can detect the chlorophyll-a content is the Aqua MODIS satellite (Utari 2013). The variables measured by the Aqua satellite include the aerosols, land-covering plants, phytoplankton and dissolved organic matter in the oceans, as well as the air, land and water temperature (Putra et al 2012). The Aqua MODIS satellite has a polar sun-synchronous orbit. The satellite crosses the equator at noon, approaching at 13.30 local time (Karif 2011).

Changes in fishing actually occur when the seasons' change. Seasonal changes directly affect the oceanographic aspects of the waters, especially sea surface temperature and chlorophyll-a, which greatly influence the presence of fish in an area, determining the fishing grounds in that area. Both of these parameters can trigger natural events or phenomena such as upwelling and fronts (Waileruny & Wiyono 2014). The fishing season in Southeast Sulawesi waters can be found in January to April and from July to September, and it can affect the salinity of the habitat of the caught fish species. In the eastern monsoon (June to September), high salinity water masses originating from the Flores Sea and Pacific Ocean flow through the Makassar Strait to the Java Sea. In the western season (December to March) surface currents move from the South China Sea into the Java Sea from west to east (Bubun & Mahmud 2016). The present research aimed to analyze how much influence chlorophyll-a has on the number of *K. pelamis*, knowing the distribution of chlorophyll-a concentrations in the Banda Sea, Maluku. In this way, fishermen can be more effective in determining the area and time of catch.

Material and Method. The tools and materials needed in the implementation of this research include: stationery, cameras, rulers, GPS, MODIS data and the softwares SeaDas, SPSS Statistics 25 and Surfer 13.0.

Method of collecting data. The data collection method uses primary data, carried out *in situ* by direct observation of the fishing operation including operating time, the number of catches and the position of the fishing area, and by using secondary data including the image of the distribution of chlorophyll-a, from the level 3 of the Aqua MODIS, downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). Data were processed using the Seadas to get the chlorophyll value and the Surfer 13 to get the distribution of chlorophyll-a in the form of images.

The chlorophyll-a image data chosen to be processed is a standard 8-day image with a 4 km resolution map of level 3, at night, from November 2017 to March 2018. Chlorophyll-a data was calculated using chlorophyll-a image data that has been adjusted with both atmospheric and geometrical corrections. Seadas produced the chlorophyll-a distribution data which was reprocessed using a computer device, then using the Surfer 13, which will produced the distribution data of chlorophyll-a in the JPEG image format.

The catch used includes the catch weight of *K. pelamis* analyzed by calculating the weight per fishing trip, so that fluctuations in the catch based on time (temporal) and fishing location (spatial) can be observed.

Multiple correlation analysis. The multiple correlations showed the direction and strength of the relationship between the studied variables. To be able to provide an interpretation of the correlation coefficients found, reference values are listed in Table 1 below (Sugiono 2007).

Table 1

Assessment of the correlation coefficient (Sugiono 2007)

Coefficient interval	*Relationship level*
0.00–0.199	Very low
0.20–0.399	Low
0.40–0.599	Moderate
0.60–0.799	Strong
0.80–1.00	Very strong

The double correlation formula for two variables is (Sugiono 2007):

$$R_{y.x_1x_2} = \sqrt{\frac{r^2_{yx1} + r^2_{yx2} - 2r_{yx1}r_{yx2}\,r_{x1x2}}{1 - r^2_{x1\,x2}}}$$

Where:
$R_{y.x_1x_2}$ - correlation of the variables X_1 and X_2 with the variable Y;
ryx_1 - correlation between X_1 and Y;
ryx_2 - correlation between X_2 and Y;
rx_1x_2 - correlation between X_1 and X_2.

Multiple linear regression analysis. When the correlation coefficient is sufficiently high, a multiple linear regression was used to examine the variables relationship (Sugiono 2005), as follows:

$$Y = a + b_1X_1 + b_2X_2$$

Where:
X_1 - variable sea surface temperature;
X_2 - chlorophyll-a variable;
Y - the maximum quantity of certain fish species caught;
a, b_1, b_2 - constants.

Multiple linear statistical test. According to Hasan (2004), multiple linear regression statistical tests are used to test the significance of the relationship of more than two variables through the regression coefficient. The multiple linear regression statistical tests can be divided into two categories, namely:
1. Concurrent test
The test is carried out in multiple linear regression using the F test, a statistical test for the regression coefficient that together affects Y, namely:

$$F_o = \frac{R^2(n-k-1)}{k(1-R^2)}$$

Where:
n - number of fish caught;
k - number of independent variables;
R^2 – determination coefficient.

2. Individual test
Individual test, namely the regression statistic with only one regression coefficient affecting Y, using the t_{test}:

$$t_o = \frac{b_1 - B_i}{S_{b1}}$$

Where:
b_1 - regression slope coefficient;
B_i - hypothesized slope;
S_{bi}- standard deviation of slope.

Geographical information analysis. The Surfer 13 software was used to map the distribution of *chlorophyll-a* from November 2017 to March 2018, based on time (temporal) and fishing location (spatial), with the aim of producing information about the relationship of these variables.

Results and Discussion

This research was conducted from November 2017 to May 2018 by following a fishing operation using a purse seiner in the Banda Sea, Maluku Indonesia.


Figure 1. Purse seiner (original photo).

Fish catch results. The fishing operation was carried out in seven trips, with a total catch of 56,689 kg and an average of 12,558.17 kg per 34 operations. The number of catches on the 2nd trip (6 operations) was the largest, with a total catch of 11,954 kg (an average of 1,992.33 kg per operation) or 21.1% of the total catch. Meanwhile, the 3rd trip (2 operations) recorded the smallest total catch, namely 5,522 kg or 9.7% of the total catch, but with the highest average per operation, of 2,761 kg (Table 2).

Table 2

The number of fish catch per trip

Trip	*Number of operations*	*Amount (Kg)*	*Average (Kg)*	*Percentage (%)*
1st	4	8,226	2,056.5	14.5
2nd	6	11,954	1,992.33	21.1
3rd	2	5,522	2,761	9.7
4th	4	7,006	1,751.5	12.4
5th	6	9,607	1,601.16	17
6th	6	7,982	1,330.33	14.1
7th	6	6,392	1,065.33	11.2
Total	34	56,689	12,558.17	100

Catch composition. The catch data consists of seven trips with 34 operations. The main catches are *K. pelamis*, *T. albacares*, *E. affinis* and *D. ruselli*. Based on the results obtained, the highest *T. albacares* catches were on the 7th trip and the lowest was on the 5th trip. *K. pelamis* catches reached the highest value on the 2nd trip and the lowest on the 6th trip. The highest *T. albacares* catches were on the 2nd trip and the lowest was on the 7th trip, and the highest *D. ruselli* was on the 6th trip and the lowest was on the 3rd trip. The composition of the catch can be seen in Table 3 below.

Table 3

The composition of the catch based on the type of fish

Trip to-	*Total catch (Kg)*				*Total*
	T. albacares	*K. pelamis*	*E. affinis*	*D. ruselli*	
1st	825	3,018	2,590	1,793	8,226
2nd	230	5,676	4,430	1,618	11,954
3rd	90	4,270	497	665	5,522
4th	569	2,948	1,817	1,672	7,006
5th	0	4,467	4,290	850	9,607
6th	13	2,536	670	4,763	7,982
7th	915	4,323	0	1,154	6,392

Based on the data mentioned above, the highest catch was on the second trip, and the lowest catch was on the 3rd trip. The highest catch of *T. albacares* was on the 7th trip, as much as 915 kg, while the lowest was on the 5th trip, with no catch. The highest catch of *K. pelamis* was on the 2nd trip, as much as 5,676 kg, while the lowest was on the 6th trip, with 2,536 kg. The highest *E. affinis* catch was on the 2nd trip, as much as 4,430 kg, and the lowest on the 7th trip, with no catch. The highest *D. ruselli* catch was on the 6th trip, as much as 4,763 kg, and the lowest was on the 3rd trip, with 665 kg. Based on all catches, *K. pelamis* was the most dominant fish caught compared to other fish (Figure 2).

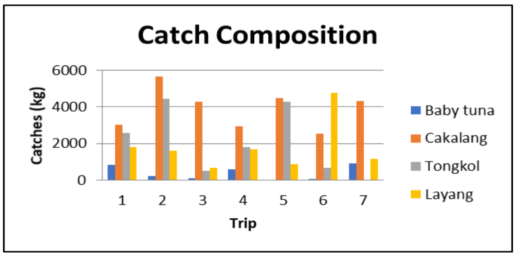

Figure 2. Composition diagram of the catch.

Average K. pelamis per operation. The catch of *K. pelamis* is higher than that of other types. The total catch of *K. pelamis* from the 1st trip to the 7th trip was 27,238 kg. The average highest catch per operation of *K. pelamis* was recorded on the 3rd trip, with 1,495 kg, while the lowest catch per operation was recorded on the 6th trip, with 422.67 kg. The catch of the 1st trip was 3,018 kg, the 2nd trip was 5,676 kg, the 3rd trip was 4,270 kg, the 4th trip was 2,948 kg, the 5th trip was 4,467 kg, the 6th trip was 2,536 kg, the 7th trip was 4,323 kg (Figure 3).

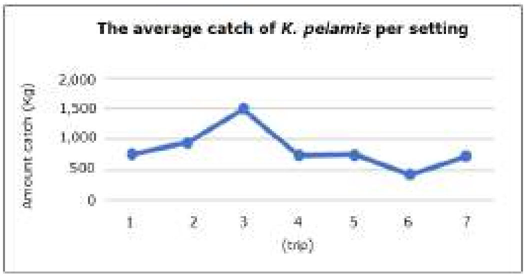

Figure 3. Diagram of the average catch of *Katsuwonus pelamis.*

Chlorophyll-a. Because fertile waters contain high chlorophyll-a concentrations, the chlorophyll-a is eligible as an indicator of fertility in waters. The chlorophyll-a concentration is also influenced by other factors such as currents. Chlorophyll-a image data were downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). The research data was processed using Seadas to produce chlorophyll-a data. Furthermore, the data was processed using Surfer 13 into JPEG format images that display the distribution of chlorophyll-a with different colors. The distribution of chlorophyll-a was taken based on the time and position of the capture operation. Figure 4 shows the chlorophyll-a distribution over the 7 fishing trips.

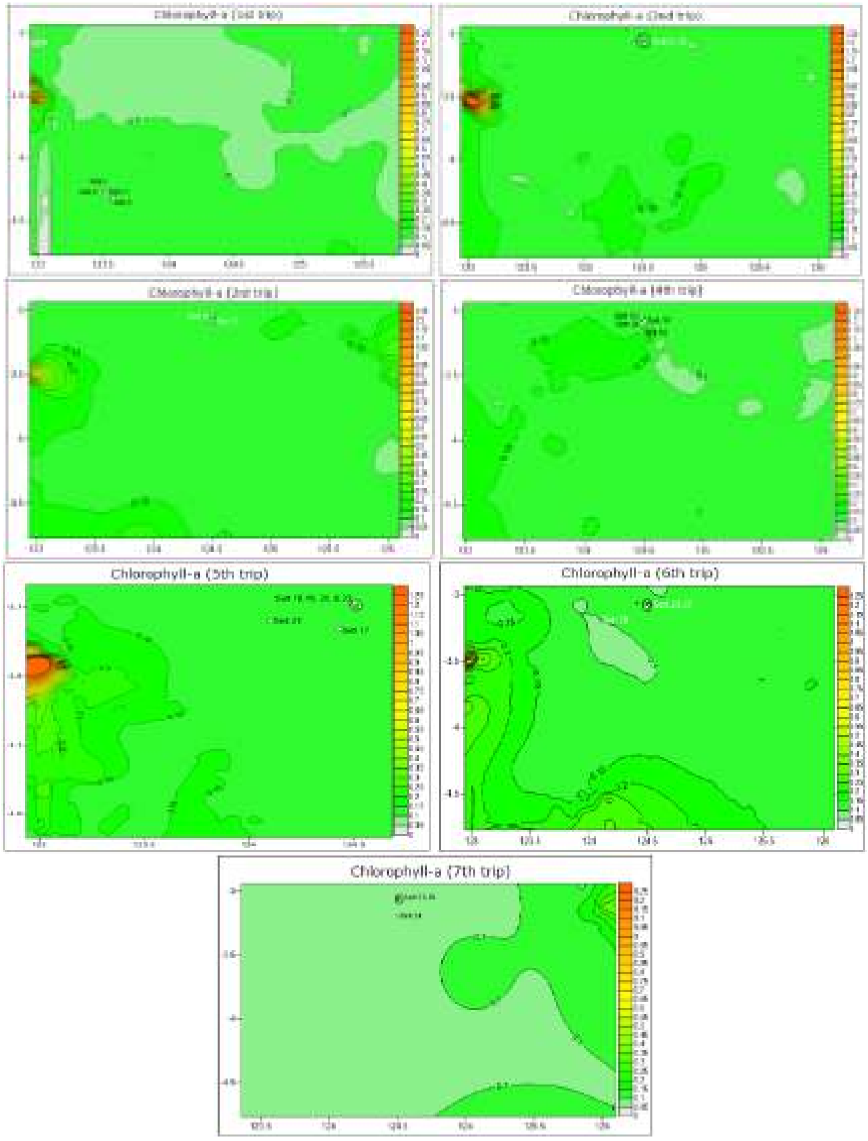

Figure 4. Distribution of chlorophyll-a over the 7 fishing trips.

The chlorophyll-a concentration values can be seen in Table 4 below:

Table 4

Chlorophyll-a concentration values

Trips	*Chlorophyll-a concentration value (mg m³)*						
	1st operation	*2nd operation*	*3rd operation*	*4th operation*	*5th operation*	*6th operation*	*Average*
Trip 1	0.1308[a]	0.1292	0.1273	0.1268[b]	-	-	0.1285
Trip 2	0.1176	0.1176	0.1173[b]	0.1266	0.1176	0.1266[a]	0.1205
Trip 3	0.1399[a]	0.1342[b]	-	-	-	-	0.1370
Trip 4	0.1046[b]	0.1080	0.1077	0.1632[a]	-	-	0.1209
Trip 5	0.1314	0.1312	0.1312	0.1314[a]	0.1313	0.1258[b]	0.1303
Trip 6	0.1208	0.1288[a]	0.1287	0.1227	0.1281	0.1001[b]	0.1215
Trip 7	0.0895	0.0903	0.0913[a]	0.0880	0.0875[b]	0.0894	0.0893

[a] the distribution of the highest chlorophyll-a concentrations; [b] the distribution of the lowest chlorophyll-a concentrations.

The chlorophyll-a concentration value on the 7th trip decreased significantly, compared to the other trips. The higher the chlorophyll-a concentration value in the waters, the more fertile the waters.

Average chlorophyll-a. The average chlorophyll-a can be seen in Figure 5, where the concentration of the 7th trip decreased, compared to the other trips. The average chlorophyll-a concentration was the highest on trip 3 and the lowest on trip 7. The difference between the highest and lowest concentrations is 0.0477 mg m^{-3}.

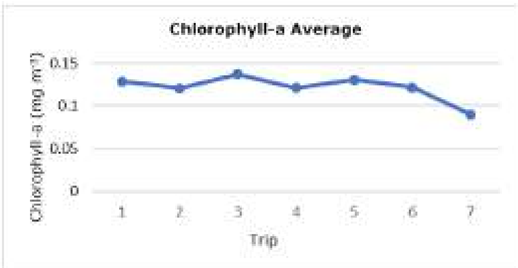

Figure 5. Diagram of average chlorophyll-a for 7 trips.

The relationship between average chlorophyll-a against K. pelamis. The relationship of chlorophyll-a to the catch of *K. pelamis* was calculated using a multiple correlation test. The multiple correlation estimator for the level of chlorophyll-a relationship to *K. pelamis* catch was determined by using SPSS 25.

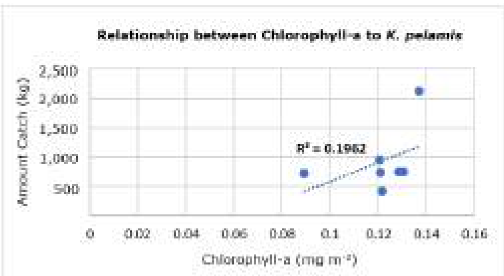

Figure 6. Graph of chlorophyll-a relationship to *Katsuwonus pelamis.*

Based on Figure 6 above, the coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents.

The value of the correlation coefficient using SPSS 25 can be seen in table 4. The correlation coefficient value was obtained at 0.443, which means that the positive relationship between chlorophyll-a and the catch of *K. pelamis* is moderate, because the correlation coefficient value is in the correlation interval 0.40-0.599. This relationship is positive: if the value of one variable is increased, it will increase the value of the other variables and vice versa (Sugiono 2007), while if the chlorophyll-a decreases, it will decrease the catch of *K. pelamis*.

Hypothesis testing via the t test is used to determine whether the hypothesis is accepted or rejected, based on the coefficients table (Table 7). Based on this table, the t_{count} value of chlorophyll-a is 3,320, $t_{count}>t_{table}$ (3,320>2.77, respectively) and the sig value of 0.029 (<0.05), therefore the null hypothesis is rejected, due to the significant effect of chlorophyll-a on the catch of *K. pelamis*, in accordance with a previous research conducted by Demena et al (2017), which states that chlorophyll-a and the number of catches *K. pelamis* have a unidirectional relationship and the chlorophyll-a concentration affects the presence of *K. pelamis*.

The effect of chlorophyll-a on the catch of K. pelamis. Chlorophyll-a is an indicator that greatly influences the presence of fish in the waters, especially *K. pelamis*, a migratory species. The effect of chlorophyll-a on the catch of K. pelamis is calculated using the multiple linear regression, with the SPSS 25, and manual calculations were performed using a computer device.

Table 5

Model summary

Model	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*
1	.882[a]	.779	.668	320.54745

[a]Predictors: (Constant), Chlorophyll-a.

Based on the results obtained in table 5 above the coefficient of determination (R^2)=0.779 or 77.9%. This shows an influence of 77.9% of the chlorophyll-a on the catch of *K. pelamis*, so that the remaining 22.1% are influenced by other factors such as currents and salinity. The correlation coefficient (R) in the model summary table above is 0.882. Based on table 5, the relationship level, given by the correlation coefficient (R), is included in the interval at 0.80-1.00, which means that the level of chlorophyll-a relationship to the catch of *K. pelamis* is very strong.

Table 6

ANOVA regression table

Model	*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*
Regression	1,444,657.089	2	722,328.544	7.030	.049[b]
Residual	411,002.672	4	102,750.668		
Total	1,855,659.760	6			

[a] Dependent variable: *K. pelamis*; [b] Predictors: (Constant), Chlorophyll-a, Sea Surface Temperature (SST).

A F_{test} was conducted to check the influence of chlorophyll-a together with the SST (independent variables) on the catch of *K. pelamis* (dependent variable), demonstrating a significant effect (in the ANOVA regression table, the significance level is 0.049<0.05 or $F_o \geq F_{table}$). A previous research, conducted by Demena et al (2017), stated that sea surface temperature and chlorophyll-a are two predictors of the presence of fish in the waters, especially concerning *K. pelamis*.

Based on the output of SPSS 25 (the coefficients matrix), the multiple linear regression equation could be expressed as follows:

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$$Y = -21{,}557.333 + 642.160\,X_1 + 33{,}535.607\,X_2$$

The multiple linear regression equation above can be interpreted as follows:

- if the variables X_1 (SST) and X_2 (chlorophyll-a) have a value of 0, then the variable Y is -21,557.33 kg (intercept).
- if the variable X_1 (SST) increases by 1ºC and the other variables are constant, then the variable Y will increase by 642,160 kg.
- if the X_2 variable (chlorophyll-a) increases by 1 mg m^{-3} and the other variables are constant, then the Y variable will increase by 33,535.607 kg.

Distribution of chlorophyll-a with K. pelamis catch. The graph of the relationship between chlorophyll-a and the catch of *K. pelamis*, shows that the concentration of chlorophyll-a and the catch of *K. pelamis* have a unidirectional relationship.

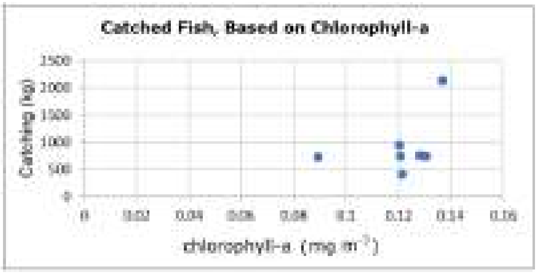

Figure 7. Catch based on chlorophyll-a.

In the figure above, the highest catch occurs at a concentration of 0.137 mg m^{-3}. The results showed that the *K. pelamis* maximum fishing potential occurs at an optimal chlorophyll-a concentration of 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a chlorophyll-a in the optimal range of 0.12-0.22 mg m^{-3}.

Conclusions. Based on the results and discussion that has been described, it can be concluded as follows:

1. The value of the coefficient of determination (R_2) is 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%. Based on the t test, the SST value was 3.243, the sig value was 0.032. For a value of 2.77. Based on the results obtained the value > and sig value 0.032 <0.05. So, if H_o is accepted and rejected, then there is a significant effect between SST and *K. pelamis* catch.
2. The coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the real model of 19.6%, so the rest is explained by other factors of 80.4%. Based on the t_{test}, the t_{count} value of chlorophyll-a was 3,320, the sig value was 0.029. A significant effect between chlorophyll-a and *K. pelamis* was demonstrated For the t_{table} value of 2.77. Based on the results, the value of t_{count} > t_{table} and sig value is 0.029 <0.05. *So that obtained H_o is accepted and rejected, then there is a significant effect between SST and skipjack catch.*

The results obtained in the ANOVA table, the value of R^2 = 0.779 or 77.9% is the effect of chlorophyll on *K. pelamis,* so that the remaining 22.1% is another factor. Based on the calculation of the F_{test} using SPSS 25 and manually, the value of F_o = 7.030 and the value of F_{table} = 6.94 is obtained. The results obtained in the ANOVA table sign value 0.049 <0.05 So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or $F_o \geq F_{table}$, so there is a significant effect of chlorophyll-a on *K. pelamis*..

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Please rewrite the conclusions section. The results should not be repeated here. A synthesis of interpretations and conclusions / recommendations are expected.

1. Based on the results obtained a value of > and a sig value of 0.029 < 0.05. So it was found that H_o was rejected and accepted, then 19.6% of the effect of chlorophyll-a on skipjack catches and 80.4% was influenced by other factors.
2. In the ANOVA table the value of R^2 = 0.779 or 77.9% the effect of chlorophyll-a on skipjack catches, so the remaining 22.1% is another factor. Based on the calculation of the F_{test} using SPSS 25 and manually, a sign value of 0.049 < 0.05 was obtained. So it can be concluded that H_o is rejected and accepted because the sign value is <0.05 or F_o then chlorophyll-a has a significant effect on (*K. pelamis)* catches.

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A synthesis of interpretations and conclusions / recommendations are expected.

What is the overall result of the paper?
Describe what did you achieve and what was determined; what did the results indicate; what can you conclude from all you observed!!!

Conflict of interest. The authors declare no conflict of interest.

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Kepada: Adnal Yeka

Dear Dr. Yeka,

Thank you for your feedback. Unfortunately, many of the reviewers comments were not addressed. Please make all the required adjustments, **highlighting them with a bright color.**

Thank you.

› Tampilkan pesan asli

Kind regards,
Editor AACL Bioflux
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The effect of chlorophyll-a on the catches of skipjack tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

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Abstract. The Banda Sea is located in the waters of Central Maluku Regency, Maluku Province. The topography of the seabed is very complex with a basin in the west and a trough in the east. The shape of the topography is also decisive in controlling the exchange of water masses. The purpose of this study was to analyze the relationship of chlorophyll-a and the effect of its distribution on the catch of skipjack tuna (*Katsuwonus pelamis*). The study used the data analysis method, namely the multiple linear regression (computerized data processing using the SPSS 25 program). Primary data was obtained by following fishing operations and secondary data was collected from chlorophyll-a images downloaded from the NASA database in the form of an average per trip. The results of the study showed that the coefficient of determination (R2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents. The results of the t-test obtained a t_count chlorophyll-a value of 3.320, sig value of 0.029 and t_table value of 2.77. Based on the value of t_count>t_table and the value of sig 0.029<0.05, there was a significant effect between chlorophyll-a and *K. pelamis*; the ANOVA table showed the value of R^2=0.779 or 77.9% the effect of chlorophyll on *K. pelamis*, so the remaining 22.1% was influenced by other factors. Based on the results obtained, chlorophyll-a had a significant effect on *K. pelamis*.

Key Words: purse seine, remote sensing, sea surface temperature (SST), catch season.

Introduction. The Banda Sea owes its abundance to a high nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea (Putra et al 2017). The topography of the seabed is very complex, with a basin in the west and a trough in the east (Suyarso 1999; Tapilatu 2016). This complex topographical shape also determines the mass exchange of water. The circulation of different water massesvaries between seasons and is influenced by the monsoon system's wind pattern. The circulation of water mass in Indonesian waters differs between the west monsoon and the east monsoon. In the west monsoon, water masses generally flow to the east of Indonesian waters. The eastern monsoons develop perfectly, supplying water masses originating from the upwelling areas in the Arafura and Banda Seas (Hasanudin 1998). The upwelling process that occurs in the Banda Sea results in a decrease of temperatures, an increase of salinity and the removal of nutrients, so that their availability will affect the abundance of plankton in the waters (Baars et al 1990; Armus et al 2019).

The potential area for catching skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ranges from 0.12 to 0.22 mg m^3 (Zainuddin 2011; Hidayat et al 2019; Wangi et al 2019). Almost all fish populations that live in marine waters, including *K. pelamis*, require optimal sea surface temperature (SST) range and chlorophyll-a values for their survival (Jufri et al 2014). Remote sensing technology helps observing the oceanographic

parameters of the surrounding waters in the Banda Sea, so that it can determine the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea.

K. pelamis likes areas where there is a convergence of currents that mostly occur in areas with many islands. The vertical distribution of *K. pelamis* starts from the surface to a depth of 260 m during the day, while at night it will go to the surface (diurnal migration) (Ekayana et al 2017). *K. pelamis* specimens from the small size category tend to be caught at a more homogeneous (warm) SST, while large *K. pelamis* are caught in a wider range of SST (cold and warm) (Simbolon & Limbong 2012). *K. pelamis* congregate at low chlorophyll-a concentrations and water depths of ≥500 m, because *K. pelamis* is a carnivorous fish with the main prey of small pelagic fish such as *Stelophorus sp.* and *Sardinella sp*., which are abundant in the continetal shelf and sloping waters (Bubun et al 2015).

Remote sensing technology is an alternative method that is very beneficial if it is used in a country with a very large area such as Indonesia (Syah 2010). Remote sensing is a technique for collecting information about objects and their environment from a distance without physical touch (Lo 1986). The use of remote sensing methods to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions is a very appropriate alternative (Tangke 2016; Mashita & Lumban-Gaol 2019). Remote sensing technology has several advantages including cheap and easily accessible data prices, wide area coverage, high temporal resolution and digitalized data supply, making it a potential source for the geographic information system (GIS) data (Louhenapessy & Waas 2009). One of the sensing satellites equipped with sensors that can detect the chlorophyll-a content is the Aqua MODIS satellite (Utari 2013). The variables measured by the Aqua satellite include the aerosols, land-covering plants, phytoplankton and dissolved organic matter in the oceans, as well as the air, land and water temperature (Putra et al 2012). The Aqua MODIS satellite has a polar sun-synchronous orbit. The satellite crosses the equator at noon, approaching at 13.30 local time (Karif 2011).

Changes in fishing actually occur when the seasons' change. Seasonal changes directly affect the oceanographic aspects of the waters, especially sea surface temperature and chlorophyll-a, which greatly influence the presence of fish in an area, determining the fishing grounds in that area. Both of these parameters can trigger natural events or phenomena such as upwelling and fronts (Waileruny & Wiyono 2014). The fishing season in Southeast Sulawesi waters can be found in January to April and from July to September, and it can affect the salinity of the habitat of the caught fish species. In the eastern monsoon (June to September), high salinity water masses originating from the Flores Sea and Pacific Ocean flow through the Makassar Strait to the Java Sea. In the western season (December to March) surface currents move from the South China Sea into the Java Sea from west to east (Bubun & Mahmud 2016). The present research aimed to analyze how much influence chlorophyll-a had on the number of *K. pelamis*, knowing the distribution of chlorophyll-a concentrations in the Banda Sea, Maluku. In this way, fishermen can be more effective in determining the area and time of catch.

Material and Method. The tools and materials needed in the implementation of this research include: stationery, cameras, rulers, GPS, MODIS data and the softwares SeaDas, SPSS Statistics 25 and Surfer 13.0.

Method of collecting data. The data collection method uses primary data, carried out *in situ* by direct observation of the fishing operation including operating time, the number of catches and the position of the fishing area, and by using secondary data including the image of the distribution of chlorophyll-a, from the level 3 of the Aqua MODIS, downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). Data were processed using the Seadas to get the chlorophyll value and the Surfer 13 to get the distribution of chlorophyll-a in the form of images.

The chlorophyll-a image data chosen to be processed is a standard 8-day image with a 4 km resolution map of level 3, at night, from November 2017 to March 2018.

Chlorophyll-a data was calculated using chlorophyll-a image data that has been adjusted with both atmospheric and geometrical corrections. Seadas produced the chlorophyll-a distribution data which was reprocessed using a computer device, then using the Surfer 13, which will produced the distribution data of chlorophyll-a in the JPEG image format. The catch used includes the catch weight of *K. pelamis* analyzed by calculating the weight per fishing trip, so that fluctuations in the catch based on time (temporal) and fishing location (spatial) can be observed.

Multiple correlation analysis. The multiple correlations showed the direction and strength of the relationship between the studied variables. To be able to provide an interpretation of the correlation coefficients found, reference values are listed in Table 1 below (Sugiono 2007).

Table 1

Assessment of the correlation coefficient (Sugiono 2007)

Coefficient interval	*Relationship level*
0.00–0.199	Very low
0.20–0.399	Low
0.40–0.599	Moderate
0.60–0.799	Strong
0.80–1.00	Very strong

The double correlation formula for two variables is the following (Sugiono 2007):

$$R_{y.x_1x_2} = \sqrt{\frac{r^2_{yx1} + r^2_{yx2} - 2r_{yx1}r_{yx2}\ r_{x1x2}}{1 - r^2_{x1\ x2}}}$$

Where:
$R_{y.x_1x_2}$ - correlation of the variables X_1 and X_2 with the variable Y;
ryx_1 - correlation between X_1 and Y;
ryx_2 - correlation between X_2 and Y;
rx_1x_2 - correlation between X_1 and X_2.

Multiple linear regression analysis. When the correlation coefficient is sufficiently high, a multiple linear regression was used to examine the variables relationship (Sugiono 2005), as follows:

$$Y = a + b_1X_1 + b_2X_2$$

Where:
X_1 - variable sea surface temperature;
X_2 - chlorophyll-a variable;
Y - the maximum quantity of certain fish species caught;
a, b_1, b_2 - constants.

Multiple linear statistical test. According to Hasan (2004), multiple linear regression statistical tests are used to test the significance of the relationship of more than two variables through the regression coefficient. The multiple linear regression statistical tests can be divided into two categories, namely:
1. Concurrent test
The test is carried out in multiple linear regression using the F test, a statistical test for the regression coefficient that together affects Y, namely:

$$F_o = \frac{R^2(n-k-1)}{k(1-R^2)}$$

Where:
n - number of fish caught;

k - number of independent variables;
R^2 – determination coefficient.
2. Individual test
Individual test, namely the regression statistic with only one regression coefficient affecting Y, using the t_{test}:

$$t_o = \frac{b_1 - B_i}{S_{b1}}$$

Where:
b_1 - regression slope coefficient;
B_i - hypothesized slope;
S_{bi}- standard deviation of slope.

Geographical information analysis. The Surfer 13 software was used to map the distribution of *chlorophyll-a* from November 2017 to March 2018, based on time (temporal) and fishing location (spatial), with the aim of producing information about the relationship of these variables.

Results and Discussion

This research was conducted from November 2017 to May 2018 by following a fishing operation using a purse seiner in the Banda Sea, Maluku Indonesia.

Figure 1. Purse seiner (original photo).

Fish catch results. The fishing operation was carried out in seven trips, with a total catch of 56,689 kg and an average of 12,558.17 kg per 34 operations. The number of catches on the 2nd trip (6 operations) was the largest, with a total catch of 11,954 kg (an average of 1,992.33 kg per operation) or 21.1% of the total catch. Meanwhile, the 3rd trip (2 operations) recorded the smallest total catch, namely 5,522 kg or 9.7% of the total catch, but with the highest average per operation, of 2,761 kg (Table 2).

Table 2

The number of fish catch per trip

Trip	*Number of operations*	*Amount (kg)*	*Average (kg)*	*Percentage (%)*
1st	4	8,226	2,056.5	14.5
2nd	6	11,954	1,992.33	21.1
3rd	2	5,522	2,761	9.7
4th	4	7,006	1,751.5	12.4
5th	6	9,607	1,601.16	17
6th	6	7,982	1,330.33	14.1
7th	6	6,392	1,065.33	11.2
Total	34	56,689	12,558.17	100

Catch composition. The catch data consists of seven trips with 34 operations. The main catches are *K. pelamis*, *T. albacares*, *E. affinis* and *D. ruselli*. Based on the results obtained, the highest *T. albacares* catches were on the 7th trip and the lowest was on the 5th trip. *K. pelamis* catches reached the highest value on the 2nd trip and the lowest on

the 6th trip. The highest *T. albacares* catches were on the 2nd trip and the lowest was on the 7th trip, and the highest *D. ruselli* was on the 6th trip and the lowest was on the 3rd trip. The composition of the catch can be seen in Table 3 below.

Table 3

The composition of the catch based on the type of fish

Trip to-	*Total catch (Kg)*				*Total*
	T. albacares	*K. pelamis*	*E. affinis*	*D. ruselli*	
1st	825	3,018	2,590	1,793	8,226
2nd	230	5,676	4,430	1,618	11,954
3rd	90	4,270	497	665	5,522
4th	569	2,948	1,817	1,672	7,006
5th	0	4,467	4,290	850	9,607
6th	13	2,536	670	4,763	7,982
7th	915	4,323	0	1,154	6,392

Based on the data mentioned above, the highest catch was on the second trip, and the lowest catch was on the 3rd trip. The highest catch of *T. albacares* was on the 7th trip, as much as 915 kg, while the lowest was on the 5th trip, with no catch. The highest catch of *K. pelamis* was on the 2nd trip, as much as 5,676 kg, while the lowest was on the 6th trip, with 2,536 kg. The highest *E. affinis* catch was on the 2nd trip, as much as 4,430 kg, and the lowest on the 7th trip, with no catch. The highest *D. ruselli* catch was on the 6th trip, as much as 4,763 kg, and the lowest was on the 3rd trip, with 665 kg. Based on all catches, *K. pelamis* was the most dominant fish caught compared to other fish (Figure 2).

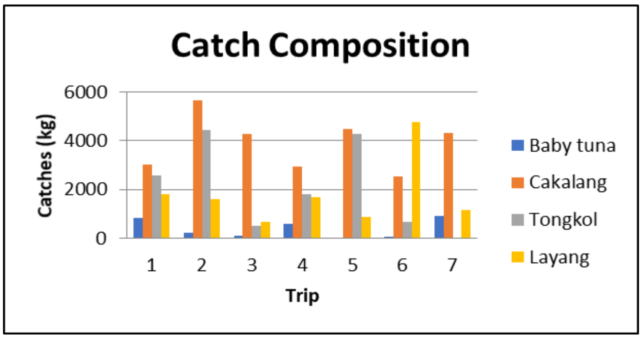

Figure 2. Composition diagram of the catch.

Average K. pelamis per operation. The catch of *K. pelamis* is higher than that of other types. The total catch of *K. pelamis* from the 1st trip to the 7th trip was 27,238 kg. The average highest catch per operation of *K. pelamis* was recorded on the 3rd trip, with 1,495 kg, while the lowest catch per operation was recorded on the 6th trip, with 422.67 kg. The catch of the 1st trip was 3,018 kg, the 2nd trip was 5,676 kg, the 3rd trip was 4,270 kg, the 4th trip was 2,948 kg, the 5th trip was 4,467 kg, the 6th trip was 2,536 kg, the 7th trip was 4,323 kg (Figure 3).

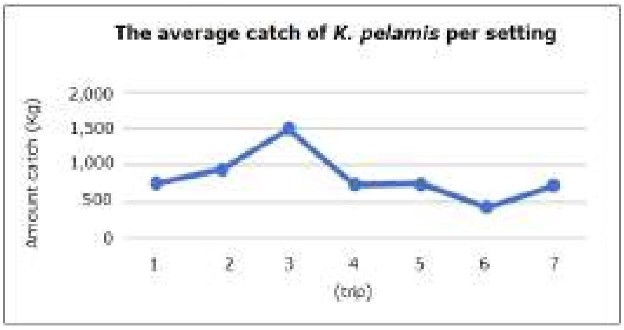

Figure 3. Diagram of the average catch of *Katsuwonus pelamis.*

Chlorophyll-a. Because fertile waters contain high chlorophyll-a concentrations, the chlorophyll-a is eligible as an indicator of fertility in waters. The chlorophyll-a concentration is also influenced by other factors such as currents. Chlorophyll-a image data were downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). The research data was processed using Seadas to produce chlorophyll-a data. Furthermore, the data was processed using Surfer 13 into JPEG format images that display the distribution of chlorophyll-a with different colors. The distribution of chlorophyll-a was taken based on the time and position of the capture operation. Figure 4 shows the chlorophyll-a distribution over the 7 fishing trips.

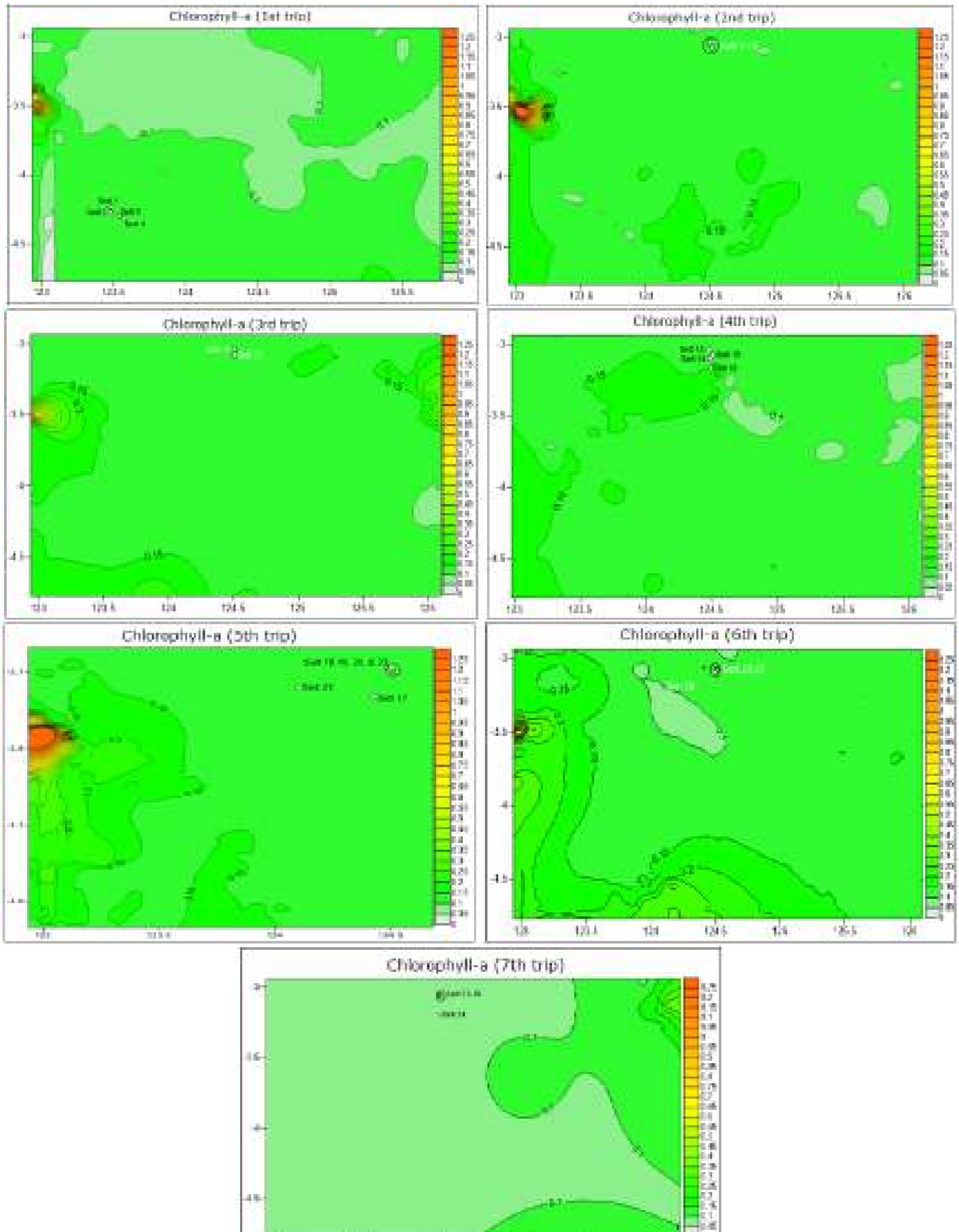

Figure 4. Distribution of chlorophyll-a over the 7 fishing trips.

The chlorophyll-a concentration values can be seen in Table 4 below.

Table 4

Chlorophyll-a concentration values

Trips	*Chlorophyll-a concentration value (mg m^3)*						*Average*
	1st operation	*2nd operation*	*3rd operation*	*4th operation*	*5th operation*	*6th operation*	
Trip 1	0.1308[a]	0.1292	0.1273	0.1268[b]	-	-	0.1285
Trip 2	0.1176	0.1176	0.1173[b]	0.1266	0.1176	0.1266[a]	0.1205
Trip 3	0.1399[a]	0.1342[b]	-	-	-	-	0.1370
Trip 4	0.1046[b]	0.1080	0.1077	0.1632[a]	-	-	0.1209
Trip 5	0.1314	0.1312	0.1312	0.1314[a]	0.1313	0.1258[b]	0.1303
Trip 6	0.1208	0.1288[a]	0.1287	0.1227	0.1281	0.1001[b]	0.1215
Trip 7	0.0895	0.0903	0.0913[a]	0.0880	0.0875[b]	0.0894	0.0893

[a] the distribution of the highest chlorophyll-a concentrations; [b] the distribution of the lowest chlorophyll-a concentrations.

The chlorophyll-a concentration value on the 7th trip decreased significantly, compared to the other trips. The higher the chlorophyll-a concentration value in the waters, the more fertile the waters.

Average chlorophyll-a. The average chlorophyll-a can be seen in Figure 5, where the concentration of the 7th trip decreased, compared to the other trips. The average chlorophyll-a concentration was the highest on trip 3 and the lowest on trip 7. The difference between the highest and lowest concentrations is 0.0477 mg m^{-3}.

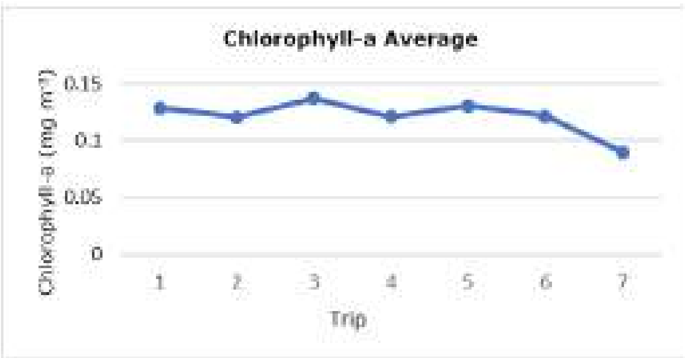

Figure 5. Diagram of average chlorophyll-a for 7 trips.

The relationship between average chlorophyll-a against K. pelamis. The relationship of chlorophyll-a to the catch of *K. pelamis* was calculated using a multiple correlation test. The multiple correlation estimator for the level of chlorophyll-a relationship to *K. pelamis* catch was determined by using SPSS 25.

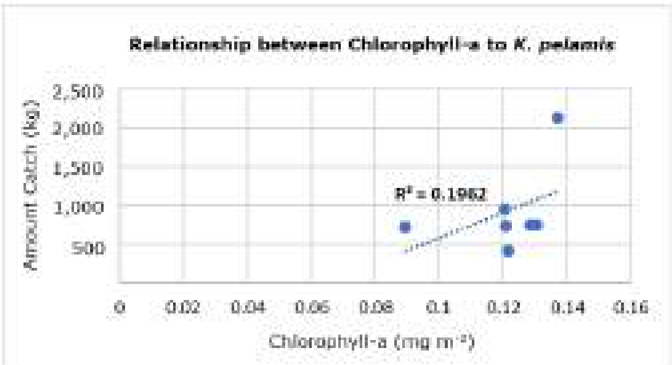

Figure 6. Graph of chlorophyll-a relationship to *Katsuwonus pelamis.*

Based on Figure 6 above, the coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents.

The value of the correlation coefficient using SPSS 25 can be seen in table 4. The correlation coefficient value was obtained at 0.443, which means that the positive relationship between chlorophyll-a and the catch of *K. pelamis* is moderate, because the correlation coefficient value is in the correlation interval 0.40-0.599. This relationship is positive: if the value of one variable is increased, it will increase the value of the other variables and vice versa (Sugiono 2007), while if the chlorophyll-a decreases, it will decrease the catch of *K. pelamis*.

Hypothesis testing via the t test is used to determine whether the hypothesis is accepted or rejected, based on the coefficients table (Table 7). Based on this table, the t_{count} value of chlorophyll-a is 3,320, $t_{count}>t_{table}$ (3,320>2.77, respectively) and the sig value of 0.029 (<0.05), therefore the null hypothesis is rejected, due to the significant effect of chlorophyll-a on the catch of *K. pelamis*, in accordance with a previous research conducted by Demena et al (2017), which states that chlorophyll-a and the number of catches *K. pelamis* have a unidirectional relationship and the chlorophyll-a concentration affects the presence of *K. pelamis*.

The effect of chlorophyll-a on the catch of K. pelamis. Chlorophyll-a is an indicator that greatly influences the presence of fish in the waters, especially *K. pelamis*, a migratory species. The effect of chlorophyll-a on the catch of *K. pelamis* is calculated using the multiple linear regression, with the SPSS 25, and manual calculations were performed using a computer device.

Based on the results obtained in Table 5, the coefficient of determination (R^2)=0.779 or 77.9%. This shows an influence of 77.9% of the chlorophyll-a on the catch of *K. pelamis*, so that the remaining 22.1% are influenced by other factors such as currents and salinity. The correlation coefficient (R) in the model summary table above is 0.882. Based on table 5, the relationship level, given by the correlation coefficient (R), is included in the interval at 0.80-1.00, which means that the level of chlorophyll-a relationship to the catch of *K. pelamis* is very strong.

Table 5

Model summary

Model	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*
1	0.882[a]	0.779	0.668	320.54745

[a]Predictors: (Constant), Chlorophyll-a.

The hypothesis test used is the F test, carried out to test the effect of SST and chlorophyll-a on *K. pelamis* catches which will determine whether the results of the hypothesis are accepted or rejected. Hypothesis testing used SPSS 25 and manually obtained the value of F_o=7.030 and value=6.94 (Table 6). The results obtained in the ANOVA table have a sign value of 0.049<0.05. Thus, it can be concluded that H_o is rejected and accepted because the sign value is <0.05 or F_o. If H_o is rejected and accepted, then there is a significant effect between SST and chlorophyll-a on *K. pelamis* catches, which is in accordance with a the research conducted by Demena et al (2017) which stated that sea surface temperature and chlorophyll-a are two very important indicators that affect the presence of fish in the waters, especially of *K. pelamis*.

Table 6

ANOVA regression table

Model	*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*
Regression	1,444,657.089	2	722,328.544	7.030	0.049[b]
Residual	411,002.672	4	102,750.668		
Total	1,855,659.760	6			

[a] Dependent variable: *K. pelamis*; [b] Predictors: (Constant), Chlorophyll-a, Sea Surface Temperature (SST).

Relationship of average SST to K. pelamis. SST can be used as an indicator to determine the presence of a fish species in waters. Each fish species has a certain temperature tolerance value so that it affects the presence and distribution of fish in the waters. Seeing the relationship or relationship between SST and the presence of *K. pelamis*, the in-situ data of the catch and *ex-situ* data of SST on the position and time of catching using SPSS 25 and using the help of computer equipment.

The relationship of SST to the catch of *K. pelamis* was calculated using the multiple correlation test. Double correlation estimator of the relationship between surface temperature and the catch of *K. pelamis.*

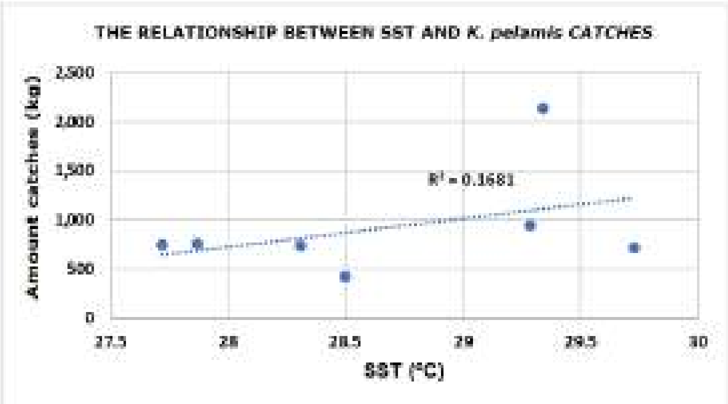

Figure 7. Graph of the relationship between SST and *Katsuwonus pelamis.*

Based on the graph above, the coefficient of determination (R_2) is 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%.

The assessment of the value of the correlation coefficient using SPSS 25 can be seen in Table 7. The correlation coefficient value obtained is 0.410, which means that the positive relationship between SST and the catch of *K. pelamis* is moderate, because the correlation value is in the correlation interval of 0.40-0.599.

Table 7

Correlations

		Correlations		
.....	......	*K. pelamis*	*SST*	*Chlorophyl-a*
Pearson correlation	*K. pelamis*	1.000	0.410	0.443
	SST	0.410	1.000	-0.532
	Chlorophyl-a	0.443	-0.532	1.000
Sig. (1-tailed)	*K. pelamis*	0	0.180	0.160
	SST	0.180	0	0.109
	Chlorophyl-a	0.160	0.109	0
N	*K. pelamis*	7	7	7
	SST	7	7	7
	Chlorophyl-a	7	7	7

Based on Table 8, the results obtained the $t_{count}>t_{table}$ and sig value 0.032<0.05, it was found that H_o was rejected and H_1 accepted, there was a significant effect between SST and the catch of *K. pelamis*. A previous research conducted by Fajrianti (2016) stated that SST had a significant effect on the catch.

Table 8

Coefficients

Coefficients[a]						
Model		*Unstandardized coefficients*		*Standardized coefficients*	*T*	*Sig.*
		B	*Std. Error*	*Beta*		
1	(Constant)	-21,557.333	6,416.374		-3.360	0.028
	SST	642.160	198.028	0.902	3.243	0.032
	Chlorophyl-a	33,535.607	10,100.263	0.923	3.320	0.029

a. Dependent variable: *K. pelamis.*

Based on the output of SPSS 25 (the coefficients matrix), the multiple linear regression equation could be expressed as follows:

$$Y = -21{,}557.333 + 642.160\ X_1 + 33{,}535.607\ X_2$$

The multiple linear regression equation above can be interpreted as follows:

- if the variables X_1 (SST) and X_2 (chlorophyll-a) have a value of 0, then the variable Y is -21,557.33 kg (intercept).
- if the variable X_1 (SST) increases by 1ºC and the other variables are constant, then the variable Y will increase by 642,160 kg.
- if the X_2 variable (chlorophyll-a) increases by 1 mg m^{-3} and the other variables are constant, then the Y variable will increase by 33,535.607 kg.

Distribution of chlorophyll-a with K. pelamis catch. The graph of the relationship between chlorophyll-a and the catch of *K. pelamis*, shows that the concentration of chlorophyll-a and the catch of *K. pelamis* have a unidirectional relationship.

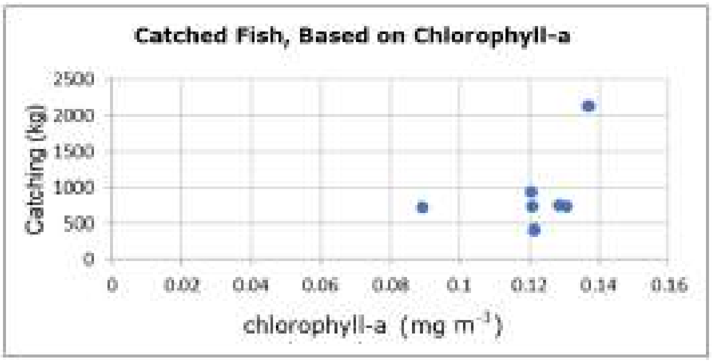

Figure 7. Catch based on chlorophyll-a.

In the figure above, the highest catch occurs at a concentration of 0.137 mg m^{-3}. The results showed that the *K. pelamis* maximum fishing potential occurs at an optimal chlorophyll-a concentration of 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a chlorophyll-a in the optimal range of 0.12-0.22 mg m^{-3}.

Conclusions. From the results of the research conducted, it can be concluded that the main catches were *T. albacares, K. pelamis, E. affinis* and *D. ruselli, K. pelamis* being the most caught type of fish. The relationship between the sea surface temperature and *K. pelamis* catches with the results obtained in the form of a coefficient of determination (R_2) of 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%. There was a positive relationship between chlorophyll-a and *K. pelamis* catches, meaning that if the chlorophyll-a is higher, it will increase the catch, and vice versa if chlorophyll-a is lower, it will decrease the catch of *K. pelamis*. The results of the study concluded that the potential area for *K. pelamis* catching based on the optimum sea surface temperature was around 29°C and the optimum concentration for chlorophyll-a was around 0.13 mg m^{-3}.

Conflict of interest. The authors declare no conflict of interest.

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The effect of chlorophyll-a on the catches of skipjack tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

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Abstract. The Banda Sea is located in the waters of Central Maluku Regency, Maluku Province. The topography of the seabed is very complex with a basin in the west and a trough in the east. The shape of the topography is also decisive in controlling the exchange of water masses. The purpose of this study was to analyze the relationship of chlorophyll-a and the effect of its distribution on the catch of skipjack tuna (*Katsuwonus pelamis*). The study used the data analysis method, namely the multiple linear regression (computerized data processing using the SPSS 25 program). Primary data was obtained by following fishing operations and secondary data was collected from chlorophyll-a images downloaded from the NASA database in the form of an average per trip. The results of the study showed that the coefficient of determination (R2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents. The results of the t-test obtained a t_count chlorophyll-a value of 3.320, sig value of 0.029 and t_table value of 2.77. Based on the value of t_count>t_table and the value of sig 0.029<0.05, there was a significant effect between chlorophyll-a and *K. pelamis*; the ANOVA table showed the value of R^2=0.779 or 77.9% the effect of chlorophyll on *K. pelamis*, so the remaining 22.1% was influenced by other factors. Based on the results obtained, chlorophyll-a had a significant effect on *K. pelamis*.
Key Words: purse seine, remote sensing, sea surface temperature (SST), catch season.

Introduction. The Banda Sea owes its abundance to a high nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea (Putra et al 2017). The topography of the seabed is very complex, with a basin in the west and a trough in the east (Suyarso 1999; Tapilatu 2016). This complex topographical shape also determines the mass exchange of water. The circulation of different water massesvaries between seasons and is influenced by the monsoon system's wind pattern. The circulation of water mass in Indonesian waters differs between the west monsoon and the east monsoon. In the west monsoon, water masses generally flow to the east of Indonesian waters. The eastern monsoons develop perfectly, supplying water masses originating from the upwelling areas in the Arafura and Banda Seas (Hasanudin 1998). The upwelling process that occurs in the Banda Sea results in a decrease of temperatures, an increase of salinity and the removal of nutrients, so that their availability will affect the abundance of plankton in the waters (Baars et al 1990; Armus et al 2019).

The potential area for catching skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ranges from 0.12 to 0.22 mg m^3 (Zainuddin 2011; Hidayat et al 2019; Wangi et al 2019). Almost all fish populations that live in marine waters, including *K. pelamis*, require optimal sea surface temperature (SST) range and chlorophyll-a values for their survival (Jufri et al 2014). Remote sensing technology helps observing the oceanographic

parameters of the surrounding waters in the Banda Sea, so that it can determine the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea.

K. pelamis likes areas where there is a convergence of currents that mostly occur in areas with many islands. The vertical distribution of *K. pelamis* starts from the surface to a depth of 260 m during the day, while at night it will go to the surface (diurnal migration) (Ekayana et al 2017). *K. pelamis* specimens from the small size category tend to be caught at a more homogeneous (warm) SST, while large *K. pelamis* are caught in a wider range of SST (cold and warm) (Simbolon & Limbong 2012). *K. pelamis* congregate at low chlorophyll-a concentrations and water depths of ≥500 m, because *K. pelamis* is a carnivorous fish with the main prey of small pelagic fish such as *Stelophorus sp.* and *Sardinella sp*., which are abundant in the continetal shelf and sloping waters (Bubun et al 2015).

Remote sensing technology is an alternative method that is very beneficial if it is used in a country with a very large area such as Indonesia (Syah 2010). Remote sensing is a technique for collecting information about objects and their environment from a distance without physical touch (Lo 1986). The use of remote sensing methods to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions is a very appropriate alternative (Tangke 2016; Mashita & Lumban-Gaol 2019). Remote sensing technology has several advantages including cheap and easily accessible data prices, wide area coverage, high temporal resolution and digitalized data supply, making it a potential source for the geographic information system (GIS) data (Louhenapessy & Waas 2009). One of the sensing satellites equipped with sensors that can detect the chlorophyll-a content is the Aqua MODIS satellite (Utari 2013). The variables measured by the Aqua satellite include the aerosols, land-covering plants, phytoplankton and dissolved organic matter in the oceans, as well as the air, land and water temperature (Putra et al 2012). The Aqua MODIS satellite has a polar sun-synchronous orbit. The satellite crosses the equator at noon, approaching at 13.30 local time (Karif 2011).

Changes in fishing actually occur when the seasons' change. Seasonal changes directly affect the oceanographic aspects of the waters, especially sea surface temperature and chlorophyll-a, which greatly influence the presence of fish in an area, determining the fishing grounds in that area. Both of these parameters can trigger natural events or phenomena such as upwelling and fronts (Waileruny & Wiyono 2014). The fishing season in Southeast Sulawesi waters can be found in January to April and from July to September, and it can affect the salinity of the habitat of the caught fish species. In the eastern monsoon (June to September), high salinity water masses originating from the Flores Sea and Pacific Ocean flow through the Makassar Strait to the Java Sea. In the western season (December to March) surface currents move from the South China Sea into the Java Sea from west to east (Bubun & Mahmud 2016). The present research aimed to analyze how much influence chlorophyll-a had on the number of *K. pelamis*, knowing the distribution of chlorophyll-a concentrations in the Banda Sea, Maluku. In this way, fishermen can be more effective in determining the area and time of catch.

Material and Method. The tools and materials needed in the implementation of this research include: stationery, cameras, rulers, GPS, MODIS data and the softwares SeaDas, SPSS Statistics 25 and Surfer 13.0.

Method of collecting data. The data collection method uses primary data, carried out *in situ* by direct observation of the fishing operation including operating time, the number of catches and the position of the fishing area, and by using secondary data including the image of the distribution of chlorophyll-a, from the level 3 of the Aqua MODIS, downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). Data were processed using the Seadas to get the chlorophyll value and the Surfer 13 to get the distribution of chlorophyll-a in the form of images.

The chlorophyll-a image data chosen to be processed is a standard 8-day image with a 4 km resolution map of level 3, at night, from November 2017 to March 2018.

Chlorophyll-a data was calculated using chlorophyll-a image data that has been adjusted with both atmospheric and geometrical corrections. Seadas produced the chlorophyll-a distribution data which was reprocessed using a computer device, then using the Surfer 13, which will produced the distribution data of chlorophyll-a in the JPEG image format. The catch used includes the catch weight of *K. pelamis* analyzed by calculating the weight per fishing trip, so that fluctuations in the catch based on time (temporal) and fishing location (spatial) can be observed.

Multiple correlation analysis. The multiple correlations showed the direction and strength of the relationship between the studied variables. To be able to provide an interpretation of the correlation coefficients found, reference values are listed in Table 1 below (Sugiono 2007).

Table 1

Assessment of the correlation coefficient (Sugiono 2007)

Coefficient interval	*Relationship level*
0.00–0.199	Very low
0.20–0.399	Low
0.40–0.599	Moderate
0.60–0.799	Strong
0.80–1.00	Very strong

The double correlation formula for two variables is the following (Sugiono 2007):

$$R_{y.x_1x_2} = \sqrt{\frac{r_{yx1}^2 + r_{yx2}^2 - 2r_{yx1}r_{yx2}\ r_{x1x2}}{1-r^2_{x1\,x2}}}$$

Where:
$R_{y.x_1x_2}$ - correlation of the variables X_1 and X_2 with the variable Y;
ryx_1 - correlation between X_1 and Y;
ryx_2 - correlation between X_2 and Y;
rx_1x_2 - correlation between X_1 and X_2.

Multiple linear regression analysis. When the correlation coefficient is sufficiently high, a multiple linear regression was used to examine the variables relationship (Sugiono 2005), as follows:

$$Y = a + b_1X_1 + b_2X_2$$

Where:
X_1 - variable sea surface temperature;
X_2 - chlorophyll-a variable;
Y - the maximum quantity of certain fish species caught;
a, b_1, b_2 - constants.

Multiple linear statistical test. According to Hasan (2004), multiple linear regression statistical tests are used to test the significance of the relationship of more than two variables through the regression coefficient. The multiple linear regression statistical tests can be divided into two categories, namely:
1. Concurrent test
The test is carried out in multiple linear regression using the F test, a statistical test for the regression coefficient that together affects Y, namely:

$$F_o = \frac{R^2(n-k-1)}{k(1-R^2)}$$

Where:
n - number of fish caught;

k - number of independent variables;
R^2 – determination coefficient.
2. Individual test
Individual test, namely the regression statistic with only one regression coefficient affecting Y, using the t_{test}:

$$t_o = \frac{b_1 - B_i}{S_{b1}}$$

Where:
b_1 - regression slope coefficient;
B_i - hypothesized slope;
S_{bi}- standard deviation of slope.

Geographical information analysis. The Surfer 13 software was used to map the distribution of *chlorophyll-a* from November 2017 to March 2018, based on time (temporal) and fishing location (spatial), with the aim of producing information about the relationship of these variables.

Results and Discussion

This research was conducted from November 2017 to May 2018 by following a fishing operation using a purse seiner in the Banda Sea, Maluku Indonesia.

Figure 1. Purse seiner (original photo).

Fish catch results. The fishing operation was carried out in seven trips, with a total catch of 56,689 kg and an average of 12,558.17 kg per 34 operations. The number of catches on the 2nd trip (6 operations) was the largest, with a total catch of 11,954 kg (an average of 1,992.33 kg per operation) or 21.1% of the total catch. Meanwhile, the 3rd trip (2 operations) recorded the smallest total catch, namely 5,522 kg or 9.7% of the total catch, but with the highest average per operation, of 2,761 kg (Table 2).

Table 2

The number of fish catch per trip

Trip	*Number of operations*	*Amount (kg)*	*Average (kg)*	*Percentage (%)*
1st	4	8,226	2,056.5	14.5
2nd	6	11,954	1,992.33	21.1
3rd	2	5,522	2,761	9.7
4th	4	7,006	1,751.5	12.4
5th	6	9,607	1,601.16	17
6th	6	7,982	1,330.33	14.1
7th	6	6,392	1,065.33	11.2
Total	34	56,689	12,558.17	100

Catch composition. The catch data consists of seven trips with 34 operations. The main catches are *K. pelamis*, *T. albacares*, *E. affinis* and *D. ruselli*. Based on the results obtained, the highest *T. albacares* catches were on the 7th trip and the lowest was on the 5th trip. *K. pelamis* catches reached the highest value on the 2nd trip and the lowest on

the 6th trip. The highest *T. albacares* catches were on the 2nd trip and the lowest was on the 7th trip, and the highest *D. ruselli* was on the 6th trip and the lowest was on the 3rd trip. The composition of the catch can be seen in Table 3 below.

Table 3

The composition of the catch based on the type of fish

Trip to-	*Total catch (Kg)*				*Total*
	T. albacares	*K. pelamis*	*E. affinis*	*D. ruselli*	
1st	825	3,018	2,590	1,793	8,226
2nd	230	5,676	4,430	1,618	11,954
3rd	90	4,270	497	665	5,522
4th	569	2,948	1,817	1,672	7,006
5th	0	4,467	4,290	850	9,607
6th	13	2,536	670	4,763	7,982
7th	915	4,323	0	1,154	6,392

Based on the data mentioned above, the highest catch was on the second trip, and the lowest catch was on the 3rd trip. The highest catch of *T. albacares* was on the 7th trip, as much as 915 kg, while the lowest was on the 5th trip, with no catch. The highest catch of *K. pelamis* was on the 2nd trip, as much as 5,676 kg, while the lowest was on the 6th trip, with 2,536 kg. The highest *E. affinis* catch was on the 2nd trip, as much as 4,430 kg, and the lowest on the 7th trip, with no catch. The highest *D. ruselli* catch was on the 6th trip, as much as 4,763 kg, and the lowest was on the 3rd trip, with 665 kg. Based on all catches, *K. pelamis* was the most dominant fish caught compared to other fish (Figure 2).

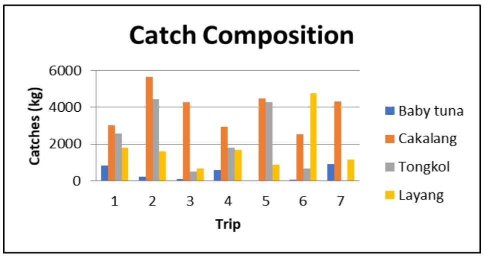

Figure 2. Composition diagram of the catch.

Average K. pelamis per operation. The catch of *K. pelamis* is higher than that of other types. The total catch of *K. pelamis* from the 1st trip to the 7th trip was 27,238 kg. The average highest catch per operation of *K. pelamis* was recorded on the 3rd trip, with 1,495 kg, while the lowest catch per operation was recorded on the 6th trip, with 422.67 kg. The catch of the 1st trip was 3,018 kg, the 2nd trip was 5,676 kg, the 3rd trip was 4,270 kg, the 4th trip was 2,948 kg, the 5th trip was 4,467 kg, the 6th trip was 2,536 kg, the 7th trip was 4,323 kg (Figure 3).

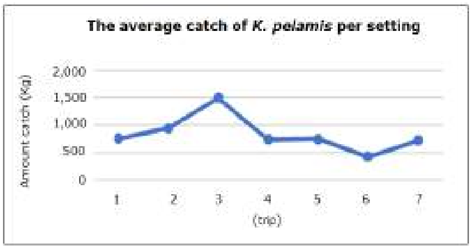

Figure 3. Diagram of the average catch of *Katsuwonus pelamis.*

Chlorophyll-a. Because fertile waters contain high chlorophyll-a concentrations, the chlorophyll-a is eligible as an indicator of fertility in waters. The chlorophyll-a concentration is also influenced by other factors such as currents. Chlorophyll-a image data were downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). The research data was processed using Seadas to produce chlorophyll-a data. Furthermore, the data was processed using Surfer 13 into JPEG format images that display the distribution of chlorophyll-a with different colors. The distribution of chlorophyll-a was taken based on the time and position of the capture operation. Figure 4 shows the chlorophyll-a distribution over the 7 fishing trips.

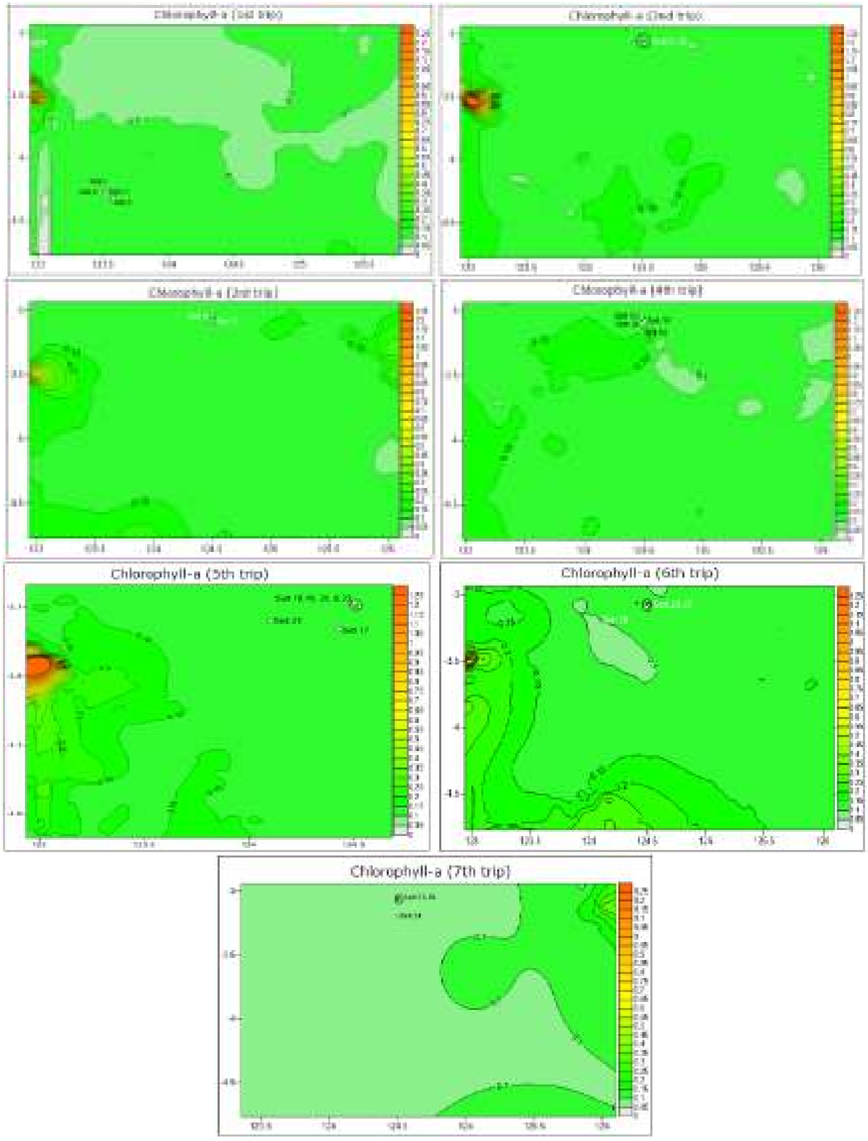

Figure 4. Distribution of chlorophyll-a over the 7 fishing trips.

The chlorophyll-a concentration values can be seen in Table 4 below.

Table 4

Chlorophyll-a concentration values

Trips	*Chlorophyll-a concentration value (mg m³)*						*Average*
	1st operation	*2nd operation*	*3rd operation*	*4th operation*	*5th operation*	*6th operation*	
Trip 1	0.1308[a]	0.1292	0.1273	0.1268[b]	-	-	0.1285
Trip 2	0.1176	0.1176	0.1173[b]	0.1266	0.1176	0.1266[a]	0.1205
Trip 3	0.1399[a]	0.1342[b]	-	-	-	-	0.1370
Trip 4	0.1046[b]	0.1080	0.1077	0.1632[a]	-	-	0.1209
Trip 5	0.1314	0.1312	0.1312	0.1314[a]	0.1313	0.1258[b]	0.1303
Trip 6	0.1208	0.1288[a]	0.1287	0.1227	0.1281	0.1001[b]	0.1215
Trip 7	0.0895	0.0903	0.0913[a]	0.0880	0.0875[b]	0.0894	0.0893

[a] the distribution of the highest chlorophyll-a concentrations; [b] the distribution of the lowest chlorophyll-a concentrations.

The chlorophyll-a concentration value on the 7th trip decreased significantly, compared to the other trips. The higher the chlorophyll-a concentration value in the waters, the more fertile the waters.

Average chlorophyll-a. The average chlorophyll-a can be seen in Figure 5, where the concentration of the 7th trip decreased, compared to the other trips. The average chlorophyll-a concentration was the highest on trip 3 and the lowest on trip 7. The difference between the highest and lowest concentrations is 0.0477 mg m^{-3}.

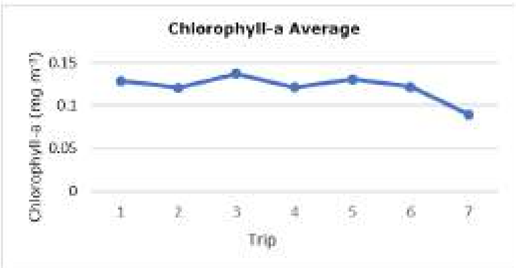

Figure 5. Diagram of average chlorophyll-a for 7 trips.

The relationship between average chlorophyll-a against K. pelamis. The relationship of chlorophyll-a to the catch of *K. pelamis* was calculated using a multiple correlation test. The multiple correlation estimator for the level of chlorophyll-a relationship to *K. pelamis* catch was determined by using SPSS 25.

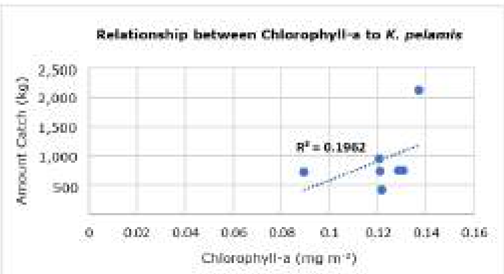

Figure 6. Graph of chlorophyll-a relationship to *Katsuwonus pelamis.*

Based on Figure 6 above, the coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents.

The value of the correlation coefficient using SPSS 25 can be seen in table 4. The correlation coefficient value was obtained at 0.443, which means that the positive relationship between chlorophyll-a and the catch of *K. pelamis* is moderate, because the correlation coefficient value is in the correlation interval 0.40-0.599. This relationship is positive: if the value of one variable is increased, it will increase the value of the other variables and vice versa (Sugiono 2007), while if the chlorophyll-a decreases, it will decrease the catch of *K. pelamis*.

Hypothesis testing via the t test is used to determine whether the hypothesis is accepted or rejected, based on the coefficients table (Table 7). Based on this table, the t_{count} value of chlorophyll-a is 3,320, $t_{count}>t_{table}$ (3,320>2.77, respectively) and the sig value of 0.029 (<0.05), therefore the null hypothesis is rejected, due to the significant effect of chlorophyll-a on the catch of *K. pelamis*, in accordance with a previous research conducted by Demena et al (2017), which states that chlorophyll-a and the number of catches *K. pelamis* have a unidirectional relationship and the chlorophyll-a concentration affects the presence of *K. pelamis*.

The effect of chlorophyll-a on the catch of K. pelamis. Chlorophyll-a is an indicator that greatly influences the presence of fish in the waters, especially *K. pelamis*, a migratory species. The effect of chlorophyll-a on the catch of *K. pelamis* is calculated using the multiple linear regression, with the SPSS 25, and manual calculations were performed using a computer device.

Based on the results obtained in Table 5, the coefficient of determination (R^2)=0.779 or 77.9%. This shows an influence of 77.9% of the chlorophyll-a on the catch of *K. pelamis*, so that the remaining 22.1% are influenced by other factors such as currents and salinity. The correlation coefficient (R) in the model summary table above is 0.882. Based on table 5, the relationship level, given by the correlation coefficient (R), is included in the interval at 0.80-1.00, which means that the level of chlorophyll-a relationship to the catch of *K. pelamis* is very strong.

Table 5

Model summary

Model	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*
1	0.882[a]	0.779	0.668	320.54745

[a]Predictors: (Constant), Chlorophyll-a.

The hypothesis test used is the F test, carried out to test the effect of SST and chlorophyll-a on *K. pelamis* catches which will determine whether the results of the hypothesis are accepted or rejected. Hypothesis testing used SPSS 25 and manually obtained the value of F_o=7.030 and value=6.94 (Table 6). The results obtained in the ANOVA table have a sign value of 0.049<0.05. Thus, it can be concluded that H_o is rejected and accepted because the sign value is <0.05 or F_o. ~~If H_o is rejected and accepted, then there is a significant effect between SST and chlorophyll-a on *K. pelamis* catches, which is in accordance with a the research conducted by Demena et al (2017) which stated that sea surface temperature and chlorophyll-a are two very important indicators that affect the presence of fish in the waters, especially of *K. pelamis*.~~

If H_o is rejected and H_1 is accepted, it means that there is a significant effect between SST and chlorophyll-a on *K. pelamis* catches, this is in accordance with research conducted by Demena et al (2017) which states that SST and chlorophyll-a are two indicators that greatly affect the presence of fish in the waters, especially *K. pelamis.*

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Table 6

ANOVA regression table

Model	Sum of squares	df	Mean square	F	Sig.
Regression	1,444,657.089	2	722,328.544	7.030	0.049[b]
Residual	411,002.672	4	102,750.668		
Total	1,855,659.760	6			

~~[a] Dependent variable: *K. pelamis*;~~ [b] Predictors: (Constant), Chlorophyll-a, Sea Surface Temperature (SST).

Relationship of average SST to K. pelamis. SST can be used as an indicator to determine the presence of a fish species in waters. Each fish species has a certain temperature tolerance value so that it affects the presence and distribution of fish in the waters. ~~Seeing the relationship or relationship between SST and the presence of *K. pelamis*, the in situ data of the catch and *ex-situ* data of SST on the position and time of catching using SPSS 25 and using the help of computer equipment.~~To see the relationship between SST and the presence of *K. pelamis*, the catch data (*in-situ*) and SST data on the position and time of catching (*ex-situ*) were taken with SPSS 25 using a computer device.

The relationship of SST to the catch of *K. pelamis* was calculated using the multiple correlation test *which was used as an estimator*. ~~Double correlation estimator of the relationship between surface temperature and the catch of *K. pelamis*.~~

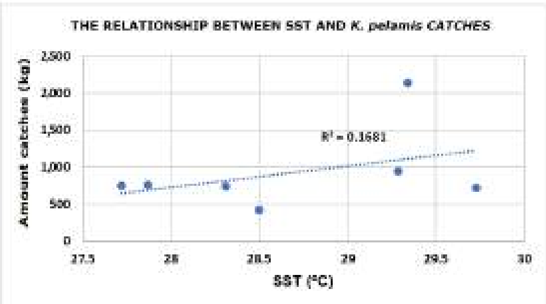

Figure 7. Graph of the relationship between SST and *Katsuwonus pelamis.*

Based on the graph above, the coefficient of determination (R_2) is 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%.

The assessment of the value of the correlation coefficient using SPSS 25 can be seen in Table 7. The correlation coefficient value obtained is 0.410, which means that the positive relationship between SST and the catch of *K. pelamis* is moderate, because the correlation value is in the correlation interval of 0.40-0.599.

Table 7

Correlations

Correlations				
	Model	*K. pelamis*	*SST*	*Chlorophyl-a*
Pearson correlation	*K. pelamis*	1.000	0.410	0.443
	SST	0.410	1.000	-0.532
	Chlorophyl-a	0.443	-0.532	1.000
Sig. (1-tailed)	*K. pelamis*	0	0.180	0.160
	SST	0.180	0	0.109
	Chlorophyl-a	0.160	0.109	0
N	*K. pelamis*	7	7	7
	SST	7	7	7

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	Chlorophyl-a	7	7	7

Based on Table 8, the results obtained the $t_{count} > t_{table}$ and sig value 0.032<0.05, it was found that H_o was rejected and H_1 accepted, there was a significant effect between SST and the catch of *K. pelamis*. A previous research conducted by Fajrianti (2016) stated that SST had a significant effect on the catch.

Table 8

Coefficients

Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	*Std. Error*	*Beta*		
1	(Constant)	-21,557.333	6,416.374		-3.360	0.028
	SST	642.160	198.028	0.902	3.243	0.032
	Chlorophyl-a	33,535.607	10,100.263	0.923	3.320	0.029

Coefficients[a]

a. Dependent variable: *K. pelamis.*

Based on the output of SPSS 25 (the coefficients matrix), the multiple linear regression equation could be expressed as follows:

$$Y = -21,557.333 + 642.160 X_1 + 33,535.607 X_2$$

The multiple linear regression equation above can be interpreted as follows:

- if the variables X_1 (SST) and X_2 (chlorophyll-a) have a value of 0, then the variable Y is -21,557.33 kg (intercept).
- if the variable X_1 (SST) increases by 1ºC and the other variables are constant, then the variable Y will increase by 642,160 kg.
- if the X_2 variable (chlorophyll-a) increases by 1 mg m^{-3} and the other variables are constant, then the Y variable will increase by 33,535.607 kg.

Distribution of chlorophyll-a with K. pelamis catch. The graph of the relationship between chlorophyll-a and the catch of *K. pelamis*, shows that the concentration of chlorophyll-a and the catch of *K. pelamis* have a unidirectional relationship.

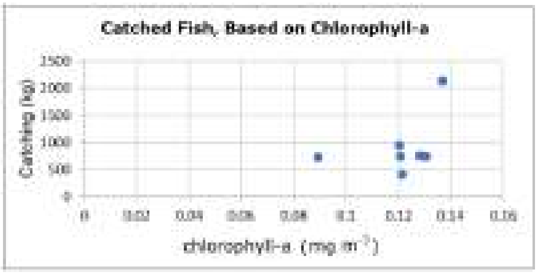

Figure 7. Catch based on chlorophyll-a.

In the figure above, the highest catch occurs at a concentration of 0.137 mg m^{-3}. The results showed that the *K. pelamis* maximum fishing potential occurs at an optimal chlorophyll-a concentration of 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a chlorophyll-a in the optimal range of 0.12-0.22 mg m^{-3}.

Conclusions. From the results of the research conducted, it can be concluded that the main catches were *T. albacares, K. pelamis, E. affinis* and *D. ruselli, K. pelamis* being the most caught type of fish. The relationship between the sea surface temperature and *K. pelamis* ~~catches with the results~~was obtained in the form of a coefficient of determination (R_2) of 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%. There was a positive relationship between chlorophyll-a and *K. pelamis* catches, meaning that if the chlorophyll-a is higher, it will increase the catch, and vice versa if chlorophyll-a is lower, it will decrease the catch of *K. pelamis*. The results of the study concluded that the potential area for *K. pelamis* catching based on the optimum sea surface temperature was around 29°C and the optimum concentration for chlorophyll-a was around 0.13 mg m^{-3}.

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Conflict of interest. The authors declare no conflict of interest.

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Kind regards,
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The effect of chlorophyll-a on the catches of skipjack tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

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Abstract. The Banda Sea is located in the waters of Central Maluku Regency, Maluku Province. The topography of the seabed is very complex with a basin in the west and a trough in the east. The shape of the topography is also decisive in controlling the exchange of water masses. The purpose of this study was to analyze the relationship of chlorophyll-a and the effect of its distribution on the catch of skipjack tuna (Katsuwonus pelamis). This study uses the data analysis method used, namely multiple linear regression, because it uses two independent variables, namely chlorophyll-a. Primary data was taken by following fishing operations and secondary data was obtained from chlorophyll-a images downloaded from the NASA database in the form of an average per trip. The results of the study showed that 1) the value of the coefficient of determination (R2) was 0.196 or 19.6% or 80.4%, the rest was influenced by other factors. The results of the t-test obtained t count chlorophyll-a value of 3.320, sig value of 0.029 and t table value of 2.77. based on the value of t count > t table and the value of sig 0.029 <0.05, there was a significant effect between chlorophyll-a and K. pelamis. 2) the ANOVA table shows the value of R^2 = 0.779 or 77.9% the effect of chlorophyll on K. pelamis, so the remaining 22.1% is influenced by other factors. Based on the results obtained in the ANOVA table, it has a sig value of 0.049 <0.05, which means H_o is rejected and H1 is accepted, so chlorophyll-a has a significant effect on K. pelamis.

The Banda Sea owes its abundance to a high nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea. The potential area for catching skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ranges from 0.12 to 0.22 mg m^{-3}. Based on the results of the study, it is known that (1) the value of the coefficient of determination (R_2) is 0.196 or 19.6%. it means that the chlorophyll-a factor can only explain the real model by 19.6% so that the rest is provided by other factors of 80.4%. Based on the t_{test}, the t_{count} value of chlorophyll-a is 3.320, the sig value is 0.029. For the t_{table} value of 2.77. the results are based on the value of $t_{count} > t_{table}$ and the value of sig 0.029 < 0.05. So that the H_o obtained is rejected and H_1 is accepted, then there is a significant effect between chlorophyll-a and *K. pelamis*. (2) in the ANOVA table the value of R^2 = 0.779 or 77.9% the effect of chlorophyll on *K. pelamis*, so the remaining 22.1% is another factor. Based on the calculation of F with SPSS 25 and manually obtained the value of F_o = 7.030 and the value of F_{table} = 6.94. The results obtained in the ANOVA table have a sig value of 0.049 <0.05. So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or F_0 F_{table}, so there is a significant effect of chlorophyll-a on *K. pelamis*.

Potential areas for catching *Katsuwonus pelamis* have a close relationship with environmental parameters, especially chlorophyll-a. Remote sensing methods are used to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions. On this purpose, the multiple linear regression method was used to analyze their relationship. Based on the results of the study, it is known that (1) the value of the coefficient of determination (R_2) is 0.196 or 19.6%. it means that the chlorophyll-a factor can only explain the real model by 19.6% so that the rest is provided by other factors of 80.4%. Based on the t_{test}, the t_{count} value of chlorophyll-a is 3.320, the sig value is 0.029. For the t_{table} value of 2.77. the results are based on the value of $t_{count} > t_{table}$ and the value of sig 0.029 < 0.05. So that the H_o obtained is rejected and H_1 is accepted, then there is a significant effect between chlorophyll-a and *K. pelamis*. (2) in the ANOVA table the value of R^2 = 0.779 or 77.9% the effect of chlorophyll on *K. pelamis*, so the remaining 22.1% is another factor. Based on the calculation of F with SPSS 25 and manually obtained the value of F_o = 7.030 and the value of F_{table} = 6.94.

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The results obtained in the ANOVA table have a sig value of 0.049 <0.05. So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or F_0 F_{table}, so there is a significant effect of chlorophyll-a on *K. pelamis*.
Key Words: purse seine, remote sensing, sea surface temperature (SST), catch season.

Introduction. The Banda Sea owes its abundance to a high nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea (Putra et al 2017). The topography of the seabed is very complex, with a basin in the west and a trough in the east (Suyarso 1999; Tapilatu 2016). This complex topographical shape also determines the mass exchange of water. The circulation of different water massesvaries between seasons and is influenced by the monsoon system's wind pattern.

The circulation of water mass in Indonesian waters differs between the west monsoon and the east monsoon. In the west monsoon, water masses generally flow to the east of Indonesian waters. The eastern monsoons develop perfectly, supplying water masses originating from the upwelling areas in the Arafura and Banda Seas (Hasanudin 1998). The upwelling process that occurs in the Banda Sea results in a decrease of temperatures, an increase of salinity and the removal of nutrients, so that their availability will affect the abundance of plankton in the waters (Baars et al 1990; Armus et al 2019).

The potential area for catching skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ranges from 0.12 to 0.22 mg m^{-3} (Zainuddin 2011; Hidayat et al 2019; Wangi et al 2019). Almost all fish populations that live in marine waters, including *K. pelamis*, require optimal sea surface temperature (SST) range and chlorophyll-a values for their survival (Jufri et al 2014). Remote sensing technology helps observing the oceanographic parameters of the surrounding waters in the Banda Sea, so that it can determine the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea.

K. pelamis likes areas where there is a convergence of currents that mostly occur in areas with many islands. The vertical distribution of *K. pelamis* starts from the surface to a depth of 260 m during the day, while at night it will go to the surface (diurnal migration) (Ekayana et al 2017). *K. pelamis* specimens from the small size category tend to be caught at a more homogeneous (warm) SST, while large *K. pelamis* are caught in a wider range of SST (cold and warm) (Simbolon & Limbong 2012). *K. pelamis* congregate at low chlorophyll-a concentrations and water depths of ≥ 500 m, because *K. pelamis* is a carnivorous fish with the main prey of small pelagic fish such as *Stelophorus sp.* and *Sardinella sp*., which are abundant in the continetal shelf and sloping waters (Bubun et al 2015).

Remote sensing technology is an alternative method that is very beneficial if it is used in a country with a very large area such as Indonesia (Syah 2010). Remote sensing is a technique for collecting information about objects and their environment from a distance without physical touch (Lo 1986). The use of remote sensing methods to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions is a very appropriate alternative (Tangke 2016; Mashita & Lumban-Gaol 2019). Remote sensing technology has several advantages including cheap and easily accessible data prices, wide area coverage, high temporal resolution and digitalized data supply, making it a potential source for the geographic information system (GIS) data (Louhenapessy & Waas 2009).

One of the sensing satellites equipped with sensors that can detect the chlorophyll-a content is the Aqua MODIS satellite (Utari 2013). The variables measured by the Aqua satellite include the aerosols, land-covering plants, phytoplankton and dissolved organic matter in the oceans, as well as the air, land and water temperature (Putra et al 2012). The Aqua MODIS satellite has a polar sun-synchronous orbit. The satellite crosses the equator at noon, approaching at 13.30 local time (Karif 2011).

Changes in fishing actually occur when the seasons' change. Seasonal changes directly affect the oceanographic aspects of the waters, especially sea surface temperature and chlorophyll-a, which greatly influence the presence of fish in an area, determining the fishing grounds in that area. Both of these parameters can trigger natural events or phenomena such as upwelling and fronts (Waileruny & Wiyono 2014). The fishing season in Southeast Sulawesi waters can be found in January to April and from July to September, and it can affect the salinity of the habitat of the caught fish species. In the eastern monsoon (June to September), high salinity water masses originating from the Flores Sea and Pacific Ocean flow through the Makassar Strait to the Java Sea. In the western season (December to March) surface currents move from the South China Sea into the Java Sea from west to east (Bubun & Mahmud 2016). ~~The purpose of this study was to analyze the relationship and effect of chlorophyll-a on the catch of *K. pelamis* (Mugo et al 2010).~~

This research aims to analyzed how much influence chlorophyll-a had on the number of skipjack tuna (*Katsuwonus pelamis*), knowing distribution of chlorophyll-a concentrations in the Banda Sea, Maluku. So that fishermen can be more effective again in determining the area and time of catch.

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Material and Method. The tools and materials needed in the implementation of this research include: stationery, cameras, rulers, GPS, MODIS data and the softwares SeaDas, SPSS Statistics 25 and Surfer 13.0.

Method of collecting data. The data collection method uses primary data, carried out *in situ* by direct observation of the fishing operation including operating time, the number of catches and the position of the fishing area, and by using secondary data including the image of the distribution of chlorophyll-a, from the level 3 of the Aqua MODIS, downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). Data were processed using the Seadas to get the chlorophyll value and the Surfer 13 to get the distribution of chlorophyll-a in the form of images.

The chlorophyll-a image data chosen to be processed is a standard 8-day image with a 4 km resolution map of level 3, at night, from November 2017 to March 2018. Chlorophyll-a data was calculated using chlorophyll-a image data that has been adjusted with both atmospheric and geometrical corrections. Seadas produced the chlorophyll-a distribution data which was reprocessed using a computer device, then using the Surfer 13, which will produced the distribution data of chlorophyll-a in the JPEG image format.

The catch used includes the catch weight of *K. pelamis* analyzed by calculating the weight per fishing trip, so that fluctuations in the catch based on time (temporal) and fishing location (spatial) can be observed.

Multiple correlation analysis. The multiple correlations showed the direction and strength of the relationship between the studied variables. To be able to provide an interpretation of the correlation coefficients found, reference values are listed in Table 1 below (Sugiono 2007).

Table 1

Assessment of the correlation coefficient (Sugiono 2007)

Coefficient interval	*Relationship level*
0.00–0.199	Very low
0.20–0.399	Low
0.40–0.599	Moderate
0.60–0.799	Strong
0.80–1.00	Very strong

The double correlation formula for two variables is (Sugiono 2007):

$$R_{y.x_1x_2} = \sqrt{\frac{r^2_{yx1} + r^2_{yx2} - 2r_{yx1}r_{yx2}\ r_{x1x2}}{1-r^2_{x1\,x2}}}$$

Where:

$R_{y.x_1x_2}$ - correlation of the variables X_1 and X_2 with the variable Y;

ryx_1 - correlation between X_1 and Y;
ryx_2 - correlation between X_2 and Y;
rx_1x_2 - correlation between X_1 and X_2.

Multiple linear regression analysis. When the correlation coefficient is sufficiently high, a multiple linear regression was used to examine the variables relationship (Sugiono 2005), as follows:

$$Y = a + b_1X_1 + b_2X_2$$

Where:
X_1 - variable sea surface temperature;
X_2 - chlorophyll-a variable;
Y - the maximum quantity of certain fish species caught;
a, b_1, b_2 - constants.

Multiple linear statistical test. According to Hasan (2004), multiple linear regression statistical tests are used to test the significance of the relationship of more than two variables through the regression coefficient. The multiple linear regression statistical tests can be divided into two categories, namely:
1. Concurrent test
The test is carried out in multiple linear regression using the F test, a statistical test for the regression coefficient that together affects Y, namely:

$$F_o = \frac{R^2(n-k-1)}{k(1-R^2)}$$

Where:
n - number of fish caught;
k - number of independent variables;
R^2 – determination coefficient.

1. Individual test
Individual test, namely the regression statistic with only one regression coefficient affecting Y, using the t_{test}:

$$t_o = \frac{b_1 - B_i}{S_{b1}}$$

$$t_0 = \frac{b_1 - \beta_1}{S_{b1}}$$

Where:
b_1 ......
B_i ......
S_{bi} ......
b_1 = regression slope coefficient;
β_1 = hypothesized slope;
S_{b1} = standard deviation of slope.

When the regression formula involves only two independent variables, the values of S_{b1} and S_{b2} are as follows (....):

$$S_{b1} = \sqrt{\frac{S_e^2 \sum x_2^2}{(\sum x_1^2)(\sum x_2^2)-(\sum x_1x_2)^2}}$$

$$S_{b2} = \sqrt{\frac{S_e^2 \sum x_1^2}{(\sum x_1^2)(\sum x_2^2)-(\sum x_1x_2)^2}}$$

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~~$$S_e = \sqrt{\frac{\sum e_i^2}{n-3}} = \sqrt{\frac{\sum y^2 - b_1 \sum x_1 y - b_2 \sum x_2 y}{n-3}}$$~~

~~Where:~~
~~S_{bk} – standard error of estimator bk, k=1, 2;~~
~~e – confounding error (values of other variables not included in the equation).~~

Geographical information analysis. The Surfer 13 software was used to map the distribution of *chlorophyll-a* from November 2017 to March 2018, based on time (temporal) and fishing location (spatial), with the aim of producing information about the relationship of these variables.

Results and Discussion

This research was conducted from November 2017 to May 2018 by following a fishing operation using a purse seiner in the Banda Sea, Maluku Indonesia.

Figure 1. Purse seiner (original photo).

Fish catch results. The fishing operation was carried out in seven trips, with ~~T~~the total catch was 56,689 kg with an average of 12,558.17 kg per 34 time operation. The number of catches on the 2nd trip (6 time operations) was the largest, with a total catch of 11,954 kg (an average of 1,992.33 kg per operation) or 21.1% of the total catch. Meanwhile, the 3rd trip (2 operations) recorded the smallest total catch, namely 5,522 kg or 9.7% of the total catch, but with the highest average per operation, of 2,761 kg (Table 2).

Table 2

The number of fish catch per trip

Trip	*Number of operations*	*Amount (Kg)*	*Average (Kg)*	*Percentage (%)*
1st	4	8,226	2,056.5	14.5
2nd	6	11,954	1,992.33	21.1
3rd	2	5,522	2,761	9.7
4th	4	7,006	1,751.5	12.4
5th	6	9,607	1,601.16	17
6th	6	7,982	1,330.33	14.1
7th	6	6,392	1,065.33	11.2
Total	34	56,689	12,558.17	100

Catch composition. The catch data consists of seven trips with 34 operations. The main catches are *K. pelamis*, *T. albacares*, *E. affinis* and *D. ruselli*. Based on the results obtained, the highest *T. albacares* catches were on the 7th trip and the lowest was on the 5th trip. *K. pelamis* catches reached the highest value on the 2nd trip and the lowest on the 6th trip. The highest *T. albacares* catches were on the 2nd trip and the lowest was on the 7th trip, and the highest *D. ruselli* was on the 6th trip and the lowest was on the 3rd trip. The composition of the catch can be seen in Table 3 below.

Table 3

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Please calculate the average per trip and the average per setting and based on the total catch of 56,689 give the results.
The 12,558.17 value represents the total of the averages per trip and IT DOES NOT REPRESENT AN AVERAGE.

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The composition of the catch based on the type of fish

Trip to-	Total catch (Kg)				Total
	T. albacares	*K. pelamis*	*E. affinis*	*D. ruselli*	
1st	825	3,018	2,590	1,793	8,226
2nd	230	5,676	4,430	1,618	11,954
3rd	90	4,270	497	665	5,522
4th	569	2,948	1,817	1,672	7,006
5th	0	4,467	4,290	850	9,607
6th	13	2,536	670	4,763	7,982
7th	915	4,323	0	1,154	6,392

Based on the data mentioned above, the highest catch was on the second trip, and the lowest catch was on the 3rd trip. The highest catch of *T. albacares* was on the 7th trip, as much as 915 kg, while the lowest was on the 5th trip, with no catch. The highest catch of *K. pelamis* was on the 2nd trip, as much as 5,676 kg, while the lowest was on the 6th trip, with 2,536 kg. The highest *E. affinis* catch was on the 2nd trip, as much as 4,430 kg, and the lowest on the 7th trip, with no catch. The highest *D. ruselli* catch was on the 6th trip, as much as 4,763 kg, and the lowest was on the 3rd trip, with 665 kg. Based on all catches, *K. pelamis* was the most dominant fish caught compared to other fish (Figure 2).

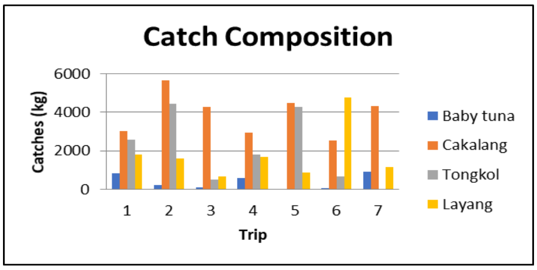


Figure 2. Composition diagram of the catch.

Average K. pelamis per operation. The catch of *K. pelamis* is higher than that of other types. The total catch of *K. pelamis* from the 1st trip to the 7th trip was 27,238 kg. The average highest catch per operation of *K. pelamis* was recorded on the 3rd trip, with 1,495 kg, while the lowest catch per operation was recorded on the 6th trip, with 422.67 kg. The catch of the 1st trip was 3,018 kg, the 2nd trip was 5,676 kg, the 3rd trip was 4,270 kg, the 4th trip was 2,948 kg, the 5th trip was 4,467 kg, the 6th trip was 2,536 kg, the 7th trip was 4,323 kg (Figure 3).

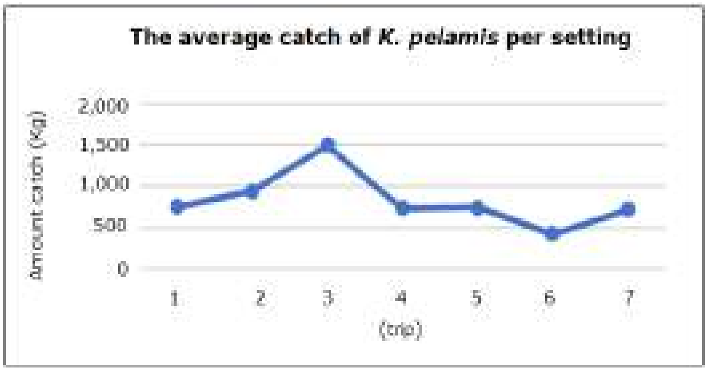
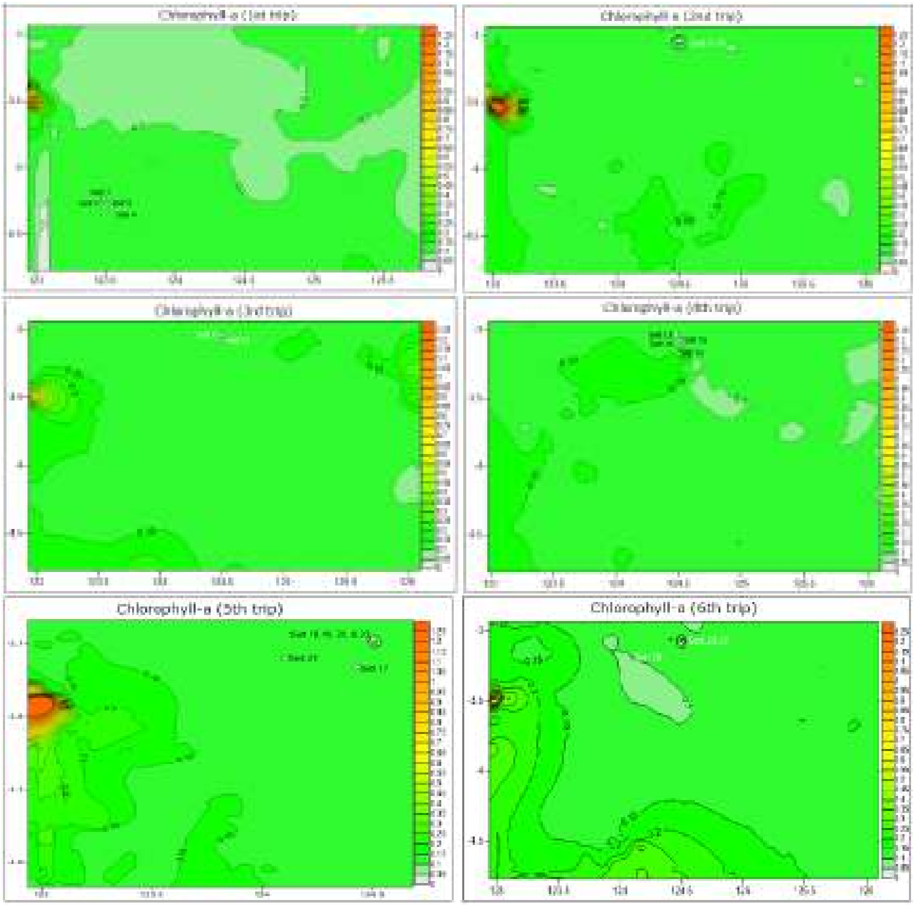


Figure 3. Diagram of the average catch of *Katsuwonus pelamis.*

Chlorophyll-a. Because fertile waters contain high chlorophyll-a concentrations, the chlorophyll-a is eligible as an indicator of fertility in waters. The chlorophyll-a concentration is also influenced by other factors such as currents. Chlorophyll-a image data were downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). The research data was processed using Seadas to produce chlorophyll-a data. Furthermore, the data was processed using Surfer 13 into JPEG format images that display the distribution of chlorophyll-a with different colors. The distribution of chlorophyll-a was taken based on the time and position of the capture operation. Figure 4 shows the chlorophyll-a distribution over the 7 fishing trips.



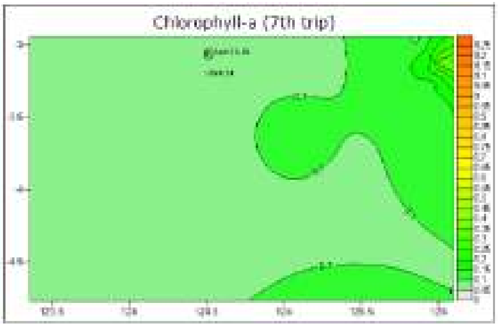


Figure 4. Distribution of chlorophyll-a over the 7 fishing trips.

chlorophyll-a concentration values can also be seen in table 4 below:

Table 4

Chlorophyll-a concentration values

Trips	Chlorophyll-a concentration value (mg m^{-3})						
	1[st] operation	2[nd] operation	3[rd] operation	4[th] operation	5[th] operation	6[th] operation	Average
Trip 1	0.1308[a]	0.1292	0.1273	0.1268[b]	-	-	0.1285
Trip 2	0.1176	0.1176	0.1173[b]	0.1266	0.1176	0.1266[a]	0.1205
Trip 3	0.1399[a]	0.1342[b]	-	-	-	-	0.1370
Trip 4	0.1046[b]	0.1080	0.1077	0.1632[a]	-	-	0.1209
Trip 5	0.1314	0.1312	0.1312	0.1314[a]	0.1313	0.1258[b]	0.1303
Trip 6	0.1208	0.1288[a]	0.1287	0.1227	0.1281	0.1001[b]	0.1215
Trip 7	0.0895	0.0903	0.0913[a]	0.0880	0.0875[b]	0.0894	0.0893

[a] the distribution of the highest chlorophyll-a concentrations; [b] the distribution of the lowest chlorophyll-a concentrations.

The chlorophyll-a concentration value on the 7th trip decreased significantly, compared to the other trips. The higher the chlorophyll-a concentration value in the waters, the more fertile the waters.

Average chlorophyll-a. The average chlorophyll-a can be seen in Figure 5, where the concentration of the 7th trip decreased, compared to the other trips. The average chlorophyll-a concentration was the highest on trip 3 and the lowest on trip 7. The difference between the highest and lowest concentrations is 0.0477 mg m^{-3}.

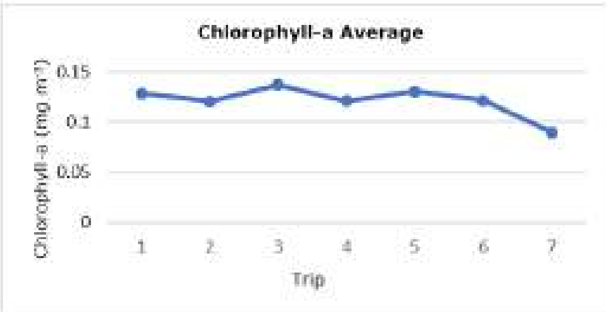


Figure 5. Diagram of average chlorophyll-a for 7 trips.

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The relationship between average chlorophyll-a against K. pelamis. The relationship of chlorophyll-a to the catch of *K. pelamis* was calculated using a multiple correlation test. The multiple correlation estimator for the level of chlorophyll-a relationship to *K. pelamis* catch was determined by using SPSS 25.

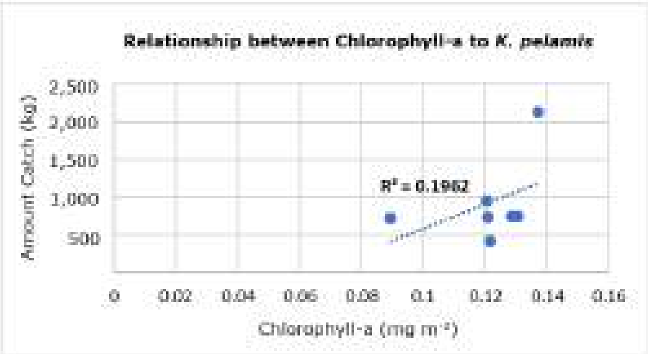

Figure 6. Graph of chlorophyll-a relationship to *Katsuwonus pelamis.*

Based on Figure 6 above, the coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents.

The value of the correlation coefficient using SPSS 25 can be seen in table 4. The correlation coefficient value was obtained at 0.443, which means that the positive relationship between chlorophyll-a and the catch of *K. pelamis* is moderate, because the correlation coefficient value is in the correlation interval 0.40-0.599. This relationship is positive: if the value of one variable is increased, it will increase the value of the other variables and vice versa (Sugiono 2007), while if the chlorophyll-a decreases, it will decrease the catch of *K. pelamis*.

Hypothesis testing via the t test is used to determine whether the hypothesis is accepted or rejected, based on the coefficients table (Table 7). Based on this table, the t_{count} value of chlorophyll-a is 3,320, $t_{count} > t_{table}$ (3,320>2.77, respectively) and the sig value of 0.029 (<0.05), therefore the null hypothesis is rejected, due to the significant effect of chlorophyll-a on the catch of *K. pelamis*, in accordance with a previous research conducted by Demena et al (2017), which states that chlorophyll-a and the number of catches *K. pelamis* have a unidirectional relationship and the chlorophyll-a concentration affects the presence of *K. pelamis*.

The effect of chlorophyll-a on the catch of K. pelamis. Chlorophyll-a is an indicator that greatly influences the presence of fish in the waters, especially *K. pelamis*, a migratory species. The effect of chlorophyll-a on the catch of K. pelamis is calculated using the multiple linear regression, with the SPSS 25, and manual calculations were performed using a computer device.

Table 5

Model summary

Model	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*
1	.882[a]	.779	.668	320.54745

[a]Predictors: (Constant), Chlorophyll-a.

Based on the results obtained in table 5 above the coefficient of determination (R^2)=0.779 or 77.9%. This shows an influence of 77.9% of the chlorophyll-a on the catch of *K. pelamis*, so that the remaining 22.1% are influenced by other factors such as currents and salinity. The correlation coefficient (R) in the model summary table above is 0.882. Based on table 5, the relationship level, given by the correlation coefficient (R), is included in the interval at 0.80-1.00, which means that the level of chlorophyll-a relationship to the catch of *K. pelamis* is very strong.

Table 6

ANOVA regression table

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	1,444,657.089	2	722,328.544	7.030	.049[b]
	Residual	411,002.672	4	102,750.668		
	Total	1,855,659.760	6			

[a] Dependent Variable: *K. pelamis*; [b] Predictors: (Constant), Chlorophyll-a, Sea Surface Temperature (SST).

A F_{test} was conducted to check the influence of chlorophyll-a together with the SST (independent variables) on the catch of *K. pelamis* (dependent variable), demonstrating a significant effect (in the ANOVA regression table, the significance level is 0.049<0.05 or $F_o \geq F_{table}$). A previous research, conducted by Demena et al (2017), stated that sea surface temperature and chlorophyll-a are two predictors of the presence of fish in the waters, especially concerning *K. pelamis*.

Based on the output of SPSS 25 (the coefficients matrix), the multiple linear regression equation could be expressed as follows:

$$Y = -21,557.333 + 642.160 X_1 + 33,535.607 X_2$$

The multiple linear regression equation above can be interpreted as follows:

- if the variables X_1 (SST) and X_2 (chlorophyll-a) have a value of 0, then the variable Y is -21,557.33 kg (intercept).
- if the variable X_1 (SST) increases by 1ºC and the other variables are constant, then the variable Y will increase by 642,160 kg.
- if the X_2 variable (chlorophyll-a) increases by 1 mg m^{-3} and the other variables are constant, then the Y variable will increase by 33,535,607 kg.

Distribution of chlorophyll-a with K. pelamis catch.

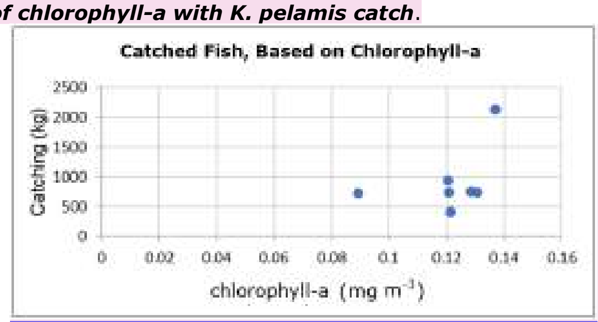

Figure 7. Catch based on chlorophyll-a.

In the figure above, the highest catch occurs at a concentration of 0.137 mg m^{-3}. The graph of the relationship between chlorophyll-a and the catch of *K. pelamis*, shows that the concentration of chlorophyll-a and the catch of *K. pelamis* have a unidirectional relationship. ~~The results showed that the *K. pelamis* maximum fishing potential occurs for an optimal chlorophyll-a concentration of 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a chlorophyll-a in the optimal range of 0.12-0.22 mg m^{-3}.~~

Conclusions.

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The results showed that the *K. pelamis* maximum fishing potential occurs for an optimal chlorophyll-a concentration of 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a chlorophyll-a in the optimal range of 0.12-0.22 mg m^{-3}.

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(*K. pelamis*)

Based on the results and discussion that has been described, it can be concluded as follows:

1. The value of the coefficient of determination (R_2) is 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%. Based on the t test, the SST value was 3.243, the sig value was 0.032. For a value of 2.77. Based on the results obtained the value > and sig value 0.032 <0.05. So, if H_o is accepted and rejected, then there is a significant effect between SST and *K. pelamis* catch.
2. The coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the real model of 19.6%, so the rest is explained by other factors of 80.4%. Based on the t_{test}, the t_{count} value of chlorophyll-a was 3,320, the sig value was 0.029. A significant effect between chlorophyll-a and *K. pelamis* was demonstrated For the t_{table} value of 2.77. Based on the results, the value of t_{count} > t_{table} and sig value is 0.029 <0.05. *So that obtained H_o is accepted and rejected, then there is a significant effect between SST and skipjack catch.*

The results obtained in the ANOVA table, the value of R^2 = 0.779 or 77.9% is the effect of chlorophyll on *K. pelamis,* so that the remaining 22.1% is another factor. Based on the calculation of the F_{test} using SPSS 25 and manually, the value of F_o = 7.030 and the value of F_{table} = 6.94 is obtained. The results obtained in the ANOVA table sign value 0.049 <0.05 So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or $F_o \geq F_{table}$, so there is a significant effect of chlorophyll-a on *K. pelamis*..

Conflict of interest. The authors declare no conflict of interest.

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Min, 12 Des 2021 jam 20.22

dear Dr. Eni,

I send you correcting manuscript. thank you.

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The effect of chlorophyll-a on the catches of skipjack tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

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Abstract. The Banda Sea is located in the waters of Central Maluku Regency, Maluku Province. The topography of the seabed is very complex with a basin in the west and a trough in the east. The shape of the topography is also decisive in controlling the exchange of water masses. The purpose of this study was to analyze the relationship of chlorophyll-a and the effect of its distribution on the catch of skipjack tuna (Katsuwonus pelamis). This study uses the data analysis method used, namely multiple linear regression, because it uses two independent variables, namely chlorophyll-a. Primary data was taken by following fishing operations and secondary data was obtained from chlorophyll-a images downloaded from the NASA database in the form of an average per trip. The results of the study showed that 1) the value of the coefficient of determination (R2) was 0.196 or 19.6% or 80.4%, the rest was influenced by other factors. The results of the t-test obtained t count chlorophyll-a value of 3.320, sig value of 0.029 and t table value of 2.77. based on the value of t count > t table and the value of sig 0.029 <0.05, there was a significant effect between chlorophyll-a and K. pelamis. 2) the ANOVA table shows the value of R^2 = 0.779 or 77.9% the effect of chlorophyll on K. pelamis, so the remaining 22.1% is influenced by other factors. Based on the results obtained in the ANOVA table, it has a sig value of 0.049 <0.05, which means H_0 is rejected and H1 is accepted, so chlorophyll-a has a significant effect on K. pelamis.

The Banda Sea owes its abundance to a high nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea. The potential area for catching skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ranges from 0.12 to 0.22 mg m^{-3}. Based on the results of the study, it is known that (1) the value of the coefficient of determination (R_2) is 0.196 or 19.6%. it means that the chlorophyll-a factor can only explain the real model by 19.6% so that the rest is provided by other factors of 80.4%. Based on the t_{test}, the t_{count} value of chlorophyll-a is 3.320, the sig value is 0.029. For the t_{table} value of 2.77. the results are based on the value of t_{count} > t_{table} and the value of sig 0.029 < 0.05. So that the H_o obtained is rejected and H_1 is accepted, then there is a significant effect between chlorophyll-a and *K. pelamis*. (2) in the ANOVA table the value of R^2 = 0.779 or 77.9% the effect of chlorophyll on *K. pelamis*, so the remaining 22.1% is another factor. Based on the calculation of F with SPSS 25 and manually obtained the value of F_o = 7.030 and the value of F_{table} = 6.94. The results obtained in the ANOVA table have a sig value of 0.049 <0.05. So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or F_0 F_{table}, so there is a significant effect of chlorophyll-a on *K. pelamis*.

Potential areas for catching *Katsuwonus pelamis* have a close relationship with environmental parameters, especially chlorophyll-a. Remote sensing methods are used to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions. On this purpose, the multiple linear regression method was used to analyze their relationship. Based on the results of the study, it is known that (1) the value of the coefficient of determination (R_2) is 0.196 or 19.6%. it means that the chlorophyll-a factor can only explain the real model by 19.6% so that the rest is provided by other factors of 80.4%. Based on the t_{test}, the t_{count} value of chlorophyll-a is 3.320, the sig value is 0.029. For the t_{table} value of 2.77. the results are based on the value of t_{count} > t_{table} and the value of sig 0.029 < 0.05. So that the H_o obtained is rejected and H_1 is accepted, then there is a significant effect between chlorophyll-a and *K. pelamis*. (2) in the ANOVA table the value of R^2 = 0.779 or 77.9% the effect of chlorophyll on *K. pelamis*, so the remaining 22.1% is another factor. Based on the calculation of F with SPSS 25 and manually obtained the value of F_o = 7.030 and the value of F_{table} = 6.94.

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Key Words: purse seine, remote sensing, sea surface temperature (SST), catch season.

Introduction. The Banda Sea owes its abundance to a high nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea (Putra et al 2017). The topography of the seabed is very complex, with a basin in the west and a trough in the east (Suyarso 1999; Tapilatu 2016). This complex topographical shape also determines the mass exchange of water. The circulation of different water massesvaries between seasons and is influenced by the monsoon system's wind pattern.

The circulation of water mass in Indonesian waters differs between the west monsoon and the east monsoon. In the west monsoon, water masses generally flow to the east of Indonesian waters. The eastern monsoons develop perfectly, supplying water masses originating from the upwelling areas in the Arafura and Banda Seas (Hasanudin 1998). The upwelling process that occurs in the Banda Sea results in a decrease of temperatures, an increase of salinity and the removal of nutrients, so that their availability will affect the abundance of plankton in the waters (Baars et al 1990; Armus et al 2019).

The potential area for catching skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ranges from 0.12 to 0.22 mg m^{-3} (Zainuddin 2011; Hidayat et al 2019; Wangi et al 2019). Almost all fish populations that live in marine waters, including *K. pelamis*, require optimal sea surface temperature (SST) range and chlorophyll-a values for their survival (Jufri et al 2014). Remote sensing technology helps observing the oceanographic parameters of the surrounding waters in the Banda Sea, so that it can determine the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea.

K. pelamis likes areas where there is a convergence of currents that mostly occur in areas with many islands. The vertical distribution of *K. pelamis* starts from the surface to a depth of 260 m during the day, while at night it will go to the surface (diurnal migration) (Ekayana et al 2017). *K. pelamis* specimens from the small size category tend to be caught at a more homogeneous (warm) SST, while large *K. pelamis* are caught in a wider range of SST (cold and warm) (Simbolon & Limbong 2012). *K. pelamis* congregate at low chlorophyll-a concentrations and water depths of ≥ 500 m, because *K. pelamis* is a carnivorous fish with the main prey of small pelagic fish such as *Stelophorus sp.* and *Sardinella sp*., which are abundant in the contineta shelf and sloping waters (Bubun et al 2015).

Remote sensing technology is an alternative method that is very beneficial if it is used in a country with a very large area such as Indonesia (Syah 2010). Remote sensing is a technique for collecting information about objects and their environment from a distance without physical touch (Lo 1986). The use of remote sensing methods to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions is a very appropriate alternative (Tangke 2016; Mashita & Lumban-Gaol 2019). Remote sensing technology has several advantages including cheap and easily accessible data prices, wide area coverage, high temporal resolution and digitalized data supply, making it a potential source for the geographic information system (GIS) data (Louhenapessy & Waas 2009).

One of the sensing satellites equipped with sensors that can detect the chlorophyll-a content is the Aqua MODIS satellite (Utari 2013). The variables measured by the Aqua satellite include the aerosols, land-covering plants, phytoplankton and dissolved organic matter in the oceans, as well as the air, land and water temperature (Putra et al 2012). The Aqua MODIS satellite has a polar sun-synchronous orbit. The satellite crosses the equator at noon, approaching at 13.30 local time (Karif 2011).

Changes in fishing actually occur when the seasons' change. Seasonal changes directly affect the oceanographic aspects of the waters, especially sea surface temperature and chlorophyll-a, which greatly influence the presence of fish in an area, determining the fishing grounds in that area. Both of these parameters can trigger natural events or phenomena such as upwelling and fronts (Waileruny & Wiyono 2014). The fishing season in Southeast Sulawesi waters can be found in January to April and from July to September, and it can affect the salinity of the habitat of the caught fish species. In the eastern monsoon (June to September), high salinity water masses originating from the Flores Sea and Pacific Ocean flow through the Makassar Strait to the Java Sea. In the western season (December to March) surface currents move from the South China Sea into the Java Sea from west to east (Bubun & Mahmud 2016). The purpose of this study was to analyze the relationship and effect of chlorophyll-a on the catch of *K. pelamis* (Mugo et al 2010).

This research aims to analyzed how much influence chlorophyll-a had on the number of skipjack tuna (*Katsuwonus pelamis*), knowing distribution of chlorophyll-a concentrations in the Banda Sea, Maluku. So that fishermen can be more effective again in determining the area and time of catch.

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Material and Method. The tools and materials needed in the implementation of this research include: stationery, cameras, rulers, GPS, MODIS data and the softwares SeaDas, SPSS Statistics 25 and Surfer 13.0.

Method of collecting data. The data collection method uses primary data, carried out *in situ* by direct observation of the fishing operation including operating time, the number of catches and the position of the fishing area, and by using secondary data including the image of the distribution of chlorophyll-a, from the level 3 of the Aqua MODIS, downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). Data were processed using the Seadas to get the chlorophyll value and the Surfer 13 to get the distribution of chlorophyll-a in the form of images.

The chlorophyll-a image data chosen to be processed is a standard 8-day image with a 4 km resolution map of level 3, at night, from November 2017 to March 2018. Chlorophyll-a data was calculated using chlorophyll-a image data that has been adjusted with both atmospheric and geometrical corrections. Seadas produced the chlorophyll-a distribution data which was reprocessed using a computer device, then using the Surfer 13, which will produced the distribution data of chlorophyll-a in the JPEG image format.

The catch used includes the catch weight of *K. pelamis* analyzed by calculating the weight per fishing trip, so that fluctuations in the catch based on time (temporal) and fishing location (spatial) can be observed.

Multiple correlation analysis. The multiple correlations showed the direction and strength of the relationship between the studied variables. To be able to provide an interpretation of the correlation coefficients found, reference values are listed in Table 1 below (Sugiono 2007).

Table 1

Assessment of the correlation coefficient (Sugiono 2007)

Coefficient interval	*Relationship level*
0.00–0.199	Very low
0.20–0.399	Low
0.40–0.599	Moderate
0.60–0.799	Strong
0.80–1.00	Very strong

The double correlation formula for two variables is (Sugiono 2007):

$$R_{y.x_1x_2} = \sqrt{\frac{r^2_{yx1} + r^2_{yx2} - 2r_{yx1}r_{yx2}\,r_{x1x2}}{1 - r^2_{x1\,x2}}}$$

Where:

$R_{y.x_1x_2}$ - correlation of the variables X_1 and X_2 with the variable Y;

ryx_1 - correlation between X_1 and Y;
ryx_2 - correlation between X_2 and Y;
rx_1x_2 - correlation between X_1 and X_2.

Multiple linear regression analysis. When the correlation coefficient is sufficiently high, a multiple linear regression was used to examine the variables relationship (Sugiono 2005), as follows:

$$Y = a + b_1X_1 + b_2X_2$$

Where:
X_1 - variable sea surface temperature;
X_2 - chlorophyll-a variable;
Y - the maximum quantity of certain fish species caught;
a, b_1, b_2 - constants.

Multiple linear statistical test. According to Hasan (2004), multiple linear regression statistical tests are used to test the significance of the relationship of more than two variables through the regression coefficient. The multiple linear regression statistical tests can be divided into two categories, namely:
1. Concurrent test
The test is carried out in multiple linear regression using the F test, a statistical test for the regression coefficient that together affects Y, namely:

$$F_o = \frac{R^2(n-k-1)}{k(1-R^2)}$$

Where:
n - number of fish caught;
k - number of independent variables;
R^2 – determination coefficient.

1. Individual test
Individual test, namely the regression statistic with only one regression coefficient affecting Y, using the t_{test}:

$$t_o = \frac{b_1 - B_i}{S_{b1}}$$

$$t_0 = \frac{b_1 - \beta_1}{S_{b1}}$$

Where:
b_1 ......
B_i ......
S_{bi} ......
b_1 = regression slope coefficient;
β_1 = hypothesized slope;
S_{b1} = standard deviation of slope.

When the regression formula involves only two independent variables, the values of S_{b1} and S_{b2} are as follows (....):

$$S_{b1} = \sqrt{S_e^2 \frac{\sum x_2^2}{(\sum x_1^2)(\sum x_2^2)-(\sum x_1x_2)^2}}$$

$$S_{b2} = \sqrt{S_e^2 \frac{\sum x_1^2}{(\sum x_1^2)(\sum x_2^2)-(\sum x_1x_2)^2}}$$

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$$S_e = \sqrt{\frac{\sum e_i^2}{n-3}} = \sqrt{\frac{\sum y^2 - b_1 \sum x_1 y - b_2 \sum x_2 y}{n-3}}$$

Where:
S_{bk} – standard error of estimator bk, k=1, 2;
e – confounding error (values of other variables not included in the equation).

Geographical information analysis. The Surfer 13 software was used to map the distribution of *chlorophyll-a* from November 2017 to March 2018, based on time (temporal) and fishing location (spatial), with the aim of producing information about the relationship of these variables.

Results and Discussion

This research was conducted from November 2017 to May 2018 by following a fishing operation using a purse seiner in the Banda Sea, Maluku Indonesia.

Figure 1. Purse seiner (original photo).

Fish catch results. The fishing operation was carried out in seven trips, with Tthe total catch was 56,689 kg with an average of 12,558.17 kg per 34 time operation. The number of catches on the 2nd trip (6 time operations) was the largest, with a total catch of 11,954 kg (an average of 1,992.33 kg per operation) or 21.1% of the total catch. Meanwhile, the 3rd trip (2 operations) recorded the smallest total catch, namely 5,522 kg or 9.7% of the total catch, but with the highest average per operation, of 2,761 kg (Table 2).

Table 2

The number of fish catch per trip

Trip	*Number of operations*	*Amount (Kg)*	*Average (Kg)*	*Percentage (%)*
1st	4	8,226	2,056.5	14.5
2nd	6	11,954	1,992.33	21.1
3rd	2	5,522	2,761	9.7
4th	4	7,006	1,751.5	12.4
5th	6	9,607	1,601.16	17
6th	6	7,982	1,330.33	14.1
7th	6	6,392	1,065.33	11.2
Total	34	56,689	12,558.17	100

Catch composition. The catch data consists of seven trips with 34 operations. The main catches are *K. pelamis*, *T. albacares*, *E. affinis* and *D. ruselli*. Based on the results obtained, the highest *T. albacares* catches were on the 7th trip and the lowest was on the 5th trip. *K. pelamis* catches reached the highest value on the 2nd trip and the lowest on the 6th trip. The highest *T. albacares* catches were on the 2nd trip and the lowest was on the 7th trip, and the highest *D. ruselli* was on the 6th trip and the lowest was on the 3rd trip. The composition of the catch can be seen in Table 3 below.

Table 3

Commented [A1]: Elementary mistake: this is the sum of the averages (total per trip per number of operations); it has no signification; the authors either calculate the average of the averages or the overall total per total number or operations

Commented [WU2]: Please clarify if 12,558.17 kg represents an average/trip or an average per setting?
Please calculate the average per trip and the average per setting and based on the total catch of 56,689 give the results.
The 12,558.17 value represents the total of the averages per trip and IT DOES NOT REPRESENT AN AVERAGE.

Commented [A3R2]: Corrected.

The composition of the catch based on the type of fish

Trip to-	Total catch (Kg)				Total
	T. albacares	*K. pelamis*	*E. affinis*	*D. ruselli*	
1st	825	3,018	2,590	1,793	8,226
2nd	230	5,676	4,430	1,618	11,954
3rd	90	4,270	497	665	5,522
4th	569	2,948	1,817	1,672	7,006
5th	0	4,467	4,290	850	9,607
6th	13	2,536	670	4,763	7,982
7th	915	4,323	0	1,154	6,392

Based on the data mentioned above, the highest catch was on the second trip, and the lowest catch was on the 3rd trip. The highest catch of *T. albacares* was on the 7th trip, as much as 915 kg, while the lowest was on the 5th trip, with no catch. The highest catch of *K. pelamis* was on the 2nd trip, as much as 5,676 kg, while the lowest was on the 6th trip, with 2,536 kg. The highest *E. affinis* catch was on the 2nd trip, as much as 4,430 kg, and the lowest on the 7th trip, with no catch. The highest *D. ruselli* catch was on the 6th trip, as much as 4,763 kg, and the lowest was on the 3rd trip, with 665 kg. Based on all catches, *K. pelamis* was the most dominant fish caught compared to other fish (Figure 2).

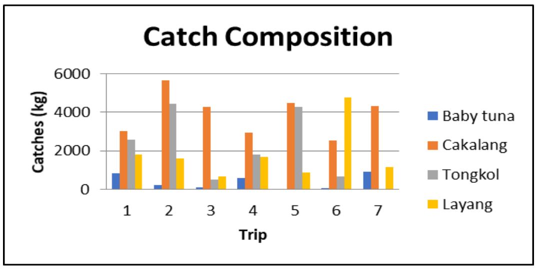


Figure 2. Composition diagram of the catch.

Average K. pelamis per operation. The catch of *K. pelamis* is higher than that of other types. The total catch of *K. pelamis* from the 1st trip to the 7th trip was 27,238 kg. The average highest catch per operation of *K. pelamis* was recorded on the 3rd trip, with 1,495 kg, while the lowest catch per operation was recorded on the 6th trip, with 422.67 kg. The catch of the 1st trip was 3,018 kg, the 2nd trip was 5,676 kg, the 3rd trip was 4,270 kg, the 4th trip was 2,948 kg, the 5th trip was 4,467 kg, the 6th trip was 2,536 kg, the 7th trip was 4,323 kg (Figure 3).

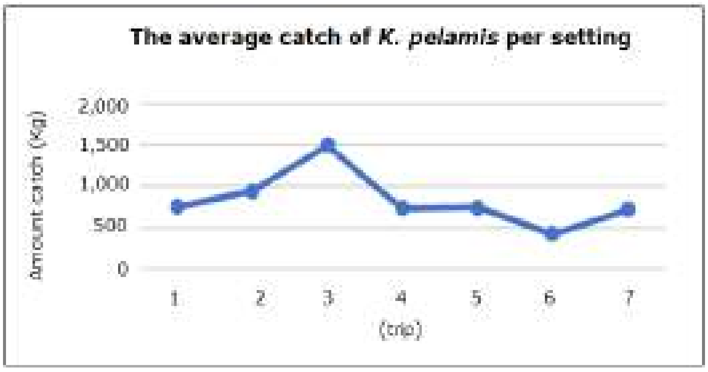
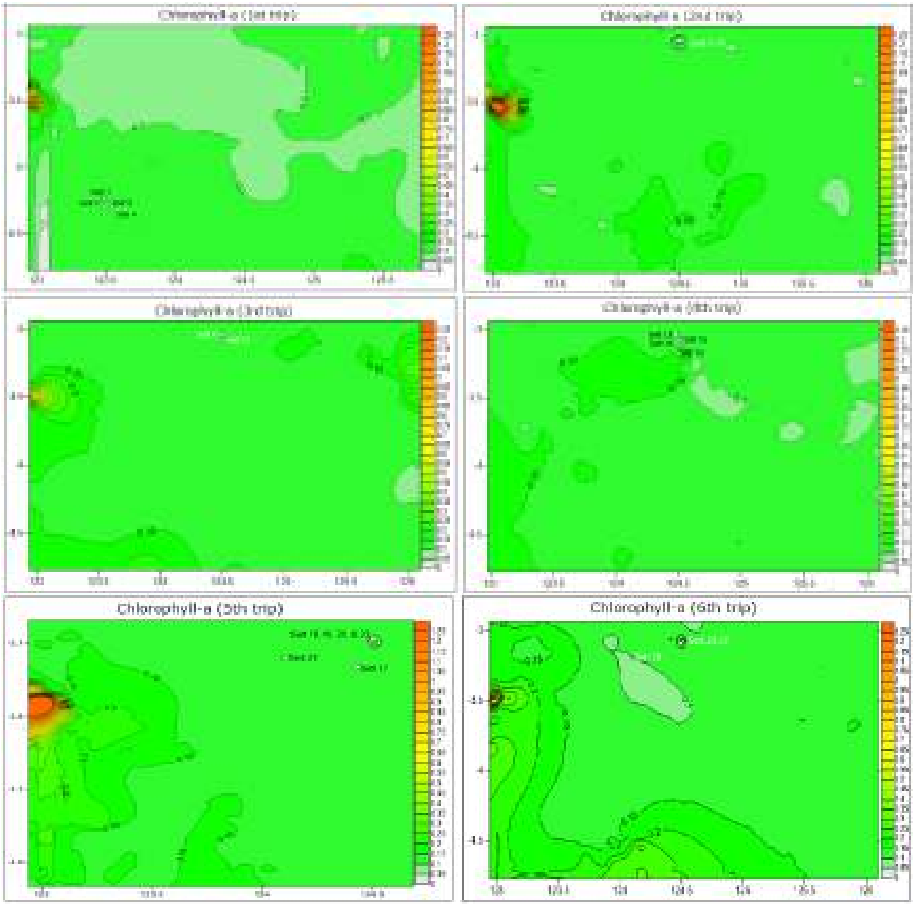


Figure 3. Diagram of the average catch of *Katsuwonus pelamis.*

Chlorophyll-a. Because fertile waters contain high chlorophyll-a concentrations, the chlorophyll-a is eligible as an indicator of fertility in waters. The chlorophyll-a concentration is also influenced by other factors such as currents. Chlorophyll-a image data were downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). The research data was processed using Seadas to produce chlorophyll-a data. Furthermore, the data was processed using Surfer 13 into JPEG format images that display the distribution of chlorophyll-a with different colors. The distribution of chlorophyll-a was taken based on the time and position of the capture operation. Figure 4 shows the chlorophyll-a distribution over the 7 fishing trips.



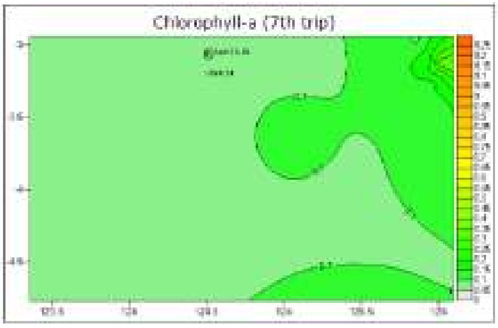


Figure 4. Distribution of chlorophyll-a over the 7 fishing trips.

chlorophyll-a concentration values can also be seen in table 4 below:

Table 4

Chlorophyll-a concentration values

Trips	*Chlorophyll-a concentration value (mg m^{-3})*						
	1st operation	*2nd operation*	*3rd operation*	*4th operation*	*5th operation*	*6th operation*	*Average*
Trip 1	0.1308[a]	0.1292	0.1273	0.1268[b]	-	-	0.1285
Trip 2	0.1176	0.1176	0.1173[b]	0.1266	0.1176	0.1266[a]	0.1205
Trip 3	0.1399[a]	0.1342[b]	-	-	-	-	0.1370
Trip 4	0.1046[b]	0.1080	0.1077	0.1632[a]	-	-	0.1209
Trip 5	0.1314	0.1312	0.1312	0.1314[a]	0.1313	0.1258[b]	0.1303
Trip 6	0.1208	0.1288[a]	0.1287	0.1227	0.1281	0.1001[b]	0.1215
Trip 7	0.0895	0.0903	0.0913[a]	0.0880	0.0875[b]	0.0894	0.0893

[a] the distribution of the highest chlorophyll-a concentrations; [b] the distribution of the lowest chlorophyll-a concentrations.

The chlorophyll-a concentration value on the 7th trip decreased significantly, compared to the other trips. The higher the chlorophyll-a concentration value in the waters, the more fertile the waters.

Average chlorophyll-a. The average chlorophyll-a can be seen in Figure 5, where the concentration of the 7th trip decreased, compared to the other trips. The average chlorophyll-a concentration was the highest on trip 3 and the lowest on trip 7. The difference between the highest and lowest concentrations is 0.0477 mg m^{-3}.

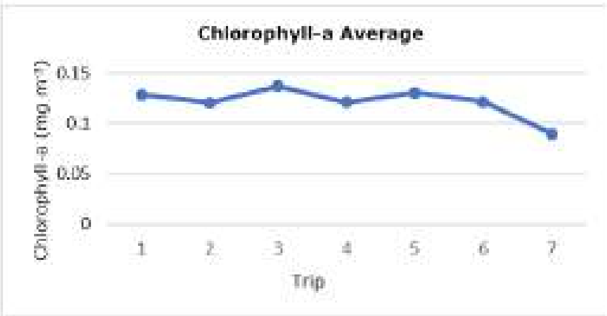


Figure 5. Diagram of average chlorophyll-a for 7 trips.

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The relationship between average chlorophyll-a against K. pelamis. The relationship of chlorophyll-a to the catch of *K. pelamis* was calculated using a multiple correlation test. The multiple correlation estimator for the level of chlorophyll-a relationship to *K. pelamis* catch was determined by using SPSS 25.

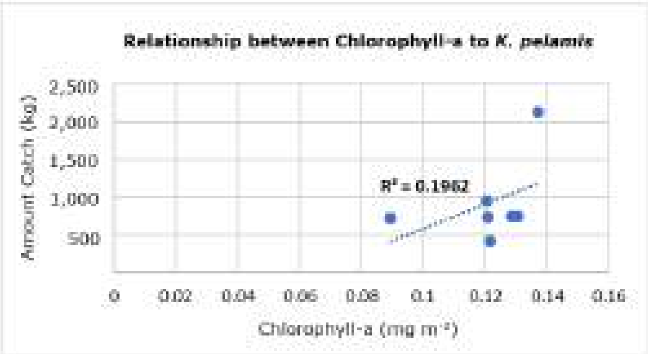

Figure 6. Graph of chlorophyll-a relationship to *Katsuwonus pelamis.*

Based on Figure 6 above, the coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents.

The value of the correlation coefficient using SPSS 25 can be seen in table 4. The correlation coefficient value was obtained at 0.443, which means that the positive relationship between chlorophyll-a and the catch of *K. pelamis* is moderate, because the correlation coefficient value is in the correlation interval 0.40-0.599. This relationship is positive: if the value of one variable is increased, it will increase the value of the other variables and vice versa (Sugiono 2007), while if the chlorophyll-a decreases, it will decrease the catch of *K. pelamis*.

Hypothesis testing via the t test is used to determine whether the hypothesis is accepted or rejected, based on the coefficients table (Table 7). Based on this table, the t_{count} value of chlorophyll-a is 3,320, $t_{count} > t_{table}$ (3,320>2.77, respectively) and the sig value of 0.029 (<0.05), therefore the null hypothesis is rejected, due to the significant effect of chlorophyll-a on the catch of *K. pelamis*, in accordance with a previous research conducted by Demena et al (2017), which states that chlorophyll-a and the number of catches *K. pelamis* have a unidirectional relationship and the chlorophyll-a concentration affects the presence of *K. pelamis*.

The effect of chlorophyll-a on the catch of K. pelamis. Chlorophyll-a is an indicator that greatly influences the presence of fish in the waters, especially *K. pelamis*, a migratory species. The effect of chlorophyll-a on the catch of K. pelamis is calculated using the multiple linear regression, with the SPSS 25, and manual calculations were performed using a computer device.

Table 5

Model summary

Model	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*
1	.882[a]	.779	.668	320.54745

[a]Predictors: (Constant), Chlorophyll-a.

Based on the results obtained in table 5 above the coefficient of determination (R^2)=0.779 or 77.9%. This shows an influence of 77.9% of the chlorophyll-a on the catch of *K. pelamis*, so that the remaining 22.1% are influenced by other factors such as currents and salinity. The correlation coefficient (R) in the model summary table above is 0.882. Based on table 5, the relationship level, given by the correlation coefficient (R), is included in the interval at 0.80-1.00, which means that the level of chlorophyll-a relationship to the catch of *K. pelamis* is very strong.

Table 6

ANOVA regression table

Model		*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*
1	Regression	1,444,657.089	2	722,328.544	7.030	.049[b]
	Residual	411,002.672	4	102,750.668		
	Total	1,855,659.760	6			

[a] Dependent Variable: *K. pelamis*; [b] Predictors: (Constant), Chlorophyll-a, Sea Surface Temperature (SST).

A F_{test} was conducted to check the influence of chlorophyll-a together with the SST (independent variables) on the catch of *K. pelamis* (dependent variable), demonstrating a significant effect (in the ANOVA regression table, the significance level is 0.049<0.05 or $F_o \geq F_{table}$). A previous research, conducted by Demena et al (2017), stated that sea surface temperature and chlorophyll-a are two predictors of the presence of fish in the waters, especially concerning *K. pelamis*.

Based on the output of SPSS 25 (the coefficients matrix), the multiple linear regression equation could be expressed as follows:

$$Y = -21,557.333 + 642.160\ X_1 + 33,535.607\ X_2$$

The multiple linear regression equation above can be interpreted as follows:

- if the variables X_1 (SST) and X_2 (chlorophyll-a) have a value of 0, then the variable Y is -21,557.33 kg (intercept).
- if the variable X_1 (SST) increases by 1ºC and the other variables are constant, then the variable Y will increase by 642,160 kg.
- if the X_2 variable (chlorophyll-a) increases by 1 mg m^{-3} and the other variables are constant, then the Y variable will increase by 33,535,607 kg.

Distribution of chlorophyll-a with K. pelamis catch.

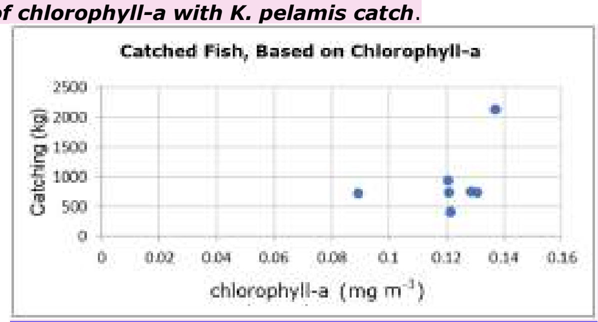

Figure 7. Catch based on chlorophyll-a.

In the figure above, the highest catch occurs at a concentration of 0.137 mg m^{-3}. The graph of the relationship between chlorophyll-a and the catch of *K. pelamis*, shows that the concentration of chlorophyll-a and the catch of *K. pelamis* have a unidirectional relationship. ~~The results showed that the *K. pelamis* maximum fishing potential occurs for an optimal chlorophyll-a concentration of 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a chlorophyll-a in the optimal range of 0.12-0.22 mg m^{-3}.~~

Conclusions.

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The results showed that the *K. pelamis* maximum fishing potential occurs for an optimal chlorophyll-a concentration of 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a chlorophyll-a in the optimal range of 0.12-0.22 mg m^{-3}.

(*K. pelamis*)

Based on the results and discussion that has been described, it can be concluded as follows:

1. The value of the coefficient of determination (R_2) is 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%. Based on the t test, the SST value was 3.243, the sig value was 0.032. For a value of 2.77. Based on the results obtained the value > and sig value 0.032 <0.05. So, if H_o is accepted and rejected, then there is a significant effect between SST and *K. pelamis* catch.
2. The coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the real model of 19.6%, so the rest is explained by other factors of 80.4%. Based on the t_{test}, the t_{count} value of chlorophyll-a was 3,320, the sig value was 0.029. A significant effect between chlorophyll-a and *K. pelamis* was demonstrated For the t_{table} value of 2.77. Based on the results, the value of t_{count} > t_{table} and sig value is 0.029 <0.05. *So that obtained H_o is accepted and rejected, then there is a significant effect between SST and skipjack catch.*

The results obtained in the ANOVA table, the value of R^2 = 0.779 or 77.9% is the effect of chlorophyll on *K. pelamis,* so that the remaining 22.1% is another factor. Based on the calculation of the F_{test} using SPSS 25 and manually, the value of F_o = 7.030 and the value of F_{table} = 6.94 is obtained. The results obtained in the ANOVA table sign value 0.049 <0.05 So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or $F_o \geq F_{table}$, so there is a significant effect of chlorophyll-a on *K. pelamis*..

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Conflict of interest. The authors declare no conflict of interest.

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Eni Kovacs <ek.bioflux@gmail.com>
Kepada: Adnal Yeka

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Please send us the revised manuscript as soon as possible.

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The effect of chlorophyll-a on the catches of skipjack tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

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Abstract. Potential areas for catching *Katsuwonus pelamis* have a close relationship with environmental parameters, especially chlorophyll-a. Remote sensing methods are used to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions. On this purpose, the multiple linear regression method was used to analyze their relationship. Based on the results of the study, it is known that (1) the value of the coefficient of determination (R_2) is 0.196 or 19.6%. it means that the chlorophyll-a factor can only explain the real model by 19.6% so that the rest is provided by other factors of 80.4%. Based on the t_{-test}, the $t_{\_count}$ value of chlorophyll-a is 3.320, the sig value is 0.029. For the $t_{\_table}$ value of 2.77. the results are based on the value of $t_{\_count}$ > $t_{\_table}$ and the value of sig 0.029 < 0.05. So that the H_o obtained is rejected and $H_{\_1}$ is accepted, then there is a significant effect between chlorophyll-a and *K. pelamis*. (2) in the ANOVA table the value of R^2 = 0.779 or 77.9% the effect of chlorophyll on *K. pelamis*, so the remaining 22.1% is another factor. Based on the calculation of F with SPSS 25 and manually obtained the value of F_o = 7.030 and the value of $F_{\_table}$ = 6.94.
The results obtained in the ANOVA table have a sig value of 0.049 <0.05. So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or F_0 F_{table}, so there is a significant effect of chlorophyll-a on *K. pelamis*.
Key Words: purse seine, remote sensing, sea surface temperature (SST), catch season.

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Please summarize the major aspects of you paper in a sequence that includes:
1) A short introductory phase of the research – the context
2) the overall purpose of the study
3) the methodology used in the study
4) your main findings, results of your analysis
5) the significance of your study

Introduction. The Banda Sea owes its abundance to a high nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea (Putra et al 2017). The topography of the seabed is very complex, with a basin in the west and a trough in the east (Suyarso 1999; Tapilatu 2016). This complex topographical shape also determines the mass exchange of water. The circulation of different water massesvaries between seasons and is influenced by the monsoon system's wind pattern.

The circulation of water mass in Indonesian waters differs between the west monsoon and the east monsoon. In the west monsoon, water masses generally flow to the east of Indonesian waters. The eastern monsoons develop perfectly, supplying water masses originating from the upwelling areas in the Arafura and Banda Seas (Hasanudin 1998). The upwelling process that occurs in the Banda Sea results in a decrease of temperatures, an increase of salinity and the removal of nutrients, so that their availability will affect the abundance of plankton in the waters (Baars et al 1990; Armus et al 2019).

The potential area for catching skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ranges from 0.12 to 0.22 mg m^3 (Zainuddin 2011; Hidayat et al 2019; Wangi et al 2019). Almost all fish populations that live in marine waters, including *K. pelamis*, require optimal sea surface temperature (SST) range and chlorophyll-a values for their survival (Jufri et al 2014). Remote sensing technology helps observing the oceanographic

parameters of the surrounding waters in the Banda Sea, so that it can determine the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea.

K. pelamis likes areas where there is a convergence of currents that mostly occur in areas with many islands. The vertical distribution of *K. pelamis* starts from the surface to a depth of 260 m during the day, while at night it will go to the surface (diurnal migration) (Ekayana et al 2017). *K. pelamis* specimens from the small size category tend to be caught at a more homogeneous (warm) SST, while large *K. pelamis* are caught in a wider range of SST (cold and warm) (Simbolon & Limbong 2012). *K. pelamis* congregate at low chlorophyll-a concentrations and water depths of ≥ 500 m, because *K. pelamis* is a carnivorous fish with the main prey of small pelagic fish such as *Stelophorus sp.* and *Sardinella sp.*, which are abundant in the contineta shelf and sloping waters (Bubun et al 2015).

Remote sensing technology is an alternative method that is very beneficial if it is used in a country with a very large area such as Indonesia (Syah 2010). Remote sensing is a technique for collecting information about objects and their environment from a distance without physical touch (Lo 1986). The use of remote sensing methods to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions is a very appropriate alternative (Tangke 2016; Mashita & Lumban-Gaol 2019). Remote sensing technology has several advantages including cheap and easily accessible data prices, wide area coverage, high temporal resolution and digitalized data supply, making it a potential source for the geographic information system (GIS) data (Louhenapessy & Waas 2009).

One of the sensing satellites equipped with sensors that can detect the chlorophyll-a content is the Aqua MODIS satellite (Utari 2013). The variables measured by the Aqua satellite include the aerosols, land-covering plants, phytoplankton and dissolved organic matter in the oceans, as well as the air, land and water temperature (Putra et al 2012). The Aqua MODIS satellite has a polar sun-synchronous orbit. The satellite crosses the equator at noon, approaching at 13.30 local time (Karif 2011).

Changes in fishing actually occur when the seasons' change. Seasonal changes directly affect the oceanographic aspects of the waters, especially sea surface temperature and chlorophyll-a, which greatly influence the presence of fish in an area, determining the fishing grounds in that area. Both of these parameters can trigger natural events or phenomena such as upwelling and fronts (Waileruny & Wiyono 2014). The fishing season in Southeast Sulawesi waters can be found in January to April and from July to September, and it can affect the salinity of the habitat of the caught fish species. In the eastern monsoon (June to September), high salinity water masses originating from the Flores Sea and Pacific Ocean flow through the Makassar Strait to the Java Sea. In the western season (December to March) surface currents move from the South China Sea into the Java Sea from west to east (Bubun & Mahmud 2016). The purpose of this study was to analyze the relationship and effect of chlorophyll-a on the catch of *K. pelamis* (Mugo et al 2010).

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What do the authors cite from Mugo et al 2010???

Material and Method. The tools and materials needed in the implementation of this research include: stationery, cameras, rulers, GPS, MODIS data and the softwares SeaDas, SPSS Statistics 25 and Surfer 13.0.

Method of collecting data. The data collection method uses primary data, carried out *in situ* by direct observation of the fishing operation including operating time, the number of catches and the position of the fishing area, and by using secondary data including the image of the distribution of chlorophyll-a, from the level 3 of the Aqua MODIS, downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). Data were processed using the Seadas to get the chlorophyll value and the Surfer 13 to get the distribution of chlorophyll-a in the form of images.

The chlorophyll-a image data chosen to be processed is a standard 8-day image with a 4 km resolution map of level 3, at night, from November 2017 to March 2018. Chlorophyll-a data was calculated using chlorophyll-a image data that has been adjusted with both atmospheric and geometrical corrections. Seadas produced the chlorophyll-a distribution data which was reprocessed using a computer device, then using the Surfer 13, which will produced the distribution data of chlorophyll-a in the JPEG image format.

The catch used includes the catch weight of *K. pelamis* analyzed by calculating the weight per fishing trip, so that fluctuations in the catch based on time (temporal) and fishing location (spatial) can be observed.

Multiple correlation analysis. The multiple correlations showed the direction and strength of the relationship between the studied variables. To be able to provide an interpretation of the correlation coefficients found, reference values are listed in Table 1 below (Sugiono 2007).

Table 1

Assessment of the correlation coefficient (Sugiono 2007)

Coefficient interval	*Relationship level*
0.00–0.199	Very low
0.20–0.399	Low
0.40–0.599	Moderate
0.60–0.799	Strong
0.80–1.00	Very strong

The double correlation formula for two variables is (Sugiono 2007):

$$R_{y.x_1x_2} = \sqrt{\frac{r_{yx1}^2 + r_{yx2}^2 - 2r_{yx1}r_{yx2}\ r_{x1x2}}{1 - r^2_{x1\,x2}}}$$

Where:
$R_{y.x_1x_2}$ - correlation of the variables X_1 and X_2 with the variable Y;
ryx_1 - correlation between X_1 and Y;
ryx_2 - correlation between X_2 and Y;
rx_1x_2 - correlation between X_1 and X_2.

Multiple linear regression analysis. When the correlation coefficient is sufficiently high, a multiple linear regression was used to examine the variables relationship (Sugiono 2005), as follows:

$$Y = a + b_1X_1 + b_2X_2$$

Where:
X_1 - variable sea surface temperature;
X_2 - chlorophyll-a variable;
Y - the maximum quantity of certain fish species caught;
a, b_1, b_2 - constants.

Multiple linear statistical test. According to Hasan (2004), multiple linear regression statistical tests are used to test the significance of the relationship of more than two variables through the regression coefficient. The multiple linear regression statistical tests can be divided into two categories, namely:
1. Concurrent test
The test is carried out in multiple linear regression using the F test, a statistical test for the regression coefficient that together affects Y, namely:

$$F_o = \frac{R^2(n-k-1)}{k(1-R^2)}$$

Where:
n - number of fish caught;

k - number of independent variables;
R^2 – determination coefficient.

2. Individual test
Individual test, namely the regression statistic with only one regression coefficient affecting Y, using the t_{test}:

$$t_o = \frac{b_1 - B_i}{S_{b1}}$$

Where:
b_1 - ......
B_i - ......
S_{bi}- ......
When the regression formula involves only two independent variables, the values of S_{b1} and S_{b2} are as follows (....):

$$S_{b1} = \sqrt{S_e^2 \frac{\sum x_2^2}{(\sum x_1^2)(\sum x_2^2)-(\sum x_1 x_2)^2}}$$

$$S_{b2} = \sqrt{S_e^2 \frac{\sum x_1^2}{(\sum x_1^2)(\sum x_2^2)-(\sum x_1 x_2)^2}}$$

$$S_e = \sqrt{\frac{\sum e_i^2}{n-3}} = \sqrt{\frac{\sum y^2 - b_1 \sum x_1 y - b_2 \sum x_2 y}{n-3}}$$

Where:
S_{bk} - standard error of estimator bk, k=1, 2;
e - confounding error (values of other variables not included in the equation).

Geographical information analysis. The Surfer 13 software was used to map the distribution of *chlorophyll-a* from November 2017 to March 2018, based on time (temporal) and fishing location (spatial), with the aim of producing information about the relationship of these variables.

Results and Discussion

This research was conducted from November 2017 to May 2018 by following a fishing operation using a purse seiner in the Banda Sea, Maluku Indonesia.

Figure 1. Purse seiner (original photo).

Fish catch results. The fishing operation was carried out in seven trips, with 34 operations. The total catch was 56,689 kg with an average of 12,558.17 kg. The number of catches on the 2nd trip (6 operations) was the largest, with a total catch of 11,954 kg (an average of 1,992.33 kg per operation) or 21.1% of the total catch. Meanwhile, the 3rd trip (2 operations) recorded the smallest total catch, namely 5,522 kg or 9.7% of the total catch, but with the highest average per operation, of 2,761 kg (Table 2).

Table 2

The number of fish catch per trip

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Commented [WU5]: Citation needed, who developed the formulas?

Commented [A6]: Please explain the symbols

Commented [A7]: Elementary mistake: this is the sum of the averages (total per trip per number of operations); it has no signification; the authors either calculate the average of the averages or the overall total per total number or operations

Commented [WU8]: Please clarify if 12,558.17 kg represents an average/trip or an average per setting?
Please calculate the average per trip and the average per setting and based on the total catch of 56,689 give the results.
The 12,558.17 value represents the total of the averages per trip and IT DOES NOT REPRESENT AN AVERAGE.

Trip	Number of operations	Amount (Kg)	Average (Kg)	Percentage (%)
1st	4	8,226	2,056.5	14.5
2nd	6	11,954	1,992.33	21.1
3rd	2	5,522	2,761	9.7
4th	4	7,006	1,751.5	12.4
5th	6	9,607	1,601.16	17
6th	6	7,982	1,330.33	14.1
7th	6	6,392	1,065.33	11.2
Total	34	56,689	12,558.17	100

Catch composition. The catch data consists of seven trips with 34 operations. The main catches are *K. pelamis*, *T. albacares*, *E. affinis* and *D. ruselli*. Based on the results obtained, the highest *T. albacares* catches were on the 7th trip and the lowest was on the 5th trip. *K. pelamis* catches reached the highest value on the 2nd trip and the lowest on the 6th trip. The highest *T. albacares* catches were on the 2nd trip and the lowest was on the 7th trip, and the highest *D. ruselli* was on the 6th trip and the lowest was on the 3rd trip. The composition of the catch can be seen in Table 3 below.

Table 3

The composition of the catch based on the type of fish

Trip to-	Total catch (Kg)				Total
	T. albacares	*K. pelamis*	*E. affinis*	*D. ruselli*	
1st	825	3,018	2,590	1,793	8,226
2nd	230	5,676	4,430	1,618	11,954
3rd	90	4,270	497	665	5,522
4th	569	2,948	1,817	1,672	7,006
5th	0	4,467	4,290	850	9,607
6th	13	2,536	670	4,763	7,982
7th	915	4,323	0	1,154	6,392

Based on the data mentioned above, the highest catch was on the second trip, and the lowest catch was on the 3rd trip. The highest catch of *T. albacares* was on the 7th trip, as much as 915 kg, while the lowest was on the 5th trip, with no catch. The highest catch of *K. pelamis* was on the 2nd trip, as much as 5,676 kg, while the lowest was on the 6th trip, with 2,536 kg. The highest *E. affinis* catch was on the 2nd trip, as much as 4,430 kg, and the lowest on the 7th trip, with no catch. The highest *D. ruselli* catch was on the 6th trip, as much as 4,763 kg, and the lowest was on the 3rd trip, with 665 kg. Based on all catches, *K. pelamis* was the most dominant fish caught compared to other fish (Figure 2).

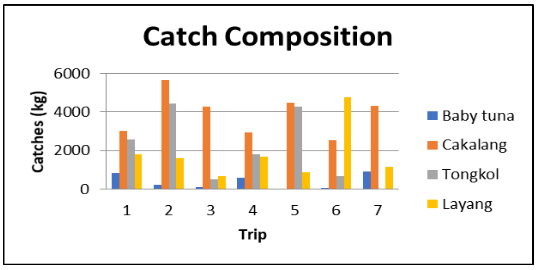


Figure 2. Composition diagram of the catch.

Average K. pelamis per operation. The catch of *K. pelamis* is higher than that of other types. The total catch of *K. pelamis* from the 1st trip to the 7th trip was 27,238 kg. The average highest catch per operation of *K. pelamis* was recorded on the 3rd trip, with

1,495 kg, while the lowest catch per operation was recorded on the 6th trip, with 422.67 kg. The catch of the 1st trip was 3,018 kg, the 2nd trip was 5,676 kg, the 3rd trip was 4,270 kg, the 4th trip was 2,948 kg, the 5th trip was 4,467 kg, the 6th trip was 2,536 kg, the 7th trip was 4,323 kg (Figure 3).

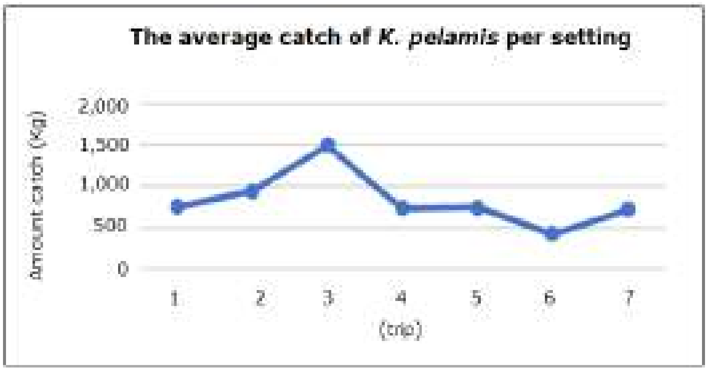
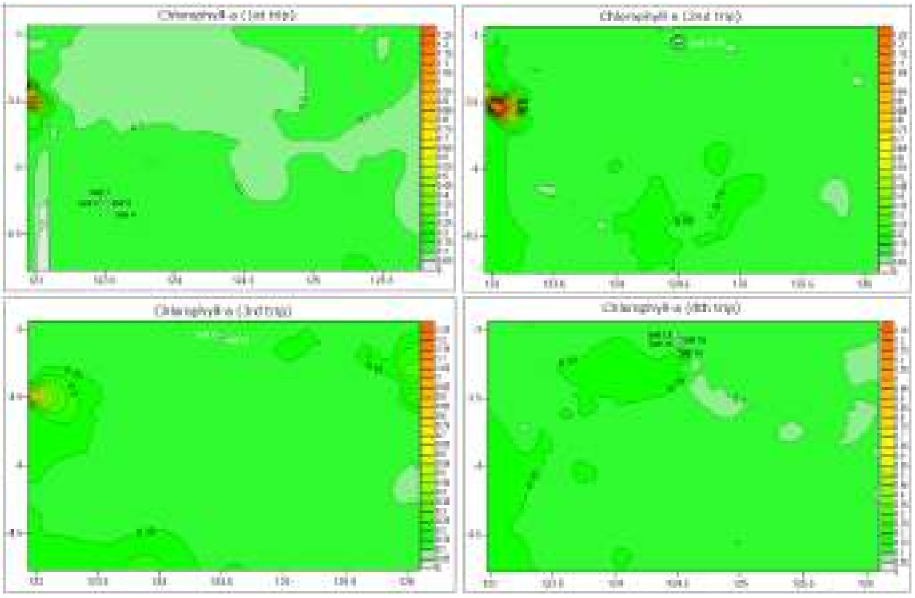


Figure 3. Diagram of the average catch of *Katsuwonus pelamis.*

Chlorophyll-a. Because fertile waters contain high chlorophyll-a concentrations, the chlorophyll-a is eligible as an indicator of fertility in waters. The chlorophyll-a concentration is also influenced by other factors such as currents. Chlorophyll-a image data were downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). The research data was processed using Seadas to produce chlorophyll-a data. Furthermore, the data was processed using Surfer 13 into JPEG format images that display the distribution of chlorophyll-a with different colors. The distribution of chlorophyll-a was taken based on the time and position of the capture operation. Figure 4 shows the chlorophyll-a distribution over the 7 fishing trips.



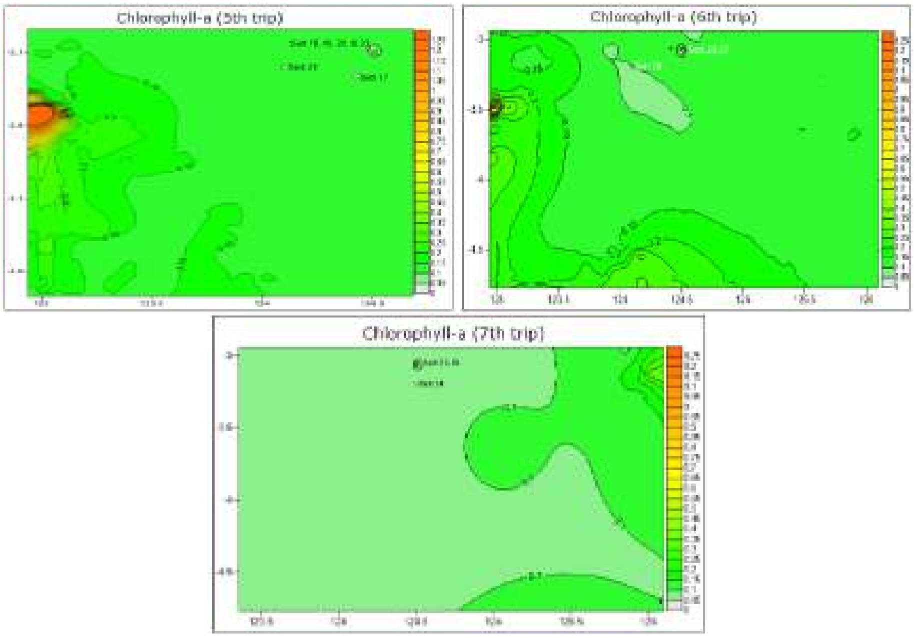


Figure 4. Distribution of chlorophyll-a over the 7 fishing trips.

Table 4

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Chlorophyll-a concentration values

Trips	*Chlorophyll-a concentration value (mg m*^{3}*)*						*Average*
	1st *operation*	*2*nd *operation*	*3*rd *operation*	*4*th *operation*	*5*th *operation*	*6*th *operation*	
Trip 1	0.1308[a]	0.1292	0.1273	0.1268[b]	-	-	0.1285
Trip 2	0.1176	0.1176	0.1173[b]	0.1266	0.1176	0.1266[a]	0.1205
Trip 3	0.1399[a]	0.1342[b]	-	-	-	-	0.1370
Trip 4	0.1046[b]	0.1080	0.1077	0.1632[a]	-	-	0.1209
Trip 5	0.1314	0.1312	0.1312	0.1314[a]	0.1313	0.1258[b]	0.1303
Trip 6	0.1208	0.1288[a]	0.1287	0.1227	0.1281	0.1001[b]	0.1215
Trip 7	0.0895	0.0903	0.0913[a]	0.0880	0.0875[b]	0.0894	0.0893

[a] the distribution of the highest chlorophyll-a concentrations; [b] the distribution of the lowest chlorophyll-a concentrations.

The chlorophyll-a concentration value on the 7th trip decreased significantly, compared to the other trips. The higher the chlorophyll-a concentration value in the waters, the more fertile the waters.

Average chlorophyll-a. The average chlorophyll-a can be seen in Figure 5, where the concentration of the 7th trip decreased, compared to the other trips. The average chlorophyll-a concentration was the highest on trip 3 and the lowest on trip 7. The difference between the highest and lowest concentrations is 0.0477 mg m^{-3}.

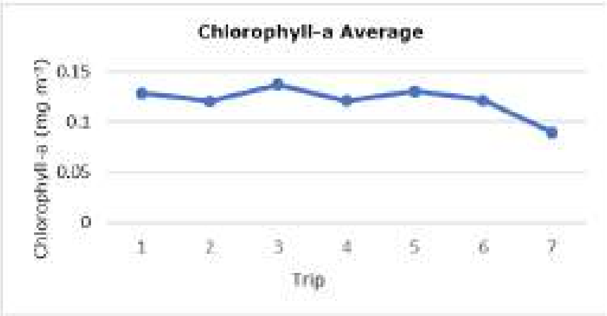

Figure 5. Diagram of average chlorophyll-a for 7 trips.

The relationship between average chlorophyll-a against K. pelamis. The relationship of chlorophyll-a to the catch of *K. pelamis* was calculated using a multiple correlation test. The multiple correlation estimator for the level of chlorophyll-a relationship to *K. pelamis* catch was determined by using SPSS 25.

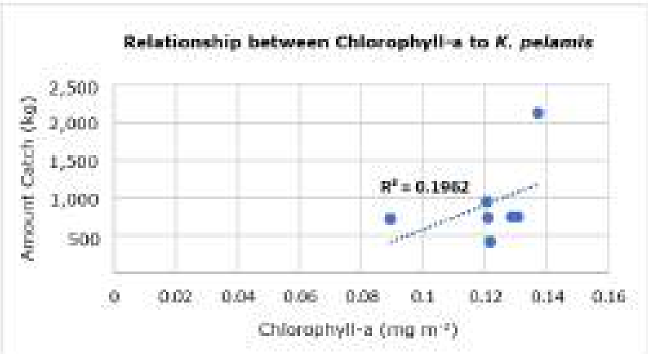

Figure 6. Graph of chlorophyll-a relationship to *Katsuwonus pelamis.*

Based on Figure 6 above, the coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents.

The value of the correlation coefficient using SPSS 25 can be seen in table 4. The correlation coefficient value was obtained at 0.443, which means that the positive relationship between chlorophyll-a and the catch of *K. pelamis* is moderate, because the correlation coefficient value is in the correlation interval 0.40-0.599. This relationship is positive: if the value of one variable is increased, it will increase the value of the other variables and vice versa (Sugiono 2007), while if the chlorophyll-a decreases, it will decrease the catch of *K. pelamis*.

Hypothesis testing via the t test is used to determine whether the hypothesis is accepted or rejected, based on the coefficients table (Table 7). Based on this table, the t_{count} value of chlorophyll-a is 3,320, t_{count} > t_{table} (3,320>2.77, respectively) and the sig value of 0.029 (<0.05), therefore the null hypothesis is rejected, due to the significant effect of chlorophyll-a on the catch of *K. pelamis*, in accordance with a previous research conducted by Demena et al (2017), which states that chlorophyll-a and the number of catches *K. pelamis* have a unidirectional relationship and the chlorophyll-a concentration affects the presence of *K. pelamis*.

The effect of chlorophyll-a on the catch of K. pelamis. Chlorophyll-a is an indicator that greatly influences the presence of fish in the waters, especially *K. pelamis*, a migratory species. The effect of chlorophyll-a on the catch of K. pelamis is calculated using the multiple linear regression, with the SPSS 25, and manual calculations were performed using a computer device.

Table 5

Model summary

Model	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*
1	.882[a]	.779	.668	320.54745

[a]Predictors: (Constant), Chlorophyll-a.

Based on the results obtained in table 5 above the coefficient of determination (R^2)=0.779 or 77.9%. This shows an influence of 77.9% of the chlorophyll-a on the catch of *K. pelamis*, so that the remaining 22.1% are influenced by other factors such as currents and salinity. The correlation coefficient (R) in the model summary table above is 0.882. Based on table 5, the relationship level, given by the correlation coefficient (R), is included in the interval at 0.80-1.00, which means that the level of chlorophyll-a relationship to the catch of *K. pelamis* is very strong.

Table 6

ANOVA regression table

Model		*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*
1	Regression	1444657.089	2	722328.544	7.030	.049[b]
	Residual	411002.672	4	102750.668		
	Total	1855659.760	6			

[a] Dependent Variable: *K. pelamis*; [b] Predictors: (Constant), Chlorophyll-a, Sea Surface Temperature (SST).

A F_{test} was conducted to check the influence of chlorophyll-a together with the SST (independent variables) on the catch of *K. pelamis* (dependent variable), demonstrating a significant effect (in the ANOVA regression table, the significance level is 0.049<0.05 or $F_o \geq F_{table}$). A previous research, conducted by Demena et al (2017), stated that sea surface temperature and chlorophyll-a are two predictors of the presence of fish in the waters, especially concerning *K. pelamis*.

Based on the output of SPSS 25 (the coefficients matrix), the multiple linear regression equation could be expressed as follows:

$$Y = -21557.333 + 642.160\ X_1 + 33535.607\ X_2$$

The multiple linear regression equation above can be interpreted as follows:

- if the variables X_1 (SST) and X_2 (chlorophyll-a) have a value of 0, then the variable Y is -21557.33 kg (intercept).
- if the variable X_1 (SST) increases by 1ºC and the other variables are constant, then the variable Y will increase by 642,160 kg.
- if the X_2 variable (chlorophyll-a) increases by 1 mg m^{-3} and the other variables are constant, then the Y variable will increase by 33535,607 kg.

Distribution of chlorophyll-a with K. pelamis catch.

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Details of the calculations are required in the manuscript's text.

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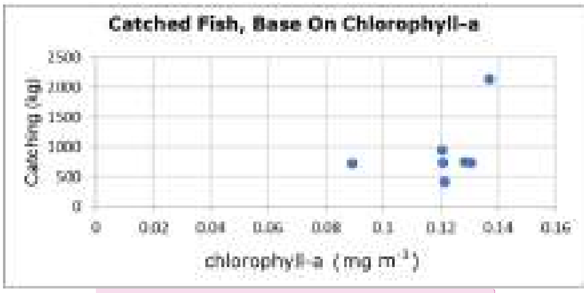

Figure 7. Catch based on chlorophyll-a.

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In the figure above, the highest catch occurs at a concentration of 0.137 mg m^{-3}. The graph of the relationship between chlorophyll-a and the catch of *K. pelamis*, shows that the concentration of chlorophyll-a and the catch of *K. pelamis* have a unidirectional relationship. The results showed that the *K. pelamis* maximum fishing potential occurs for an optimal chlorophyll-a concentration of 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a chlorophyll-a in the optimal range of 0.12-0.22 mg m^{-3}.

Conclusions. Based on the results and discussion that has been described, it can be concluded as follows:

1. The value of the coefficient of determination (R_2) is 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%. Based on the t test, the SST value was 3.243, the sig value was 0.032. For a value of 2.77. Based on the results obtained the value > and sig value 0.032 <0.05. So, if H_o is accepted and rejected, then there is a significant effect between SST and *K. pelamis* catch.
2. The coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the real model of 19.6%, so the rest is explained by other factors of 80.4%. Based on the t_{test}, the t_{count} value of chlorophyll-a was 3,320, the sig value was 0.029. A significant effect between chlorophyll-a and *K. pelamis* was demonstrated For the t_{table} value of 2.77. Based on the results, the value of t_{count} > t_{table} and sig value is 0.029 <0.05. *So that obtained H_o is accepted and rejected, then there is a significant effect between SST and skipjack catch.*

The results obtained in the ANOVA table, the value of R^2 = 0.779 or 77.9% is the effect of chlorophyll on *K. pelamis,* so that the remaining 22.1% is another factor. Based on the calculation of the F_{test} using SPSS 25 and manually, the value of F_o = 7.030 and the value of F_{table} = 6.94 is obtained. The results obtained in the ANOVA table sign value 0.049 <0.05 So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or $F_o \geq F_{table}$, so there is a significant effect of chlorophyll-a on *K. pelamis.*.

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Please rewrite the conclusions section. The results should not be repeated here. A synthesis of interpretations and conclusions / recommendations are expected.

Conflict of interest. The authors declare no conflict of interest.

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*** http://www.oceancolor.gsfc.nasa.gov.

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The effect of chlorophyll-a on the catches of skipjack tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

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Abstract. The Banda Sea is located in the waters of Central Maluku Regency, Maluku Province. The topography of the seabed is very complex with a basin in the west and a trough in the east. The shape of the topography is also decisive in controlling the exchange of water masses. The purpose of this study was to analyze the relationship of chlorophyll-a and the effect of its distribution on the catch of skipjack tuna (*Katsuwonus pelamis*). The study used the data analysis method, namely multiple linear regression, ~~because it uses two independent variables, namely chlorophyll-a~~ (computerized data processing using the SPSS 25 program). Primary data was obtained by following fishing operations and secondary data was collected from chlorophyll-a images downloaded from the NASA database in the form of an average per trip. The results of the study showed that: ~~the value of the coefficient of determination (R2) was 0.196 or 19.6% or 80.4%~~ the coefficient of determination (R2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents, the rest was influenced by other factors. The results of the t-test obtained a t_count chlorophyll-a value of 3.320, sig value of 0.029 and t_table value of 2.77. Based on the value of t_count>t_table and the value of sig 0.029<0.05, there was a significant effect between chlorophyll-a and *K. pelamis*; the ANOVA table showed the value of R^2=0.779 or 77.9% the effect of chlorophyll on *K. pelamis*, so the remaining 22.1% was influenced by other factors. Based on the results obtained, chlorophyll-a had a significant effect on *K. pelamis*.

Key Words: purse seine, remote sensing, sea surface temperature (SST), catch season.

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Introduction. The Banda Sea owes its abundance to a high nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea (Putra et al 2017). The topography of the seabed is very complex, with a basin in the west and a trough in the east (Suyarso 1999; Tapilatu 2016). This complex topographical shape also determines the mass exchange of water. The circulation of different water massesvaries between seasons and is influenced by the monsoon system's wind pattern.

The circulation of water mass in Indonesian waters differs between the west monsoon and the east monsoon. In the west monsoon, water masses generally flow to the east of Indonesian waters. The eastern monsoons develop perfectly, supplying water masses originating from the upwelling areas in the Arafura and Banda Seas (Hasanudin 1998). The upwelling process that occurs in the Banda Sea results in a decrease of temperatures, an increase of salinity and the removal of nutrients, so that their availability will affect the abundance of plankton in the waters (Baars et al 1990; Armus et al 2019).

The potential area for catching skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ranges from 0.12 to 0.22 mg m^3 (Zainuddin 2011; Hidayat et al 2019; Wangi et al 2019). Almost all fish populations that live in marine waters, including *K. pelamis*, require optimal sea surface temperature (SST) range and chlorophyll-a values for their survival (Jufri et al 2014). Remote sensing technology helps observing the oceanographic

parameters of the surrounding waters in the Banda Sea, so that it can determine the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea.

K. pelamis likes areas where there is a convergence of currents that mostly occur in areas with many islands. The vertical distribution of *K. pelamis* starts from the surface to a depth of 260 m during the day, while at night it will go to the surface (diurnal migration) (Ekayana et al 2017). *K. pelamis* specimens from the small size category tend to be caught at a more homogeneous (warm) SST, while large *K. pelamis* are caught in a wider range of SST (cold and warm) (Simbolon & Limbong 2012). *K. pelamis* congregate at low chlorophyll-a concentrations and water depths of ≥500 m, because *K. pelamis* is a carnivorous fish with the main prey of small pelagic fish such as *Stelophorus sp.* and *Sardinella sp*., which are abundant in the continetal shelf and sloping waters (Bubun et al 2015).

Remote sensing technology is an alternative method that is very beneficial if it is used in a country with a very large area such as Indonesia (Syah 2010). Remote sensing is a technique for collecting information about objects and their environment from a distance without physical touch (Lo 1986). The use of remote sensing methods to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions is a very appropriate alternative (Tangke 2016; Mashita & Lumban-Gaol 2019). Remote sensing technology has several advantages including cheap and easily accessible data prices, wide area coverage, high temporal resolution and digitalized data supply, making it a potential source for the geographic information system (GIS) data (Louhenapessy & Waas 2009).

One of the sensing satellites equipped with sensors that can detect the chlorophyll-a content is the Aqua MODIS satellite (Utari 2013). The variables measured by the Aqua satellite include the aerosols, land-covering plants, phytoplankton and dissolved organic matter in the oceans, as well as the air, land and water temperature (Putra et al 2012). The Aqua MODIS satellite has a polar sun-synchronous orbit. The satellite crosses the equator at noon, approaching at 13.30 local time (Karif 2011).

Changes in fishing actually occur when the seasons' change. Seasonal changes directly affect the oceanographic aspects of the waters, especially sea surface temperature and chlorophyll-a, which greatly influence the presence of fish in an area, determining the fishing grounds in that area. Both of these parameters can trigger natural events or phenomena such as upwelling and fronts (Waileruny & Wiyono 2014). The fishing season in Southeast Sulawesi waters can be found in January to April and from July to September, and it can affect the salinity of the habitat of the caught fish species. In the eastern monsoon (June to September), high salinity water masses originating from the Flores Sea and Pacific Ocean flow through the Makassar Strait to the Java Sea. In the western season (December to March) surface currents move from the South China Sea into the Java Sea from west to east (Bubun & Mahmud 2016). The present research aimed to analyze how much influence chlorophyll-a had on the number of *K. pelamis*, knowing the distribution of chlorophyll-a concentrations in the Banda Sea, Maluku. In this way, fishermen can be more effective in determining the area and time of catch.

Material and Method. The tools and materials needed in the implementation of this research include: stationery, cameras, rulers, GPS, MODIS data and the softwares SeaDas, SPSS Statistics 25 and Surfer 13.0.

Method of collecting data. The data collection method uses primary data, carried out *in situ* by direct observation of the fishing operation including operating time, the number of catches and the position of the fishing area, and by using secondary data including the image of the distribution of chlorophyll-a, from the level 3 of the Aqua MODIS, downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). Data were processed using the Seadas to get the chlorophyll value and the Surfer 13 to get the distribution of chlorophyll-a in the form of images.

The chlorophyll-a image data chosen to be processed is a standard 8-day image with a 4 km resolution map of level 3, at night, from November 2017 to March 2018.

Chlorophyll-a data was calculated using chlorophyll-a image data that has been adjusted with both atmospheric and geometrical corrections. Seadas produced the chlorophyll-a distribution data which was reprocessed using a computer device, then using the Surfer 13, which will produced the distribution data of chlorophyll-a in the JPEG image format.

The catch used includes the catch weight of *K. pelamis* analyzed by calculating the weight per fishing trip, so that fluctuations in the catch based on time (temporal) and fishing location (spatial) can be observed.

Multiple correlation analysis. The multiple correlations showed the direction and strength of the relationship between the studied variables. To be able to provide an interpretation of the correlation coefficients found, reference values are listed in Table 1 below (Sugiono 2007).

Table 1

Assessment of the correlation coefficient (Sugiono 2007)

Coefficient interval	*Relationship level*
0.00–0.199	Very low
0.20–0.399	Low
0.40–0.599	Moderate
0.60–0.799	Strong
0.80–1.00	Very strong

The double correlation formula for two variables is (Sugiono 2007):

$$R_{y.x_1x_2} = \sqrt{\frac{r^2_{yx1} + r^2_{yx2} - 2r_{yx1}r_{yx2}\ r_{x1x2}}{1-r^2_{x1\,x2}}}$$

Where:
$R_{y.x_1x_2}$ - correlation of the variables X_1 and X_2 with the variable Y;
ryx_1 - correlation between X_1 and Y;
ryx_2 - correlation between X_2 and Y;
rx_1x_2 - correlation between X_1 and X_2.

Multiple linear regression analysis. When the correlation coefficient is sufficiently high, a multiple linear regression was used to examine the variables relationship (Sugiono 2005), as follows:

$$Y = a + b_1X_1 + b_2X_2$$

Where:
X_1 - variable sea surface temperature;
X_2 - chlorophyll-a variable;
Y - the maximum quantity of certain fish species caught;
a, b_1, b_2 - constants.

Multiple linear statistical test. According to Hasan (2004), multiple linear regression statistical tests are used to test the significance of the relationship of more than two variables through the regression coefficient. The multiple linear regression statistical tests can be divided into two categories, namely:
1. Concurrent test
The test is carried out in multiple linear regression using the F test, a statistical test for the regression coefficient that together affects Y, namely:

$$F_o = \frac{R^2(n-k-1)}{k(1-R^2)}$$

Where:
n - number of fish caught;

k - number of independent variables;
R^2 – determination coefficient.
2. Individual test
Individual test, namely the regression statistic with only one regression coefficient affecting Y, using the t_{test}:

$$t_o = \frac{b_1 - B_i}{S_{b1}}$$

Where:
b_1 - regression slope coefficient;
B_i - hypothesized slope;
S_{bi}- standard deviation of slope.

Geographical information analysis. The Surfer 13 software was used to map the distribution of *chlorophyll-a* from November 2017 to March 2018, based on time (temporal) and fishing location (spatial), with the aim of producing information about the relationship of these variables.

Results and Discussion

This research was conducted from November 2017 to May 2018 by following a fishing operation using a purse seiner in the Banda Sea, Maluku Indonesia.

Figure 1. Purse seiner (original photo).

Fish catch results. The fishing operation was carried out in seven trips, with a total catch of 56,689 kg and an average of 12,558.17 kg per 34 operations. The number of catches on the 2nd trip (6 operations) was the largest, with a total catch of 11,954 kg (an average of 1,992.33 kg per operation) or 21.1% of the total catch. Meanwhile, the 3rd trip (2 operations) recorded the smallest total catch, namely 5,522 kg or 9.7% of the total catch, but with the highest average per operation, of 2,761 kg (Table 2).

Table 2

The number of fish catch per trip

Trip	*Number of operations*	*Amount (Kg)*	*Average (Kg)*	*Percentage (%)*
1st	4	8,226	2,056.5	14.5
2nd	6	11,954	1,992.33	21.1
3rd	2	5,522	2,761	9.7
4th	4	7,006	1,751.5	12.4
5th	6	9,607	1,601.16	17
6th	6	7,982	1,330.33	14.1
7th	6	6,392	1,065.33	11.2
Total	34	56,689	12,558.17	100

Catch composition. The catch data consists of seven trips with 34 operations. The main catches are *K. pelamis*, *T. albacares*, *E. affinis* and *D. ruselli*. Based on the results obtained, the highest *T. albacares* catches were on the 7th trip and the lowest was on the

5th trip. *K. pelamis* catches reached the highest value on the 2nd trip and the lowest on the 6th trip. The highest *T. albacares* catches were on the 2nd trip and the lowest was on the 7th trip, and the highest *D. ruselli* was on the 6th trip and the lowest was on the 3rd trip. The composition of the catch can be seen in Table 3 below.

Table 3

The composition of the catch based on the type of fish

Trip to-	*Total catch (Kg)*				*Total*
	T. albacares	*K. pelamis*	*E. affinis*	*D. ruselli*	
1st	825	3,018	2,590	1,793	8,226
2nd	230	5,676	4,430	1,618	11,954
3rd	90	4,270	497	665	5,522
4th	569	2,948	1,817	1,672	7,006
5th	0	4,467	4,290	850	9,607
6th	13	2,536	670	4,763	7,982
7th	915	4,323	0	1,154	6,392

Based on the data mentioned above, the highest catch was on the second trip, and the lowest catch was on the 3rd trip. The highest catch of *T. albacares* was on the 7th trip, as much as 915 kg, while the lowest was on the 5th trip, with no catch. The highest catch of *K. pelamis* was on the 2nd trip, as much as 5,676 kg, while the lowest was on the 6th trip, with 2,536 kg. The highest *E. affinis* catch was on the 2nd trip, as much as 4,430 kg, and the lowest on the 7th trip, with no catch. The highest *D. ruselli* catch was on the 6th trip, as much as 4,763 kg, and the lowest was on the 3rd trip, with 665 kg. Based on all catches, *K. pelamis* was the most dominant fish caught compared to other fish (Figure 2).

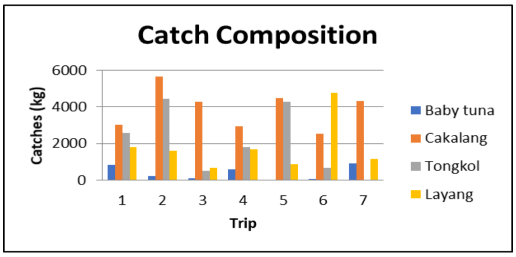


Figure 2. Composition diagram of the catch.

Average K. pelamis per operation. The catch of *K. pelamis* is higher than that of other types. The total catch of *K. pelamis* from the 1st trip to the 7th trip was 27,238 kg. The average highest catch per operation of *K. pelamis* was recorded on the 3rd trip, with 1,495 kg, while the lowest catch per operation was recorded on the 6th trip, with 422.67 kg. The catch of the 1st trip was 3,018 kg, the 2nd trip was 5,676 kg, the 3rd trip was 4,270 kg, the 4th trip was 2,948 kg, the 5th trip was 4,467 kg, the 6th trip was 2,536 kg, the 7th trip was 4,323 kg (Figure 3).

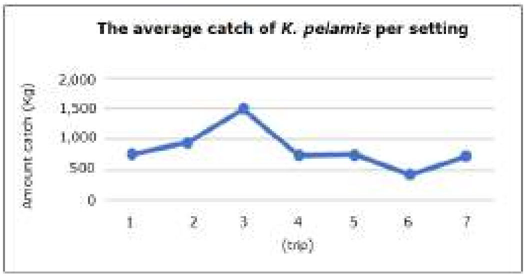
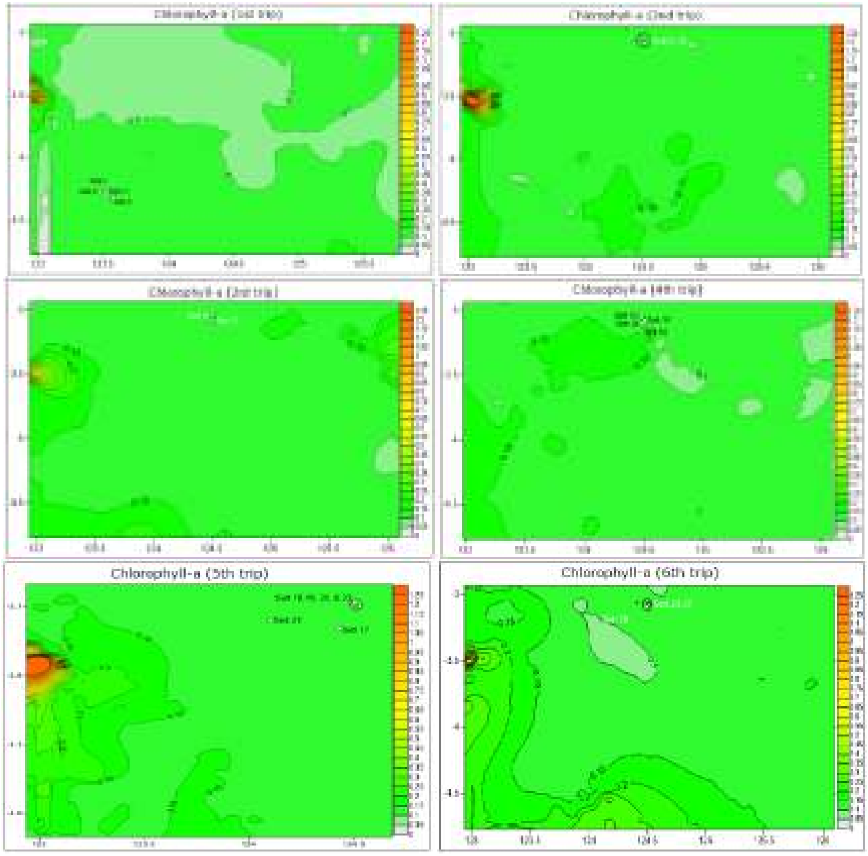


Figure 3. Diagram of the average catch of *Katsuwonus pelamis.*

Chlorophyll-a. Because fertile waters contain high chlorophyll-a concentrations, the chlorophyll-a is eligible as an indicator of fertility in waters. The chlorophyll-a concentration is also influenced by other factors such as currents. Chlorophyll-a image data were downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). The research data was processed using Seadas to produce chlorophyll-a data. Furthermore, the data was processed using Surfer 13 into JPEG format images that display the distribution of chlorophyll-a with different colors. The distribution of chlorophyll-a was taken based on the time and position of the capture operation. Figure 4 shows the chlorophyll-a distribution over the 7 fishing trips.



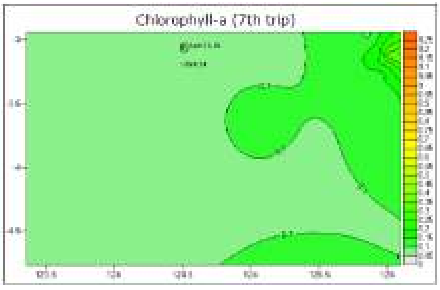


Figure 4. Distribution of chlorophyll-a over the 7 fishing trips.

The chlorophyll-a concentration values can be seen in Table 4 below:

Table 4

Chlorophyll-a concentration values

Trips	Chlorophyll-a concentration value (mg m3)						
	1st operation	2nd operation	3rd operation	4th operation	5th operation	6th operation	Average
Trip 1	0.1308[a]	0.1292	0.1273	0.1268[b]	-	-	0.1285
Trip 2	0.1176	0.1176	0.1173[b]	0.1266	0.1176	0.1266[a]	0.1205
Trip 3	0.1399[a]	0.1342[b]	-	-	-	-	0.1370
Trip 4	0.1046[b]	0.1080	0.1077	0.1632[a]	-	-	0.1209
Trip 5	0.1314	0.1312	0.1312	0.1314[a]	0.1313	0.1258[b]	0.1303
Trip 6	0.1208	0.1288[a]	0.1287	0.1227	0.1281	0.1001[b]	0.1215
Trip 7	0.0895	0.0903	0.0913[a]	0.0880	0.0875[b]	0.0894	0.0893

[a] the distribution of the highest chlorophyll-a concentrations; [b] the distribution of the lowest chlorophyll-a concentrations.

The chlorophyll-a concentration value on the 7th trip decreased significantly, compared to the other trips. The higher the chlorophyll-a concentration value in the waters, the more fertile the waters.

Average chlorophyll-a. The average chlorophyll-a can be seen in Figure 5, where the concentration of the 7th trip decreased, compared to the other trips. The average chlorophyll-a concentration was the highest on trip 3 and the lowest on trip 7. The difference between the highest and lowest concentrations is 0.0477 mg m^{-3}.

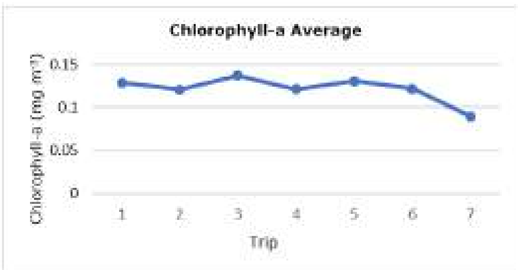


Figure 5. Diagram of average chlorophyll-a for 7 trips.

The relationship between average chlorophyll-a against K. pelamis. The relationship of chlorophyll-a to the catch of *K. pelamis* was calculated using a multiple correlation test. The multiple correlation estimator for the level of chlorophyll-a relationship to *K. pelamis* catch was determined by using SPSS 25.

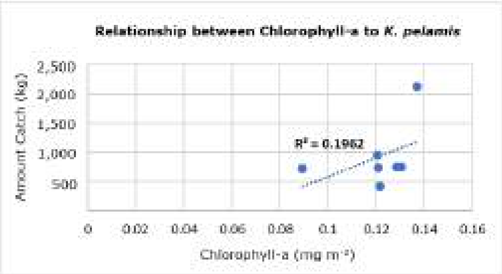


Figure 6. Graph of chlorophyll-a relationship to *Katsuwonus pelamis.*

Based on Figure 6 above, the coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents.

The value of the correlation coefficient using SPSS 25 can be seen in table 4. The correlation coefficient value was obtained at 0.443, which means that the positive relationship between chlorophyll-a and the catch of *K. pelamis* is moderate, because the correlation coefficient value is in the correlation interval 0.40-0.599. This relationship is positive: if the value of one variable is increased, it will increase the value of the other variables and vice versa (Sugiono 2007), while if the chlorophyll-a decreases, it will decrease the catch of *K. pelamis*.

Hypothesis testing via the t test is used to determine whether the hypothesis is accepted or rejected, based on the coefficients table (Table 7). Based on this table, the t_{count} value of chlorophyll-a is 3,320, $t_{count}>t_{table}$ (3,320>2.77, respectively) and the sig value of 0.029 (<0.05), therefore the null hypothesis is rejected, due to the significant effect of chlorophyll-a on the catch of *K. pelamis*, in accordance with a previous research conducted by Demena et al (2017), which states that chlorophyll-a and the number of catches *K. pelamis* have a unidirectional relationship and the chlorophyll-a concentration affects the presence of *K. pelamis*.

The effect of chlorophyll-a on the catch of K. pelamis. Chlorophyll-a is an indicator that greatly influences the presence of fish in the waters, especially *K. pelamis*, a migratory species. The effect of chlorophyll-a on the catch of K. pelamis is calculated using the multiple linear regression, with the SPSS 25, and manual calculations were performed using a computer device.

Table 5

Model summary

Model	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*
1	.882[a]	.779	.668	320.54745

[a]Predictors: (Constant), Chlorophyll-a.

Based on the results obtained in table 5 above the coefficient of determination (R^2)=0.779 or 77.9%. This shows an influence of 77.9% of the chlorophyll-a on the catch of *K. pelamis*, so that the remaining 22.1% are influenced by other factors such as currents and salinity. The correlation coefficient (R) in the model summary table above is 0.882. Based on table 5, the relationship level, given by the correlation coefficient (R), is included in the interval at 0.80-1.00, which means that the level of chlorophyll-a relationship to the catch of *K. pelamis* is very strong.

Table 6

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ANOVA regression table

Model	Sum of squares	df	Mean square	F	Sig.
Regression	1,444,657.089	2	722,328.544	7.030	.049[b]
Residual	411,002.672	4	102,750.668		
Total	1,855,659.760	6			

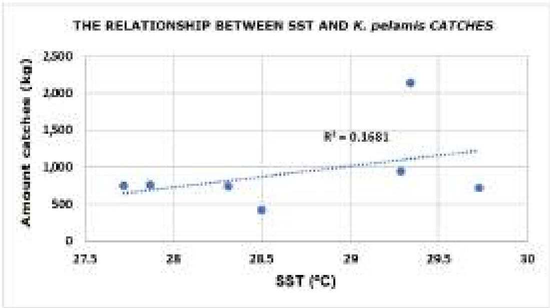
[a] Dependent variable: *K. pelamis*; [b] Predictors: (Constant), Chlorophyll-a, Sea Surface Temperature (SST).

The hypothesis test used is the F_{test}, this test is carried out to test the effect of SST and chlorophyll-a (independent variable) on *K. pelamis* catches (dependent variable) which will determine whether the results of the hypothesis are accepted or rejected. Hypothesis testing using SPSS 25 and manually obtained the value of F_o = 7.030 and value = 6.94. The results obtained in the ANOVA table have a sign value of 0.049 <0.05. So it can be concluded that H_o is rejected and accepted because the sign value is <0.05 or F_o . If H_o is rejected and accepted, then there is a significant effect between SST and chlorophyll-a on *K. pelamis* catches, this is in accordance with previous research conducted by Demena et al (2017) which stated that sea surface temperature and chlorophyll-a are two very important indicators. affect the presence of fish in the waters, especially *K. pelamis*.

A F_{test} was conducted to check the influence of chlorophyll-a together with the SST (independent variables) on the catch of *K. pelamis* (dependent variable), demonstrating a significant effect (in the ANOVA regression table, the significance level is 0.049<0.05 or $F_o \geq F_{table}$). A previous research, conducted by Demena et al (2017), stated that sea surface temperature and chlorophyll-a are two predictors of the presence of fish in the waters, especially concerning *K. pelamis*.

Relationship of Average SST to K. pelamis. SST can be used as an indicator to determine the presence of a fish species in a waters. Each fish species has a certain temperature tolerance value that is preferred to carry out its life so that it affects the presence and distribution of fish in the waters. Seeing the relationship or relationship between SST and the presence of *K. pelamis*, the in-situ data of the catch and *ex-situ* data of SST on the position and time of catching using SPSS 25 and using the help of computer equipment.

The relationship of SST to the catch of *K. pelamis* was calculated using the multiple correlation test. Double correlation estimator of the relationship between surface temperature and the catch of *K. pelamis*.



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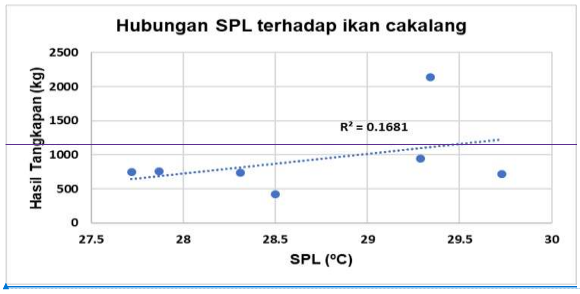

Figure ~~6~~7. Graph of the relationship between SST and *K. pelamis.*

Based on the graph above, the coefficient of determination (R_2) is 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%.

Table 7

Correlations

Correlations				
		K. pelamis	SST	Chlorophyl-a
Pearson Correlation	*K. pelamis*	1.000	.410	.443
	SST	.410	1.000	-.532
	Chlorophyl-a	.443	-.532	1.000
Sig. (1-tailed)	*K. pelamis*	.	.180	.160
	SST	.180	.	.109
	Chlorophyl-a	.160	.109	.
N	*K. pelamis*	7	7	7
	SST	7	7	7
	Chlorophyl-a	7	7	7

Assessment of the value of the correlation coefficient using SPSS 25 can be seen in table 7 and manual calculations using the help of computer equipment. The correlation coefficient value obtained is 0.410, which means that the positive relationship between SST and the catch of K. pelamis is moderate, because the correlation value is in the correlation interval of 0.40-0.599.

Table 8

Coefficiens[a]

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	-21557.333	6416.374		-3.360	.028
	SST	642.160	198.028	.902	3.243	.032
	Chlorophyl-a	33535.607	10100.263	.923	3.320	.029

a. Dependent Variable: *K. pelamis*

Based on the table above, the SST t_{count} is 3.243, the sig value is 0.032. The t_{table} is 2.77. Based on the results obtained the t_{count} > t_{table} and sig value 0.032 <0.05. So it was found that H_0 was rejected and H_1 accepted, then there was a significant effect between SST and the catch of *K. pelamis*, this is based on previous research conducted by Fajrianti (2016) which stated that SST had a significant effect on the catch.

Based on the output of SPSS 25 (the coefficients matrix), the multiple linear regression equation could be expressed as follows:

$$Y = -21{,}557.333 + 642.160\ X_1 + 33{,}535.607\ X_2$$

The multiple linear regression equation above can be interpreted as follows:

- if the variables X_1 (SST) and X_2 (chlorophyll-a) have a value of 0, then the variable Y is -21,557.33 kg (intercept).
- if the variable X_1 (SST) increases by 1ºC and the other variables are constant, then the variable Y will increase by 642,160 kg.
- if the X_2 variable (chlorophyll-a) increases by 1 mg m^{-3} and the other variables are constant, then the Y variable will increase by 33,535.607 kg.

Distribution of chlorophyll-a with K. pelamis catch. The graph of the relationship between chlorophyll-a and the catch of *K. pelamis*, shows that the concentration of chlorophyll-a and the catch of *K. pelamis* have a unidirectional relationship.

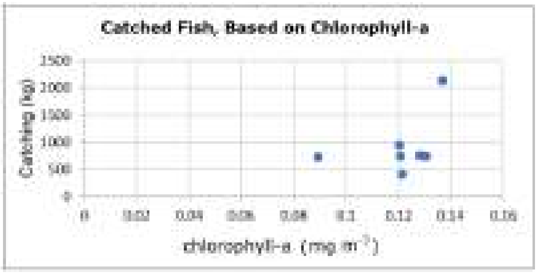

Figure 7. Catch based on chlorophyll-a.

In the figure above, the highest catch occurs at a concentration of 0.137 mg m^{-3}. The results showed that the *K. pelamis* maximum fishing potential occurs at an optimal chlorophyll-a concentration of 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a chlorophyll-a in ~~the j;oj;ohhkh~~ optimal range of 0.12-0.22 mg m^{-3}.

Conclusions.

From the results of the research conducted, it can be concluded that:

1. The main catches were *T. albacares*, *K. pelamis*, *E. affinis* and *D. ruselli*. *K. pelamis* was the most caught type of fish with a total *K. pelamis* catch from trip one to trip seven as much as 27,238 kg.
2. The distribution of SST in the Banda Sea varies greatly. The distribution of SST is in the range of 26ºC - 29ºC.
3. The relationship between sea surface temperature and *K. pelamis* catches with the results obtained in the form of a coefficient of determination (R_2) of 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%.
4. The correlation coefficient value is 0.443, which means that the positive relationship between chlorophyll-a and *K. pelamis* catches is moderate, because the correlation coefficient is in the correlation interval 0.40-0.599. This relationship is declared

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positive, if the value of one variable is increased it will increase the value of the other variable and vice versa. So there is a positive relationship between chlorophyll-a and *K. pelamis* catches, this means that if the chlorophyll-a is higher, it will increase the catch, and vice versa if chlorophyll-a is lower, it will decrease the catch of *K. pelamis*.

5. Based on the results of the coefficient of determination (R^2) = 0.779 or 77.9%. This shows that 77.9% influence of SST and chlorophyll-a on *K. pelamis* catches, so the remaining 22.1% is influenced by other factors such as currents, salinity, and others. The correlation coefficient (R) in the model summary table above is 0.882. The value of the correlation coefficient (R) included in the interval at 0.80-1.00 means that the level of relationship between SST and chlorophyll-a to *K. pelamis* catches is very strong.
6. In general, the SST in the Banda Sea, especially in the fishing area on the first trip, was cold, on the next trip it was dominated by warm temperatures. Most areas in the Banda Sea tend to be warm, although there are still certain areas where the temperature is cold. The sea surface temperature on the fifth trip was cold due to the influence of rainfall which caused very little solar radiation because it was covered by clouds. The low SST can also be caused by other oceanographic factors such as currents, upwelling. However, more detailed observations are needed to see the extent of the influence of currents and upwelling on SST in the Banda Sea.
7. The highest catch was at a concentration of 0.137 mg m^{-3}. Based on the graph of the relationship of chlorophyll-a to skipjack catches, it shows that the concentration of chlorophyll-a with *K. pelamis* catches has a unidirectional relationship, it can be interpreted that the increase in skipjack catches means the concentration in these waters increases, and vice versa.
8. The results of the study concluded that the potential area for *K. pelamis* catching based on the optimum sea surface temperature was around 29°C and the optimum concentration for chlorophyll-a was around 0.13 mg m^{-3}.

The results showed that the *K. pelamis* maximum fishing potential occurs for an optimal chlorophyll-a concentration of 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a chlorophyll-a in the optimal range of 0.12-0.22 mg m^{-3}.

Berdasarkan hasil dan pembahasan yang telah diuraikan, maka dapat disimpulkan sebagai berikut :

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The conclusion section should state:
What is the overall result of the paper?
Describe what did you achieve and what was determined; what did the results indicate; what can you conclude from all you observed!!!!!

NO CITATIONS ARE ALLOWED IN THE CONCLUSION SECTION OF ANY SCIENTIFIC ARTICLE!

Conflict of interest. The authors declare no conflict of interest.

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*** http://www.oceancolor.gsfc.nasa.gov.

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Eni Kovacs <ek.bioflux@gmail.com>

Kepada: Adnal Yeka

Min, 15 Mei 2022 jam 03.16

Dear Dr. Yeka,

Please find the manuscript attached and make all the necessary corrections as soon as possible, highlighting by color..

Thank you.

› Tampilkan pesan asli

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Kind regards,
Editor AACL Bioflux
Eniko Kovacs

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The effect of chlorophyll-a on the catches of skipjack tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

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Abstract. Potential areas for catching *K. pelamis* haves a close relationship with environmental parameters, especially chlorophyll-a. The use of rRemote sensing methods are used to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions,. Remote sensingas a technology which helps in observing oceanographic parameters and so that they can determine determining the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea. The On this purpose, the multiple linear regression method of this study was towas used to analyze their relationship and effect of chlorophyll-a on the catch of *K. pelamis*. This study uses the data analysis method used, namely multiple linear regression, because it uses two independent variables, namely chlorophyll-a. Based on the results and discussions that have been described, it can be concluded that; : (1) the value of the coefficient of determination (R_2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the real model data by 19.6%, so that the rest remaining 80.4% of the catch volume is explained by other factors of 80.4%;. (2) Based on the t_{test}, the t_{count} value of chlorophyll-a was 3.320, the sig value was 0.029. For the t_{table} value of 2.77. Based on tThe results obtainedshow that the value of $t_{count} > t_{table}$ and sig value of 0.029 <0.05. So it was found that H_0 was rejected and H_1 was accepted, then there was a significant effect between chlorophyll-a and *K. pelamis*. (23) in the ANOVA regression table the value of R^2 = 0.779 or 77.9% the effect of chlorophyll-a on *K. pelamis*, so the remaining 22.1% is another factor. ; Based on(4) from the calculation of the F_{test} using SPSS 25 and manually, it is obtainedresults that the value of F_0 = 7.030 and the value of F_{table} = 6.94. The results obtained in the ANOVA table have a sign value of 0.049 <0.05. So it can be concluded that H_0 is rejected and H_1 is accepted because the sign value is <0.05 or F_0 F_{table}, so there is a significant effect of chlorophyll-a on *K. pelamis*.

Key Words: purse seine, remote sensing, sea surface temperature (SST), catch season.

Introduction. The Banda Sea owes is one of the waters that has this its wealth abundance which hasto a high an abundant nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea (Putra et al 2017). The topography of the seabed is very complex, with a basin in the west and a trough in the east (Suyarso 1999; Tapilatu 2016). This complex topographical shape also determines the mass exchange of water. The circulation of different water masses and varies between seasons and is influenced by the monsoon wind pattern system's wind pattern.

The circulation of water mass in Indonesian waters differs between the west monsoon and the east monsoon. In the west monsoon, water masses generally flow to the east of Indonesian waters, and vice versa. T when the eastern monsoons develop perfectly, supplying water masses originating from the upwelling areas in the Arafura and Banda Seas (Hasanudin 1998). The upwelling process that occurs in the Banda Sea results in a decrease in of temperatures, an increase in of salinity, and a the removal of nutrients, so that their availability of nutrients in the Banda Sea will affect the abundance of plankton in the waters (Baars et al 1990; Armus et al 2019).

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The potential area for catching Skipjack tuna (*K.*~~.~~ atsuwonus *pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ~~chlorophyll-a in the~~ ranges from 0.12~~–~~ to 0.22 mg m^3 (Zainuddin 2011; Hidayat et al 2019; Wangi et al 2019). Almost all fish populations that live in marine waters, including *K. pelamis*~~–, have~~ require ~~an optimum~~ optimal sea surface temperature (SST) range and chlorophyll-a values for their survival~~life, including *K. pelamis*~~ (Jufri et al 2014). Remote sensing technology helps ~~in~~ observing the oceanographic parameters of the surrounding waters in the Banda Sea, so that ~~they~~ it can determine the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea. The purpose of this study was to analyze the relationship and effect of chlorophyll-a on the catch of *K. pelamis* (Mugo et al 2010).

K. pelamis likes areas where there is a convergence of currents that mostly occur in areas ~~that have~~with many islands. The vertical distribution of *K. pelamis* starts from the surface to a depth of 260 m during the day, while at night it will go to the surface (diurnal migration) (Ekayana et al 2017). *K. pelamis* specimens from~~in~~ the small size category tend~~s~~ to be caught ~~in~~ at a more homogeneous (warm) SST, while large *K. pelamis* ~~is~~ are caught in a wider range of SST (cold and warm) (Simbolon & Limbong 2012). *K. pelamis* congregate~~s~~ at low chlorophyll-a concentrations and water depths of ≥ 500 m, because *K. pelamis* is a carnivorous fish with the main prey of small pelagic fish such as *Stelophorus sp.* and *Sardinella sp.*, which are abundant in the continetal shelf and ~~continetal slope~~ sloping waters (Bubun et al 2015).

Remote sensing technology is an alternative method that is very beneficial if it is used in a country with a very large area such as Indonesia (Syah 2010). Remote sensing is a technique for collecting information about objects and their environment from a distance without physical touch (Lo 1986). The use of remote sensing methods to detect ~~osenographic~~ oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions is a very appropriate alternative (Tangke 2016; Mashita & Lumban-Gaol 2019). Remote sensing technology has several advantages including cheap and easily accessible data prices, wide area coverage, high temporal resolution and digitalized data ~~forms~~ supply, making it a potential source ~~of~~ for the geographic information system (GIS) data (Louhenapessy & Waas 2009).

One of the sensing satellites equipped with sensors that can detect the chlorophyll-a content is the Aqua MODIS satellite (Utari 2013). The variables measured by the Aqua satellite include the aerosols~~aeserol~~, land-covering plants~~ covering land~~, phytoplankton and dissolved organic matter in the oceans, as well as the air, land and water temperature (Putra et al 2012). The Aqua MODIS satellite has a polar sun-synchronous orbit. The satellite crosses the equator at noon, approaching at 13.30 local time (Karif 2014).

Changes in fishing actually occur when the seasons' change. Seasonal changes directly affect the oceanographic aspects of the waters, especially sea surface temperature and chlorophyll-a, which greatly ~~affect~~ influence the presence of fish in an area, ~~which has an impact on changes in~~determining the fishing grounds in that area. Both of these parameters can trigger natural events or phenomena such as upwelling and fronts (Waileruny et al 2014). The fishing season in Southeast Sulawesi waters can be found in January to April and from July to September, and~~.~~ ~~The fishing season~~it can~~ be~~ affect~~ed by~~ the salinity ~~which is~~of the habitat of the caught fish species. In the eastern monsoon (June to September), high salinity water masses originating from the Flores Sea and Pacific Ocean flow through the Makassar Strait to the Java Sea. In the western season (December to March) surface currents move from the South China Sea into the Java Sea from west to east (Bubun & Mahmud 2016). (...)

Material and Method. The tools and materials needed in the implementation of this research include: stationery, cameras, rulers, GPS, MODIS data~~, –~~ and the softwares SeaDas, SPSS Statistics 25~~,~~ and Surfer 13.0.

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Method of collecting data. The data collection method uses primary data, (carried out *in situ*) which isby direct observation in the field by followingof the fishing operation including operating time, the number of catches and the position of the fishing area, and by using secondary data including the image of the distribution of chlorophyll-a, from the level 3 of the Aqua MODIS, downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). then Data were processed using the Seadas to get the chlorophyll value and the and processed using Surfer 13 to get the results of the distribution of chlorophyll-a in the form of images.

The chlorophyll-a image data chosen to be processed is a standard 8-day image with a 4 km resolution map with of level 3, at night, in from November 2017 to March 2018. Chlorophyll-a data is was calculated using chlorophyll-a image data that has been adjusted with corrected both atmospheric and geometrically corrections. using Seadas which will produced the chlorophyll-a distribution data which will bewas reprocessed using a computer device, then the data is reprocessed using the Surfer 13, which will find outproduced the distribution data of chlorophyll-a in the form of JPEG image format.

The catch used includes the catch weight of *K. pelamis* during November 2017 to March 2018, analyzed by calculating the weight per fishing trip, so that fluctuations in the catch based on time (temporal) and fishing location (spatial) can be observed.

Multiple correlation analysis. Multiple The multiple correlation is a number that shows showed the direction and strength of the relationship between the two studied variables together or more with other variables. To be able to provide an interpretation of the correlation coefficients found, reference values are to be large or small, it can be guided by the conditions listed in table Table 1 below (Sugiono 2007).

Table 1

Assessment of the correlation coefficient (Sugiono 2007)

Coefficient interval	*Relationship level*
0.00–0.199	Very low
0.20–0.399	Low
0.40–0.599	Moderate
0.60–0.799	Strong
0.80–1.00	Very strong

The double correlation formula for two variables is as follows (...):

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$$R_{y.x_1x_2} = \sqrt{\frac{r^2_{yx1} + r^2_{yx2} - 2r_{yx1}r_{yx2}\,r_{x1x2}}{1 - r^2_{x1x2}}}$$

Where:

$R_{y.x_1x_2}$ - correlation between of the variables X_1 and X_2 together with the variable Y;

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ryx_1 - correlation between X_1 and Y;

ryx_2 - correlation between X_2 and Y;

rx_1x_2 - correlation between X_1 and X_2.

Multiple linear regression analysis. The data where When the correlation coefficient is at a sufficiently high level or more than sufficient, then tested againa using multiple linear regression was used to examine the variables relationship (Sugiono 2005),. The multiple linear regression formula is as follows:

$$Y = a + b_1X_1 + b_2X_2$$

Where:

X_1 - variable sea surface temperature;

X_2 - chlorophyll-a variable;

Y - the most maximum number quantity of certain fish species caught;

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a, b_1, b_2 - constants.

Multiple linear statistical test. According to Hasan (2004), multiple linear regression statistical tests are used to test the significance ~~or not~~ of the relationship of more than two variables through the regression coefficient. ~~Multiple~~ The multiple linear regression~~,~~ statistical tests can be divided into two categories, namely ~~as follows~~:

1. Concurrent Test

The test conducted in multiple linear regression uses the simultaneous test, which is a statistical test for the regression coefficient that simultaneously or jointly affects Y, this test uses the F test, namely:

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$$F_o = \frac{R^2(n-k-1)}{k(1-R^2)}$$

$$F_o = \frac{\frac{R^2(\sum y^2)}{k}}{\frac{(1-R^2)(\sum y^2)}{n-k-1}}$$

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Where:

n - number of subjects;

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k - number of independent variables.~~;~~

$\sum y^2$ - sum of squares of the variable Y.

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2. Individual Test

Individual test, namely the ~~statistic for the~~ regression statistic ~~coefficient~~ with only one regression coefficient ~~that affects~~ affecting Y, ~~.~~ ~~This test uses~~ using the t_{test}~~, namely~~:

$$t_o = \frac{b_1 - B_i}{S_{b1}}$$

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~~Especially for~~ When the regression formula ~~involving~~ involves only two independent variables, the values of S_{b1} and S_{b2} are as follows:

$$S_{b1} = \sqrt{S_e^2 \frac{\sum x_2^2}{(\sum x_1^2)(\sum x_2^2) - (\sum x_1 x_2)^2}}$$

$$S_{b2} = \sqrt{S_e^2 \frac{\sum x_1^2}{(\sum x_1^2)(\sum x_2^2) - (\sum x_1 x_2)^2}}$$

$$S_e = \sqrt{\frac{\sum e_i^2}{n-3}} = \sqrt{\frac{\sum y^2 - b_1 \sum x_1 y - b_2 \sum x_2 y}{n-3}}$$

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Geographical information ~~systems (GIS)~~ analysis. ~~Geographical information system (GIS) analysis using~~ The Surfer 13 software was used to map the distribution of *chlorophyll-a* ~~in~~ from November 2017 to March 2018, based on time (temporal) and fishing location (spatial), with the aim of producing information about the relationship of these variables.

Results and Discussion

This research was conducted ~~in~~ from November 2017 to May 2018 by following a fishing operation using a purse seiner in the Banda Sea, Maluku Indonesia.

Figure 1. Purse seiner.

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Fish catch results. The fishing operation ~~is~~ was carried out in seven trips, with 34 ~~setting~~Operation~~s~~operations. The total catch was 56,689 kg with an average of 12,558.17 kg. The number of catches on the 2nd trip (6 ~~times the setting~~Operationoperations) was the largest, with a total catch of 11,954 kg ~~with~~ (an average of 1,992.33 kg per operation) or 21.1% of the total catch. Meanwhile, the 3rd trip (2 operations~~times setting~~Operation) ~~was~~ recorded the ~~minimum~~ smallest total catch, namely 5,522 kg or 9.7% of the total catch, but with the highest~~an~~ average p~~f~~er operation, of 2,761 kg ~~or 9.7% of the total catch~~. ~~For more details, see table~~ (Table 2).

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Table 2

The number of fish catch per trip

Trip ~~to-~~	*Number of ~~setting~~Operation~~s~~operations*	*Amount (Kg)*	*Average (Kg)*	*Percentage (%)*
1st	4	8,226	2,056.5	14.5
2nd	6	11,954	1,992.33	21.1
3rd	2	5,522	2,761	9.7
4th	4	7,006	1,751.5	12.4
5th	6	9,607	1,601.16	17
6th	6	7,982	1,330.33	14.1
7th	6	6,392	1,065.33	11.2
Total	34	56,689	12,558.17	100

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Composition of catch. The catch data consists of seven trips with 34 ~~setting~~Operation~~s~~operations. The main catches are *K. pelamis*, *T. albacares*, *E. affinis* and *D. ruselli*. Based on the results obtained, the highest *T. albacares* catches were on the 7th trip ~~7th~~ and the lowest was on the 5th trip ~~5th~~. *K. pelamis* catches reached the highest value on the 2nd trip ~~2nd~~ and the lowest on the 6th trip ~~6th~~. The highest *T. albacares* catches were on the 2nd trip ~~2nd~~ and the lowest was on the 7th trip ~~7th~~, and the highest *D. ruselli* was on the 6th trip ~~6th~~ and the lowest was on the 3rd trip ~~3rd~~. The composition of the catch can be seen in table 3 below.

Table 3

The composition of the catch based on the type of fish

Trip to-	*Total catch (Kg)*				*Total*
	T. albacares	*K. pelamis*	*E. affinis*	*D.ruselli*	
1st	825	3,018	2,590	1,793	8,226
2nd	230	5,676	4,430	1,618	11,954
3rd	90	4,270	497	665	5,522
4th	569	2,948	1,817	1,672	7,006

5th	0	4,467	4,290	850	9,607
6th	13	2,536	670	4,763	7,982
7th	915	4,323	0	1,154	6,392

Based on the ~~table~~ data mentioned above, the highest catch was on the second trip, as much as 11,954 kg, consisting of 230 kg *T. albacares*, 5,676 kg *K. pelamis*, 4,430 kg *E. affinis*~~,~~ and 1,618 kg *D. ruselli*. The lowest catch was on the 3rd trip, as much as 5,522 kg, consisting of 90 kg *T. albacares*, 4,270 kg *K. pelamis*, 497 kg *E. affinis*~~,~~ and 665 kg *D. ruselli*.

The highest catch of *T. albacares* was on the 7th trip, as much as 915 kg, while the lowest was on the 5th trip, with no catch. The highest catch of *K. pelamis* was on the 2nd trip, as much as 5,676 kg, while the lowest was on the 6th trip, with ~~was~~ 2,536 kg. The highest *E. affinis* ~~*T. albacares*~~ catch was on the 2nd trip, as much as 4,430 kg, and the lowest on the 7th trip, with no catch. The highest *D. ruselli* catch was on the 6th trip, as much as 4,763 kg, and the lowest was on the 3rd trip, with ~~was~~ 665 kg. Based on all catches, *K. pelamis* was the most dominant fish caught compared to other fish. This can be seen in Figure 2 below.

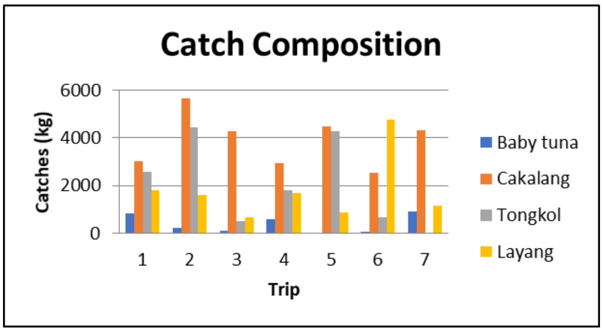

Figure 2. Composition diagram of the catch.

Average K. pelamis per operation~~setting~~operation ~~results~~. The catch of *K. pelamis* is higher than that of other types. The total catch of *K. pelamis* from the 1st trip to the 7th trip was 27,238 kg. The average highest catch of *K. pelamis* ~~with the highest setting~~Operationper operation was recorded on the 3rd trip, with~~as~~ 1,495 kg, while the lowest catch ~~on~~ per operation was recorded on the 6th trip, with ~~was~~ 422.67 kg. The catch of the 1st trip was 754.5 kg, the 2nd trip was 946 kg, the 3rd trip was 1,495 kg, the 4th trip was 737 kg, the 5th trip was 744.5 kg, the 6th trip was 422, 67 kg, the 7th trip was 720.5 kg, as shown in Figure 3 below.

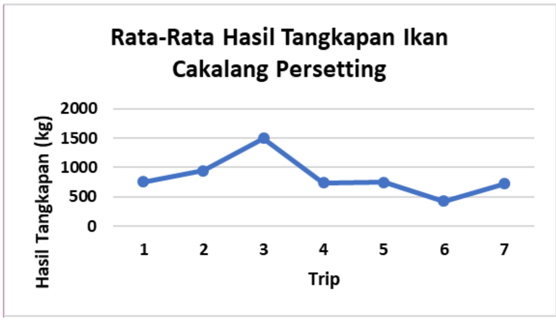

Figure 3. Diagram of the average catch of *K. pelamis*.

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Chlorophyll-a. Because ~~Fertile~~ fertile waters contain high chlorophyll-a concentrations, ~~because~~ the chlorophyll-a is eligible as an indicator of fertility in waters. The chlorophyll-a concentration is also influenced by other factors such as currents. Chlorophyll-a image data were downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). The data ~~will be~~ were processed using Seadas which ~~will~~ produce chlorophyll-a data which is recycled using the help of a computer device, then the data will be processed using Surfer 13 which will be processed in the form of a JPEG image format which displays the distribution of chlorophyll-a with different colors for each chlorophyll-a. The distribution of chlorophyll-a was taken based on the time and position of the capture operation. The following ~~is a~~ JPG images ~~format of~~ represent the chlorophyll-a distribution ~~in~~ over the 7 fishing trips ~~of fishing~~.

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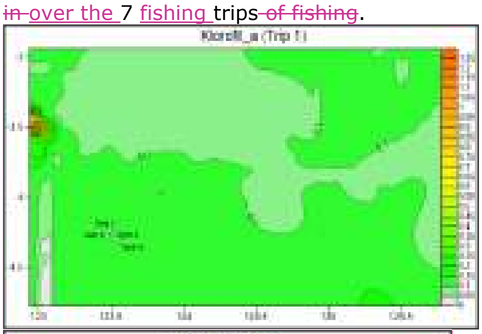

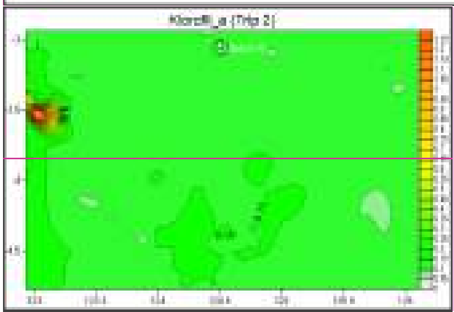

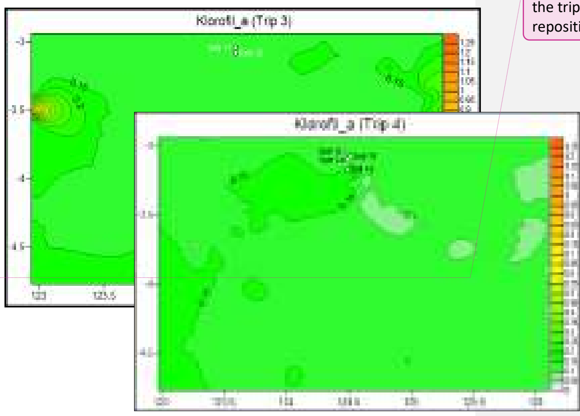

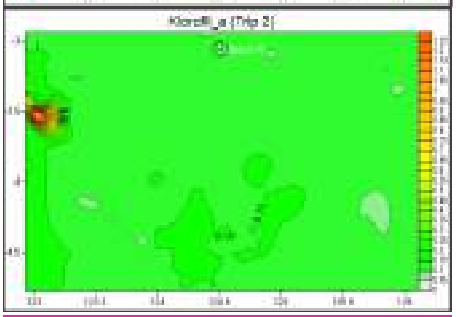

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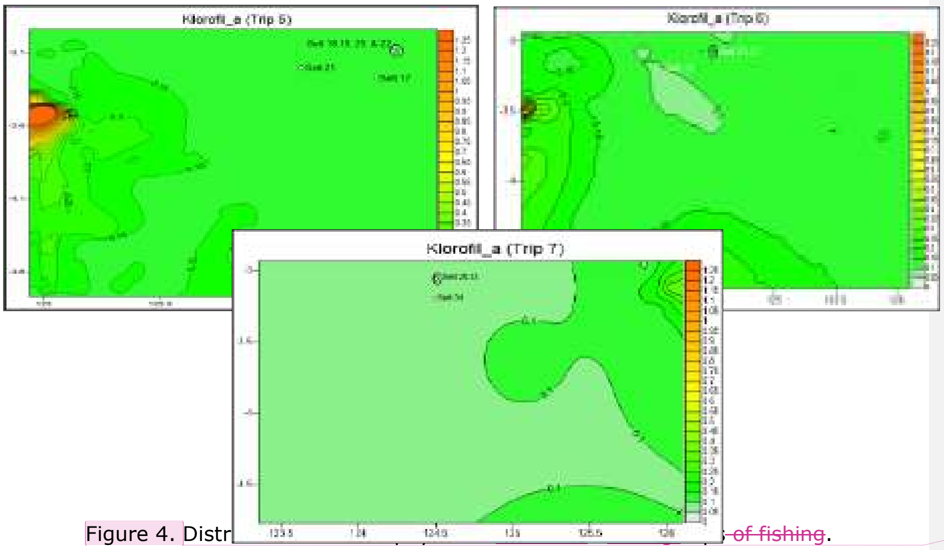

Figure 4. Distr ~~-of fishing~~.

Table 4

Chlorophyll-a Concentration Values

	Chlorophyll-a Concentration Value (mg m^{3})						
	1st ~~Setting~~Operation	2nd ~~Setting~~Operation	3rd ~~Setting~~Operation	4th ~~Setting~~Operation	5th ~~Setting~~Operation	6th ~~Setting~~Operation	Average
Trip 1	0.1308	0.1292	0.1273	0.1268	-	-	0.1285
Trip 2	0.1176	0.1176	0.1173	0.1266	0.1176	0.1266	0.1205
Trip 3	0.1399	0.1342	-	-	-	-	0.1370
Trip 4	0.1046	0.1080	0.1077	0.1632	-	-	0.1209
Trip 5	0.1314	0.1312	0.1312	0.1314	0.1313	0.1258	0.1303
Trip 6	0.1208	0.1288	0.1287	0.1227	0.1281	0.1001	0.1215
Trip 7	0.0895	0.0903	0.0913	0.0880	0.0875	0.0894	0.0893

The distribution of the highest chlorophyll-a concentrations

The distribution of the lowest chlorophyll-a concentrations

The chlorophyll-a concentration value on the 7th trip decreased significantly, ~~which was the lowest concentration value~~ compared to the other trips. The higher the chlorophyll-a concentration value in the waters, the more fertile the waters. ~~will be and conversely the lower the concentration of the waters, the less fertile the waters will be.~~

Average chlorophyll-a. The average chlorophyll-a can be seen in Figure 5, where the concentration of the 7th trip decreased, ~~the concentration of chlorophyll-a which was greatly decreased~~ compared to the ~~concentration on the~~ other trips. ~~The chlorophyll-a concentration can be seen in the image below which shows a decrease and an increase in the chlorophyll-a concentration.~~ The average chlorophyll-a concentration was the highest ~~in~~ on trip ~~three~~ 3 and the lowest ~~in~~ on trip 7. The difference between the highest and lowest concentrations is 0.0477 mg m^{-3}.

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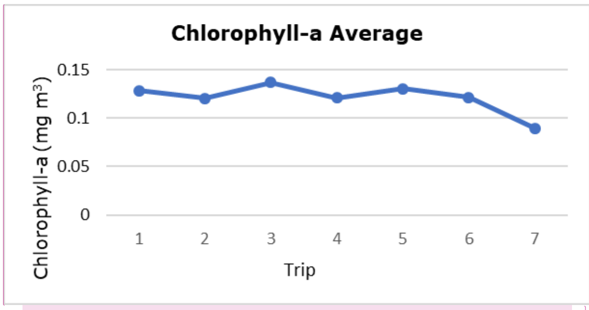

Figure 5. Diagram of average chlorophyll-a for 7 trips.

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The relationship between average chlorophyll-a against K. pelamis. The relationship of chlorophyll-a to the catch of *K. pelamis* was calculated using a multiple correlation test. ~~Multiple~~ The multiple correlation estimator for the level of chlorophyll-a relationship to *K. pelamis* catch~~.~~ was determined by~~Manual multiple correlation test~~ using SPSS 25.

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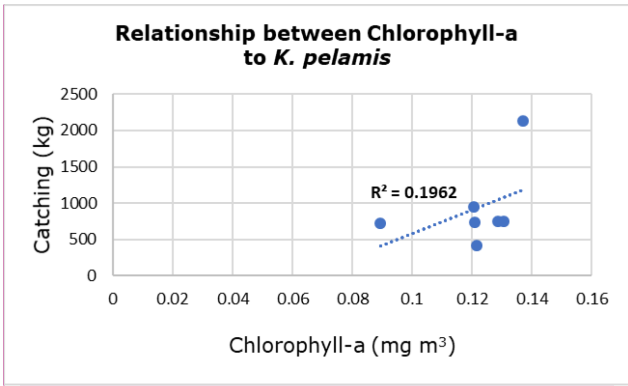

Figure 6. Graph of chlorophyll-a relationship to *K. pelamis*.

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Based on graph 6 above, the coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% ~~is~~ are explained by other factors such as salinity~~,~~ and currents. ~~and others.~~

The value of the correlation coefficient using SPSS 25 can be seen in table 4. The correlation coefficient value was obtained at 0.443, which means that the positive relationship between chlorophyll-a and the catch of *K. pelamis* is moderate, because the correlation coefficient value is in the correlation interval 0.40-0.599. This relationship is ~~stated as~~ positive~~,~~: if the value of one variable is increased, it will increase the value of the other variables and vice versa (Sugiono 2007~~).~~), while ~~So the positive relationship between chlorophyll-a and the catch of *K. pelamis*, this means that if the chlorophyll-a is higher it will increase the catch, and vice versa i~~if the chlorophyll-a ~~is lower~~decreases, it will decrease the catch of *K. pelamis*.

Hypothesis testing via the t test is used to determine whether the hypothesis is accepted or rejected~~, then the t test is used~~, based on~~.~~ ~~This hypothesis uses the help of~~ the c~~C~~oefficients table (Table 7). Based on this table, the t_{count} value of chlorophyll-a is 3,320, $t_{count} > t_{table}$ (3,320 > 2.77, respectively) and ~~a~~ the sig value of 0.029 (< 0.05~~.~~), therefore ~~Based on the results obtained, the value $t_{count} > t_{table}$ = 3,320 > 2.77 and the value of sig. 0.029 < 0.05. Obtained H_0~~the null hypothesis is rejected~~ and H_1 is accepted~~,

~~so there is~~due to the~~a~~ significant effect ~~between~~ of chlorophyll-a ~~and~~ on the catch of *K. pelamis*, ~~this is~~ in accordance with a previous research conducted by Demena et al (2017), which states that chlorophyll-a and the number of catches *K. pelamis* ~~has~~ have a unidirectional relationship~~,~~ and the chlorophyll-a concentration affects the presence of *K. pelamis*.

The effect of chlorophyll-a on the catch of K. pelamis. Chlorophyll-a is an indicator that greatly influences the presence of fish in the waters, especially *K. pelamis*, ~~because *K. pelamis* is a fish~~a migratory species~~ that likes to immigrate its life~~. ~~Knowing T~~the effect of chlorophyll-a on the catch of K. pelamis is calculated using the multiple linear regression, with the ~~help of~~ SPSS 25, and manual calculations were performed using a computer device.

Table 5

Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.882[a]	.779	.668	320.54745
a. Predictors: (Constant), Chlorophyll-a				

Based on the results obtained in table 5 above the coefficient of determination (R^2) = 0.779 or 77.9%. This shows ~~that~~ an influence of 77.9% of the ~~influence~~ chlorophyll-a on the catch of *K. pelamis*, so that the remaining 22.1% ~~is~~ are influenced by other factors such as currents and ~~,~~ salinity~~, and others~~. The correlation coefficient (R) in the model summary table above is 0.882. Based on table 5, the relationship level, ~~of~~ given by the correlation coefficient (R), is included in the interval at 0.80-1.00, which means that the level of chlorophyll-a relationship to the catch of *K. pelamis* is very strong.

Table 6

ANOVA regression table

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1444657.089	2	722328.544	7.030	.049[b]
	Residual	411002.672	4	102750.668		
	Total	1855659.760	6			
a. Dependent Variable: *K. pelamis*						
b. Predictors: (Constant), Chlorophyll-a, Sea Surface Temperature (SST)						

~~Hypothesis test used is the~~A F_{test}~~, this test is~~ was conducted to ~~test~~ check the ~~effect~~ influence of chlorophyll-a ~~(independent)~~ together with the SST (independent variables) on the catch of *K. pelamis* (dependent variable)~~ which will know the results of the hypothesis are accepted or rejected. ,~~ demonstrating ~~The results obtained in the~~a significant effect (in the ANOVA regression table, the significance level is ~~value~~ 0.049 < 0.05 ~~So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05~~ or $F_o \geq F_{table}$). ~~If H_o is rejected and H_1 is accepted, then there is a significant effect between SST and chlorophyll-a on the catch of *K. pelamis*, this is based on~~ A ~~p~~previous research, conducted by Demena et al (2017), ~~which states~~ stated that sea surface temperature and chlorophyll-a are two ~~indicators. which greatly affects~~predictors of the presence of fish in the waters, especially concerning *K. pelamis*.

Based on the output of SPSS 25 ~~in~~ (the coefficients ~~a table~~matrix) and on the manual calculations using ~~the help of~~ a computer device, the ~~results of the~~ multiple linear regression equation ~~are~~ could be expressed as follows:

$$Y = -21557.333 + 642.160\ X_1 + 33535.607\ X_2$$

T~~Based on t~~he multiple linear regression equation above~~, it~~ can be interpreted as follows:

- ~~a = -21557.333 means that~~ if the variables X_1 (SST) and X_2 (chlorophyll-a) have a value of 0, then the variable Y is -21557.33 kg (intercept).

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- ~~b_1 = 642,160 means that~~ if the variable X_1 (SST) increases by 1ºC and the other variables are constant, then the variable Y will increase by 642,160 kg.
- ~~b_2 = 33535,607 means that~~ if the X_2 variable (chlorophyll-a) increases by 1 mg m^3 and the other variables are constant, then the Y variable will increase by 33535,607 kg.

***Distribution of chlorophyll-a against K. pelamis catch*.**

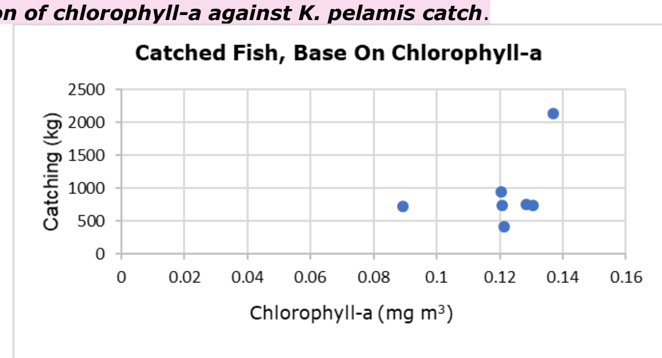

Figure 7. Catch ~~fish~~ based on chlorophyll-a.

~~Based on~~In the figure above, the highest catch ~~is~~ occurs at a concentration of 0.137 mg m^{-3}. T~~Based on t~~he graph of the relationship between chlorophyll-a and the catch of *K. pelamis*, ~~it~~ shows that the concentration of chlorophyll-a and the catch of *K. pelamis* ~~has~~ have a unidirectional relationship~~, which means that the catch of *K. pelamis* increases, so the concentration in these waters increases, and vice versa~~. The results showed that the ~~potential area for~~ *K. pelamis* maximum fishing potential occurs for~~based on the~~ an ~~optimum~~ optimal chlorophyll-a concentration ~~for chlorophyll-a~~of ~~was~~ 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a ~~optimum~~ chlorophyll-a in the optimal range of 0.12-0.22 mg m^{-3}.

Conclusions. Based on the results and discussion that has been described, it can be concluded as follows:

1. The coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the real model of 19.6%, so the rest is explained by other factors of 80.4%. Based on the t_{test}, the t_{count} value of chlorophyll-a was 3,320, the sig value was 0.029. A significant effect between chlorophyll-a and *K. pelamis* was demonstrated For the t_{table} value of 2.77. Based on the results, the value of $t_{count} > t_{table}$ and sig value is $0.029 < 0.05$. ~~So it is obtained that H_o is rejected and H_1 is accepted~~, so ~~there is a significant effect between chlorophyll-a and *K. pelamis*~~.
2. The results obtained in the ANOVA table, the value of $R^2 = 0.779$ or 77.9% is the effect of chlorophyll on *K. pelamis,* so that the remaining 22.1% is another factor. Based on the calculation of the F_{test} using SPSS 25 and manually, the value of F_o = 7.030 and the value of F_{table} = 6.94 is obtained. The results obtained in the ANOVA table sign value 0.049 <0.05 So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or $F_o \geq F_{table}$, so there is a significant effect of chlorophyll-a on *K. pelamis.*

Conflict of interest. The authors declare no conflict of interest.

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Kembali Arsipkan Pindahkan Hapus Spam

Adnal Yeka <[illegible]@yahoo.com>
Kepada: Eni Kovacs

Kam, 19 Mei 2022 jam 07.21

Dear Dr. Eni...
I send edited manuscript. thank you.

Tampilkan pesan asli

Yeka Katau... .doc

The effect of chlorophyll-a on the catches of skipjack tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

[1]Adnal Yeka, [1]Defra Monika, [1]Ratih M. Rahmani, [1]Deni Sarianto, [1]Yulia Fitri, [2]Eli Nurlaela, [2]Bongbongan Kusmedy, [2]Erick Nugraha

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Abstract. Potential areas for catching *K. pelamis* have a close relationship with environmental parameters, especially chlorophyll-a. Remote sensing methods are used to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions.~~, as a technology which helps observing oceanographic parameters and determining the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea. On this purpose, the multiple linear regression method was used to analyze their relationship.~~ Based on the results of the study, it is known that (1) the value of the coefficient of determination (R_2) is 0.196 or 19.6%. it means that the chlorophyll-a factor can only explain the real model by 19.6% so that the rest is provided by other factors of 80.4%. Based on the t_{test}, the t_{count} value of chlorophyll-a is 3.320, the sig value is 0.029. For the t_{table} value of 2.77. the results are based on the value of $t_{count} > t_{table}$ and the value of sig $0.029 < 0.05$. So that the H_o obtained is rejected and H_1 is accepted, then there is a significant effect between chlorophyll-a and *K. pelamis*. (2) in the ANOVA table the value of $R^2 = 0.779$ or 77.9% the effect of chlorophyll on *K. pelamis*, so the remaining 22.1% is another factor. Based on the calculation of F with SPSS 25 and manually obtained the value of $F_o = 7.030$ and the value of $F_{table} = 6.94$.
~~Based on the results and discussions that have been described, it can be concluded that: (1) the value of the coefficient of determination (R_2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor can only explain the real data by 19.6%, so that the remaining 80.4% of the catch volume is explained by other factors; (2) Based on the t_{test}, the t_{count} value of chlorophyll-a was 3.32, the sig value was 0.029. For the t_{table} value of 2.77. The results show that $t_{count} > t_{table}$ and sig value of $0.029 < 0.05$. So it was found that H_o was rejected and H_1 was accepted, then there was a significant effect between chlorophyll-a and K. pelamis. (3) in the ANOVA regression table the value of $R^2 = 0.779$ or 77.9% the effect of chlorophyll-a on K. pelamis, so the remaining 22.1% is another factor; (4) from the calculation of the F_{test} using SPSS 25 and manually, it results that the value of $F_0 = 7.030$ and the value of $F_{table} = 6.94$.~~ The results obtained in the ANOVA table have a sig value of $0.049 < 0.05$. So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or F_0 F_{table}, so there is a significant effect of chlorophyll-a on *K. pelamis*.

Key Words: purse seine, remote sensing, sea surface temperature (SST), catch season.

Introduction. The Banda Sea owes its abundance to a high –nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea (Putra et al 2017). The topography of the seabed is very complex, with a basin in the west and a trough in the east (Suyarso 1999; Tapilatu 2016). This complex topographical shape also determines the mass exchange of water. The circulation of different water massesvaries between seasons and is influenced by the monsoon system's wind pattern.

The circulation of water mass in Indonesian waters differs between the west monsoon and the east monsoon. In the west monsoon, water masses generally flow to the east of Indonesian waters. The eastern monsoons develop perfectly, supplying water

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masses originating from the upwelling areas in the Arafura and Banda Seas (Hasanudin 1998). The upwelling process that occurs in the Banda Sea results in a decrease of temperatures, an increase of salinity and the removal of nutrients, so that their availability will affect the abundance of plankton in the waters (Baars et al 1990; Armus et al 2019).

The potential area for catching Skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ranges from 0.12 to 0.22 mg m^{-3} (Zainuddin 2011; Hidayat et al 2019; Wangi et al 2019). Almost all fish populations that live in marine waters, including *K. pelamis*, require optimal sea surface temperature (SST) range and chlorophyll-a values for their survival (Jufri et al 2014). Remote sensing technology helps observing the oceanographic parameters of the surrounding waters in the Banda Sea, so that it can determine the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea. The purpose of this study was to analyze the relationship and effect of chlorophyll-a on the catch of *K. pelamis* (Mugo et al 2010).

K. pelamis likes areas where there is a convergence of currents that mostly occur in areas with many islands. The vertical distribution of *K. pelamis* starts from the surface to a depth of 260 m during the day, while at night it will go to the surface (diurnal migration) (Ekayana et al 2017). *K. pelamis* specimens from the small size category tend to be caught at a more homogeneous (warm) SST, while large *K. pelamis* are caught in a wider range of SST (cold and warm) (Simbolon & Limbong 2012). *K. pelamis* congregate at low chlorophyll-a concentrations and water depths of ≥ 500 m, because *K. pelamis* is a carnivorous fish with the main prey of small pelagic fish such as *Stelophorus sp.* and *Sardinella sp.*, which are abundant in the continetal shelf and sloping waters (Bubun et al 2015).

Remote sensing technology is an alternative method that is very beneficial if it is used in a country with a very large area such as Indonesia (Syah 2010). Remote sensing is a technique for collecting information about objects and their environment from a distance without physical touch (Lo 1986). The use of remote sensing methods to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions is a very appropriate alternative (Tangke 2016; Mashita & Lumban-Gaol 2019). Remote sensing technology has several advantages including cheap and easily accessible data prices, wide area coverage, high temporal resolution and digitalized data supply, making it a potential source for the geographic information system (GIS) data (Louhenapessy & Waas 2009).

One of the sensing satellites equipped with sensors that can detect the chlorophyll-a content is the Aqua MODIS satellite (Utari 2013). The variables measured by the Aqua satellite include the aerosols, land-covering plants, phytoplankton and dissolved organic matter in the oceans, as well as the air, land and water temperature (Putra et al 2012). The Aqua MODIS satellite has a polar sun-synchronous orbit. The satellite crosses the equator at noon, approaching at 13.30 local time (Karif ~~2014~~2011).

Changes in fishing actually occur when the seasons' change. Seasonal changes directly affect the oceanographic aspects of the waters, especially sea surface temperature and chlorophyll-a, which greatly influence the presence of fish in an area, determining the fishing grounds in that area. Both of these parameters can trigger natural events or phenomena such as upwelling and fronts (Waileruny & Wiyono 2014~~Waileruny et al 2014~~). The fishing season in Southeast Sulawesi waters can be found in January to April and from July to September, and it can affect the salinity of the habitat of the caught fish species. In the eastern monsoon (June to September), high salinity water masses originating from the Flores Sea and Pacific Ocean flow through the Makassar Strait to the Java Sea. In the western season (December to March) surface currents move from the South China Sea into the Java Sea from west to east (Bubun & Mahmud 2016). On this purpose, the multiple linear regression method was used to analyze their relationship. ~~(...)~~

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Material and Method. The tools and materials needed in the implementation of this research include: stationery, cameras, rulers, GPS, MODIS data and the softwares SeaDas, SPSS Statistics 25 and Surfer 13.0.

Method of collecting data. The data collection method uses primary data, carried out *in situ* by direct observation of the fishing operation including operating time, the number of catches and the position of the fishing area, and by using secondary data including the image of the distribution of chlorophyll-a, from the level 3 of the Aqua MODIS, downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). Data were processed using the Seadas to get the chlorophyll value and the Surfer 13 to get the distribution of chlorophyll-a in the form of images.

The chlorophyll-a image data chosen to be processed is a standard 8-day image with a 4 km resolution map of level 3, at night, from November 2017 to March 2018. Chlorophyll-a data was calculated using chlorophyll-a image data that has been adjusted with both atmospheric and geometrical corrections. Seadas produced the chlorophyll-a distribution data which was reprocessed using a computer device, then using the Surfer 13, which will produced the distribution data of chlorophyll-a in the JPEG image format.

The catch used includes the catch weight of *K. pelamis* during November 2017 to March 2018, analyzed by calculating the weight per fishing trip, so that fluctuations in the catch based on time (temporal) and fishing location (spatial) can be observed.

Multiple correlation analysis. The multiple correlation showed the direction and strength of the relationship between the studied variables. To be able to provide an interpretation of the correlation coefficients found, reference values are listed in Table 1 below (Sugiono 2007).

Table 1

Assessment of the correlation coefficient (Sugiono 2007)

Coefficient interval	*Relationship level*
0.00–0.199	Very low
0.20–0.399	Low
0.40–0.599	Moderate
0.60–0.799	Strong
0.80–1.00	Very strong

The double correlation formula for two variables is ~~(...):~~ (Sugiyono 2007):

$$R_{y.x_1x_2} = \sqrt{\frac{r^2_{yx1} + r^2_{yx2} - 2r_{yx1}r_{yx2}\,r_{x1x2}}{1 - r^2_{x1x2}}}$$

Where:
$R_{y.x_1x_2}$ - correlation of the variables X_1 and X_2 with the variable Y;
ryx_1 - correlation between X_1 and Y;
ryx_2 - correlation between X_2 and Y;
rx_1x_2 - correlation between X_1 and X_2.

Multiple linear regression analysis. When the correlation coefficient is sufficiently high, a multiple linear regression was used to examine the variables relationship (Sugiono 2005), as follows:

$$Y = a + b_1X_1 + b_2X_2$$

Where:
X_1 - variable sea surface temperature;
X_2 - chlorophyll-a variable;
Y - the maximum quantity of certain fish species caught;

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Multiple linear statistical test. According to Hasan (2004), multiple linear regression statistical tests are used to test the significance of the relationship of more than two variables through the regression coefficient. The multiple linear regression statistical tests can be divided into two categories, namely:

~~1. Concurrent Test~~

1. Simultaneous Test

The test is carried out in multiple linear regression using the F test, which is a statistical test for the regression coefficient that together affects Y, namely: ~~The test conducted in multiple linear regression uses the simultaneous test, which is a statistical test for the regression coefficient that simultaneously or jointly affects Y, this test uses the F test, namely:~~

$$F_o = \frac{R^2(n-k-1)}{k(1-R^2)}$$

Where:

n - number of ~~subjects~~fish caught;

k - number of independent variables.

~~$\sum y^2$ - sum of squares of the variable Y.~~

R^2 – determinant coefficient

1. Individual Test

Individual test, namely the regression statistic with only one regression coefficient affecting Y, using the t_{test}:

$$t_o = \frac{b_1 - B_i}{S_{b1}}$$

where t : the value of t_{table}

When the regression formula involves only two independent variables, the values of S_{b1} and S_{b2} are as follows:

$$S_{b1} = \sqrt{S_e^2 \frac{\sum x_2^2}{(\sum x_1^2)(\sum x_2^2) - (\sum x_1 x_2)^2}}$$

$$S_{b2} = \sqrt{S_e^2 \frac{\sum x_1^2}{(\sum x_1^2)(\sum x_2^2) - (\sum x_1 x_2)^2}}$$

$$S_e = \sqrt{\frac{\sum e_i^2}{n-3}} = \sqrt{\frac{\sum y^2 - b_1 \sum x_1 y - b_2 \sum x_2 y}{n-3}}$$

Where :

S_{bk} = Standard Error of Estimator bk, k = 1, 2

e = confounding error (values of other variables not included in the equation)

Geographical information analysis. The Surfer 13 software was used to map the distribution of *chlorophyll-a* from November 2017 to March 2018, based on time (temporal) and fishing location (spatial), with the aim of producing information about the relationship of these variables.

Results and Discussion

This research was conducted from November 2017 to May 2018 by following a fishing operation using a purse seiner in the Banda Sea, Maluku Indonesia.

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Figure 1. Purse seiner (original).

Fish catch results. The fishing operation was carried out in seven trips, with 34 setting. The total catch was 56,689 kg with an average of 12,558.17 kg. The number of catches on the 2nd trip (6 setting) was the largest, with a total catch of 11,954 kg (an average of 1,992.33 kg per setting) or 21.1% of the total catch. Meanwhile, the 3rd trip (2 setting) recorded the smallest total catch, namely 5,522 kg or 9.7% of the total catch, but with the highest average per setting, of 2,761 kg (Table 2).

Table 2

The number of fish catch per trip

Trip	*Number of settings*	*Amount (Kg)*	*Average (Kg)*	*Percentage (%)*
1st	4	8,226	2,056.5	14.5
2nd	6	11,954	1,992.33	21.1
3rd	2	5,522	2,761	9.7
4th	4	7,006	1,751.5	12.4
5th	6	9,607	1,601.16	17
6th	6	7,982	1,330.33	14.1
7th	6	6,392	1,065.33	11.2
Total	34	56,689	12,558.17	100

Composition of catch. The catch data consists of seven trips with 34 settings. The main catches are *K. pelamis*, *T. albacares*, *E. affinis* and *D. ruselli*. Based on the results obtained, the highest *T. albacares* catches were on the 7th trip and the lowest was on the 5th trip. *K. pelamis* catches reached the highest value on the 2nd trip and the lowest on the 6th trip. The highest *T. albacares* catches were on the 2nd trip and the lowest was on the 7th trip, and the highest *D. ruselli* was on the 6th trip and the lowest was on the 3rd trip. The composition of the catch can be seen in table 3 below.

Table 3

The composition of the catch based on the type of fish

Trip to-	*Total catch (Kg)*				*Total*
	T. albacares	*K. pelamis*	*E. affinis*	*D.ruselli*	
1st	825	3,018	2,590	1,793	8,226
2nd	230	5,676	4,430	1,618	11,954
3rd	90	4,270	497	665	5,522
4th	569	2,948	1,817	1,672	7,006
5th	0	4,467	4,290	850	9,607
6th	13	2,536	670	4,763	7,982
7th	915	4,323	0	1,154	6,392

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Based on the data mentioned above, the highest catch was on the second trip, as much as 11,954 kg, consisting of 230 kg *T. albacares*, 5,676 kg *K. pelamis*, 4,430 kg *E. affinis* and 1,618 kg *D. ruselli*. The lowest catch was on the 3rd trip, as much as 5,522 kg, consisting of 90 kg *T. albacares*, 4,270 kg *K. pelamis*, 497 kg *E. affinis* and 665 kg *D. ruselli*.

The highest catch of *T. albacares* was on the 7th trip, as much as 915 kg, while the lowest was on the 5th trip, with no catch. The highest catch of *K. pelamis* was on the 2nd trip, as much as 5,676 kg, while the lowest was on the 6th trip, with 2,536 kg. The highest *E. affinis* catch was on the 2nd trip, as much as 4,430 kg, and the lowest on the 7th trip, with no catch. The highest *D. ruselli* catch was on the 6th trip, as much as 4,763 kg, and the lowest was on the 3rd trip, with 665 kg. Based on all catches, *K. pelamis* was the most dominant fish caught compared to other fish. This can be seen in Figure 2 below.

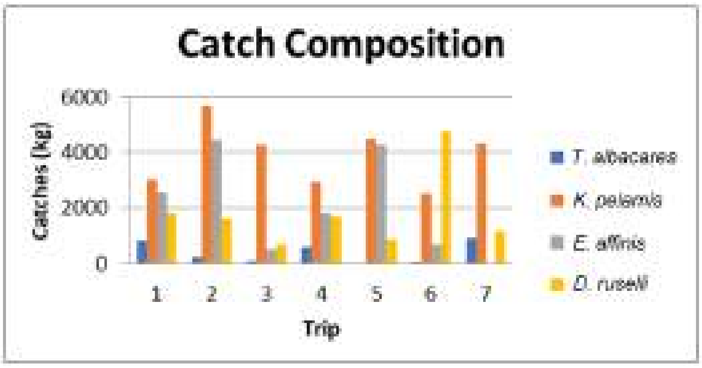

Figure 2. Composition diagram of the catch.

Average K. pelamis per setting. The catch of *K. pelamis* is higher than that of other types. The total catch of *K. pelamis* from the 1st trip to the 7th trip was 27,238 kg. The average highest catch of *K. pelamis* Operationper operation was recorded on the 3rd trip, with 1,495 kg, while the lowest catch per operation was recorded on the 6th trip, with 422.67 kg. The catch of the 1st trip was ~~754.5~~3,018 kg, the 2nd trip was ~~946~~ 5,676 kg, the 3rd trip was ~~1,495~~4,270 kg, the 4th trip was ~~737~~ 2,948 kg, the 5th trip was ~~744.5~~4,467 kg, the 6th trip was ~~422, 67~~2,536 kg, the 7th trip was ~~720.5~~4,323 kg, as shown in Figure 3 below.

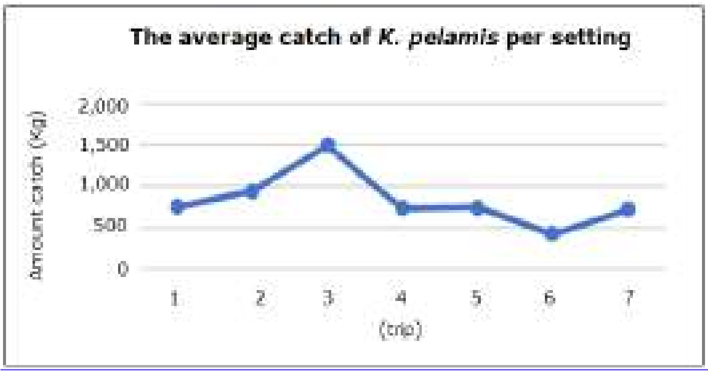

Figure 3. Diagram of the average catch of *K. pelamis.*

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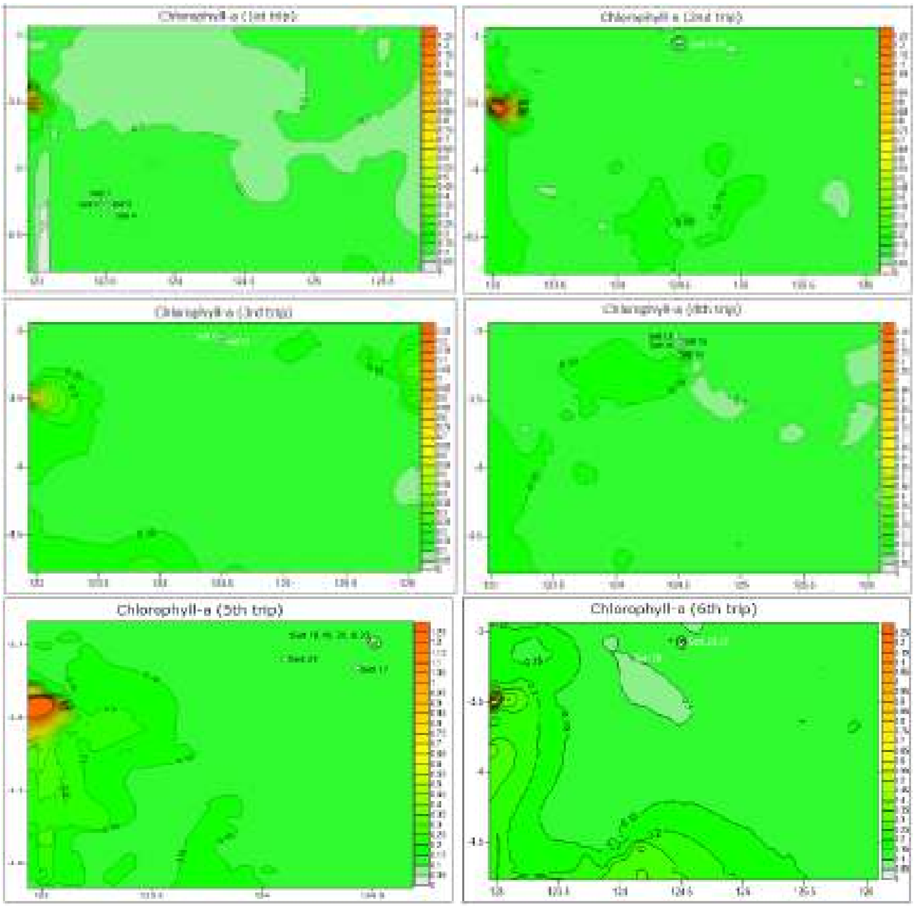
Chlorophyll-a. Because fertile waters contain high chlorophyll-a concentrations, the chlorophyll-a is eligible as an indicator of fertility in waters. The chlorophyll-a concentration is also influenced by other factors such as currents. Chlorophyll-a image data were downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). ~~The data were processed using Seadas which produce chlorophyll-a data which is recycled using the help of a computer device, then the data will be processed using Surfer 13 which will be processed in the form of a JPEG image format which displays the distribution of chlorophyll-a with different colors for each chlorophyll-a.~~ The research data was processed using Seadas to produce chlorophyll-a data. Furthermore, the data is processed using Surfer 13 into JPEG format images that display the distribution of chlorophyll-a with different colors. The distribution of chlorophyll-a was taken based on the time and position of the capture operation. The following JPG images represent the chlorophyll-a distribution over the 7 fishing trips.



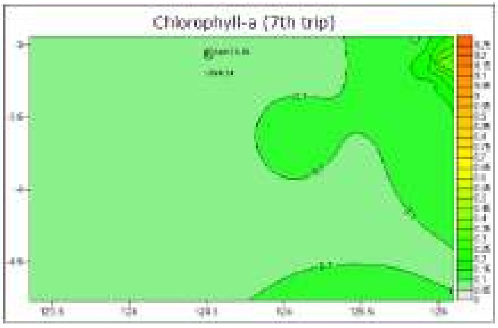


Figure 4. Distribution of chlorophyll-a over the 7 fishing trips.

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Table 4

Chlorophyll-a Concentration Values

	Chlorophyll-a Concentration Value (mg m^3)						
	1st Setting	2nd Setting	3rd Setting	4th Setting	5th Setting	6th Setting	Average
Trip 1	0.1308	0.1292	0.1273	0.1268	-	-	0.1285
Trip 2	0.1176	0.1176	0.1173	0.1266	0.1176	0.1266	0.1205
Trip 3	0.1399	0.1342	-	-	-	-	0.1370
Trip 4	0.1046	0.1080	0.1077	0.1632	-	-	0.1209
Trip 5	0.1314	0.1312	0.1312	0.1314	0.1313	0.1258	0.1303
Trip 6	0.1208	0.1288	0.1287	0.1227	0.1281	0.1001	0.1215
Trip 7	0.0895	0.0903	0.0913	0.0880	0.0875	0.0894	0.0893

The distribution of the highest chlorophyll-a concentrations

The distribution of the lowest chlorophyll-a concentrations

The chlorophyll-a concentration value on the 7th trip decreased significantly, compared to the other trips. The higher the chlorophyll-a concentration value in the waters, the more fertile the waters.

Average chlorophyll-a. The average chlorophyll-a can be seen in Figure 5, where the concentration of the 7th trip decreased, compared to the other trips. The average chlorophyll-a concentration was the highest on trip 3 and the lowest on trip 7. The difference between the highest and lowest concentrations is 0.0477 mg m^{-3}.

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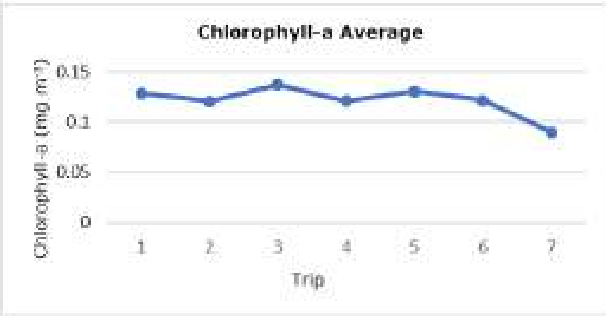

Figure 5. Diagram of average chlorophyll-a for 7 trips.

The relationship between average chlorophyll-a against K. pelamis. The relationship of chlorophyll-a to the catch of *K. pelamis* was calculated using a multiple correlation test. The multiple correlation estimator for the level of chlorophyll-a relationship to *K. pelamis* catch was determined by using SPSS 25.

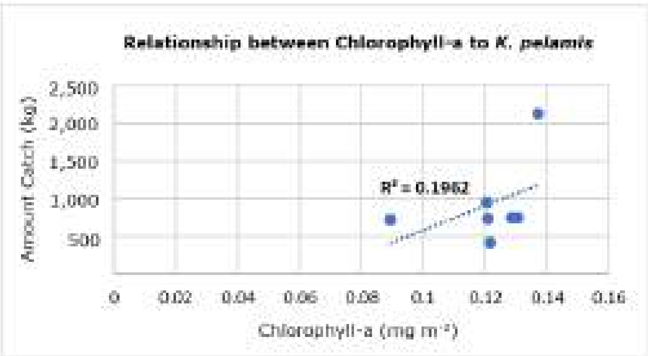

Figure 6. Graph of chlorophyll-a relationship to *K. pelamis.*

Based on graph 6 above, the coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents.

The value of the correlation coefficient using SPSS 25 can be seen in table 4. The correlation coefficient value was obtained at 0.443, which means that the positive relationship between chlorophyll-a and the catch of *K. pelamis* is moderate, because the correlation coefficient value is in the correlation interval 0.40-0.599. This relationship is positive: if the value of one variable is increased, it will increase the value of the other variables and vice versa (Sugiono 2007), while if the chlorophyll-a decreases, it will decrease the catch of *K. pelamis*.

Hypothesis testing via the t test is used to determine whether the hypothesis is accepted or rejected, based on the coefficients table (Table 7). Based on this table, the t_{count} value of chlorophyll-a is 3,320, $t_{count} > t_{table}$ (3,320 > 2.77, respectively) and the sig value of 0.029 (< 0.05), therefore the null hypothesis is rejected, due to the significant effect of chlorophyll-a on the catch of *K. pelamis*, in accordance with a previous research conducted by Demena et al (2017), which states that chlorophyll-a and the number of catches *K. pelamis* have a unidirectional relationship and the chlorophyll-a concentration affects the presence of *K. pelamis*.

The effect of chlorophyll-a on the catch of K. pelamis. Chlorophyll-a is an indicator that greatly influences the presence of fish in the waters, especially *K. pelamis*, a migratory species. The effect of chlorophyll-a on the catch of *K. pelamis* is calculated using the multiple linear regression, with the SPSS 25, and manual calculations were performed using a computer device.

Table 5

Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.882[a]	.779	.668	320.54745
a. Predictors: (Constant), Chlorophyll-a				

Based on the results obtained in table 5 above the coefficient of determination (R^2) = 0.779 or 77.9%. This shows an influence of 77.9% of the chlorophyll-a on the catch of *K. pelamis*, so that the remaining 22.1% are influenced by other factors such as currents and salinity. The correlation coefficient (R) in the model summary table above is 0.882. Based on table 5, the relationship level, given by the correlation coefficient (R), is included in the interval at 0.80-1.00, which means that the level of chlorophyll-a relationship to the catch of *K. pelamis* is very strong.

Table 6

ANOVA regression table

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1444657.089	2	722328.544	7.030	.049[b]
	Residual	411002.672	4	102750.668		
	Total	1855659.760	6			
a. Dependent Variable: *K. pelamis*						
b. Predictors: (Constant), Chlorophyll-a, Sea Surface Temperature (SST)						

A F_{test} was conducted to check the influence of chlorophyll-a together with the SST (independent variables) on the catch of *K. pelamis* (dependent variable), demonstrating a significant effect (in the ANOVA regression table, the significance level is 0.049 < 0.05 or $F_o \geq F_{table}$). A previous research, conducted by Demena et al (2017), stated that sea surface temperature and chlorophyll-a are two predictors of the presence of fish in the waters, especially concerning *K. pelamis*.

Based on the output of SPSS 25 (the coefficients matrix) ~~and on the manual calculations using a computer device,~~ the multiple linear regression equation could be expressed as follows:

$$Y = -21557.333 + 642.160\ X_1 + 33535.607\ X_2$$

The multiple linear regression equation above can be interpreted as follows:

1. if the variables X_1 (SST) and X_2 (chlorophyll-a) have a value of 0, then the variable Y is -21557.33 kg (intercept).
2. if the variable X_1 (SST) increases by 1ºC and the other variables are constant, then the variable Y will increase by 642,160 kg.
3. if the X_2 variable (chlorophyll-a) increases by 1 mg m^{-3} and the other variables are constant, then the Y variable will increase by 33535,607 kg.

Distribution of chlorophyll-a ~~against~~ with K. pelamis catch.

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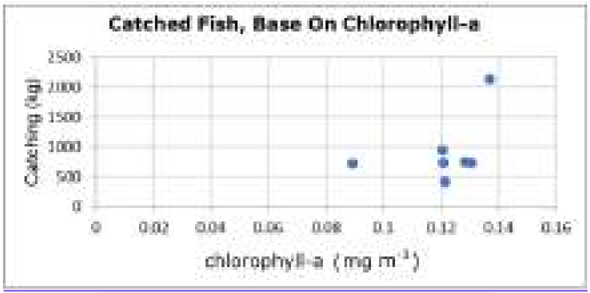

Figure 7. Catch based on chlorophyll-a.

In the figure above, the highest catch occurs at a concentration of 0.137 mg m^{-3}. The graph of the relationship between chlorophyll-a and the catch of *K. pelamis*, shows that the concentration of chlorophyll-a and the catch of *K. pelamis* have a unidirectional relationship. The results showed that the *K. pelamis* maximum fishing potential occurs for an optimal chlorophyll-a concentration of 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a chlorophyll-a in the optimal range of 0.12-0.22 mg m^{-3}.

Conclusions. Based on the results and discussion that has been described, it can be concluded as follows:

1. The value of the coefficient of determination (R_2) is 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%. Based on the t test, the SST value was 3.243, the sig value was 0.032. For a value of 2.77. Based on the results obtained the value > and sig value 0.032 <0.05. So, if H_o is accepted and rejected, then there is a significant effect between SST and *K. pelamis* catch.
2. The coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the real model of 19.6%, so the rest is explained by other factors of 80.4%. Based on the t_{test}, the t_{count} value of chlorophyll-a was 3,320, the sig value was 0.029. A significant effect between chlorophyll-a and *K. pelamis* was demonstrated For the t_{table} value of 2.77. Based on the results, the value of $t_{count} > t_{table}$ and sig value is 0.029 < 0.05. ~~so~~. *So that obtained H_o is accepted and rejected, then there is a significant effect between SST and skipjack catch.*
3. ~~3.~~ The results obtained in the ANOVA table, the value of R^2 = 0.779 or 77.9% is the effect of chlorophyll on *K. pelamis,* so that the remaining 22.1% is another factor. Based on the calculation of the F_{test} using SPSS 25 and manually, the value of F_o = 7.030 and the value of F_{table} = 6.94 is obtained. The results obtained in the ANOVA table sign value 0.049 <0.05 So it can be concluded that H_o is rejected and H_1 is accepted because the sign value is <0.05 or $F_o \geq F_{table}$, so there is a significant effect of chlorophyll-a on *K. pelamis.*

Conflict of interest. The authors declare no conflict of interest.

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The effect of chlorophyll-a on the catches of skipjack tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

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Abstract. The Banda Sea is located in the waters of Central Maluku Regency, Maluku Province. The topography of the seabed is very complex with a basin in the west and a trough in the east. The shape of the topography is also decisive in controlling the exchange of water masses. The purpose of this study was to analyze the relationship of chlorophyll-a and the effect of its distribution on the catch of skipjack tuna (*Katsuwonus pelamis*). The study used the data analysis method, namely the multiple linear regression (computerized data processing using the SPSS 25 program). Primary data was obtained by following fishing operations and secondary data was collected from chlorophyll-a images downloaded from the NASA database in the form of an average per trip. The results of the study showed that the coefficient of determination (R_2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents. The results of the t-test obtained a t_count chlorophyll-a value of 3.320, sig value of 0.029 and t_table value of 2.77. Based on the value of t_count>t_table and the value of sig 0.029<0.05, there was a significant effect between chlorophyll-a and *K. pelamis*; the ANOVA table showed the value of R^2=0.779 or 77.9% the effect of chlorophyll on *K. pelamis*, so the remaining 22.1% was influenced by other factors. Based on the results obtained, chlorophyll-a had a significant effect on *K. pelamis*.

Key Words: purse seine, remote sensing, sea surface temperature (SST), catch season.

Introduction. The Banda Sea owes its abundance to a high nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea (Putra et al 2017). The topography of the seabed is very complex, with a basin in the west and a trough in the east (Suyarso 1999; Tapilatu 2016). This complex topographical shape also determines the mass exchange of water. The circulation of different water massesvaries between seasons and is influenced by the monsoon system's wind pattern. The circulation of water mass in Indonesian waters differs between the west monsoon and the east monsoon. In the west monsoon, water masses generally flow to the east of Indonesian waters. The eastern monsoons develop perfectly, supplying water masses originating from the upwelling areas in the Arafura and Banda Seas (Hasanudin 1998). The upwelling process that occurs in the Banda Sea results in a decrease of temperatures, an increase of salinity and the removal of nutrients, so that their availability will affect the abundance of plankton in the waters (Baars et al 1990; Armus et al 2019).

The potential area for catching skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ranges from 0.12 to 0.22 mg m^3 (Zainuddin 2011; Hidayat et al 2019; Wangi et al 2019). Almost all fish populations that live in marine waters, including *K. pelamis*, require optimal sea surface temperature (SST) range and chlorophyll-a values for their survival (Jufri et al 2014). Remote sensing technology helps observing the oceanographic

parameters of the surrounding waters in the Banda Sea, so that it can determine the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea.

K. pelamis likes areas where there is a convergence of currents that mostly occur in areas with many islands. The vertical distribution of *K. pelamis* starts from the surface to a depth of 260 m during the day, while at night it will go to the surface (diurnal migration) (Ekayana et al 2017). *K. pelamis* specimens from the small size category tend to be caught at a more homogeneous (warm) SST, while large *K. pelamis* are caught in a wider range of SST (cold and warm) (Simbolon & Limbong 2012). *K. pelamis* congregate at low chlorophyll-a concentrations and water depths of ≥500 m, because *K. pelamis* is a carnivorous fish with the main prey of small pelagic fish such as *Stelophorus sp.* and *Sardinella sp.*, which are abundant in the continental shelf and sloping waters (Bubun et al 2015).

Remote sensing technology is an alternative method that is very beneficial if it is used in a country with a very large area such as Indonesia (Syah 2010). Remote sensing is a technique for collecting information about objects and their environment from a distance without physical touch (Lo 1986). The use of remote sensing methods to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions is a very appropriate alternative (Tangke 2016; Mashita & Lumban-Gaol 2019). Remote sensing technology has several advantages including cheap and easily accessible data prices, wide area coverage, high temporal resolution and digitalized data supply, making it a potential source for the geographic information system (GIS) data (Louhenapessy & Waas 2009). One of the sensing satellites equipped with sensors that can detect the chlorophyll-a content is the Aqua MODIS satellite (Utari 2013). The variables measured by the Aqua satellite include the aerosols, land-covering plants, phytoplankton and dissolved organic matter in the oceans, as well as the air, land and water temperature (Putra et al 2012). The Aqua MODIS satellite has a polar sun-synchronous orbit. The satellite crosses the equator at noon, approaching at 13:30 local time (Karif 2011).

Changes in fishing actually occur when the seasons' change. Seasonal changes directly affect the oceanographic aspects of the waters, especially sea surface temperature and chlorophyll-a, which greatly influence the presence of fish in an area, determining the fishing grounds in that area. Both of these parameters can trigger natural events or phenomena such as upwelling and fronts (Waileruny & Wiyono 2014). The fishing season in Southeast Sulawesi waters can be found in January to April and from July to September, and it can affect the salinity of the habitat of the caught fish species. In the eastern monsoon (June to September), high salinity water masses originating from the Flores Sea and Pacific Ocean flow through the Makassar Strait to the Java Sea. In the western season (December to March) surface currents move from the South China Sea into the Java Sea from west to east (Bubun & Mahmud 2016). The present research aimed to analyze how much influence chlorophyll-a had on the number of *K. pelamis*, knowing the distribution of chlorophyll-a concentrations in the Banda Sea, Maluku. In this way, fishermen can be more effective in determining the area and time of catch.

Material and Method. The tools and materials needed in the implementation of this research include: stationery, cameras, rulers, GPS, MODIS data and the softwares SeaDas, SPSS Statistics 25 and Surfer 13.0.

Method of collecting data. The data collection method uses primary data, carried out *in situ* by direct observation of the fishing operation including operating time, the number of catches and the position of the fishing area, and by using secondary data including the image of the distribution of chlorophyll-a, from the level 3 of the Aqua MODIS, downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). Data were processed using the Seadas to get the chlorophyll value and the Surfer 13 to get the distribution of chlorophyll-a in the form of images.

The chlorophyll-a image data chosen to be processed is a standard 8-day image with a 4 km resolution map of level 3, at night, from November 2017 to March 2018.

Chlorophyll-a data was calculated using chlorophyll-a image data that has been adjusted with both atmospheric and geometrical corrections. Seadas produced the chlorophyll-a distribution data which was reprocessed using a computer device, then using the Surfer 13, which will produced the distribution data of chlorophyll-a in the JPEG image format. The catch used includes the catch weight of *K. pelamis* analyzed by calculating the weight per fishing trip, so that fluctuations in the catch based on time (temporal) and fishing location (spatial) can be observed.

Multiple correlation analysis. The multiple correlations showed the direction and strength of the relationship between the studied variables. To be able to provide an interpretation of the correlation coefficients found, reference values are listed in Table 1 (Sugiono 2007).

Table 1

Assessment of the correlation coefficient (Sugiono 2007)

Coefficient interval	*Relationship level*
0.00–0.199	Very low
0.20–0.399	Low
0.40–0.599	Moderate
0.60–0.799	Strong
0.80–1.00	Very strong

The double correlation formula for two variables is the following (Sugiono 2007):

$$R_{y.x_1x_2} = \sqrt{\frac{r^2_{yx1} + r^2_{yx2} - 2r_{yx1}r_{yx2}\ r_{x1x2}}{1-r^2_{x1\,x2}}}$$

Where:
$R_{y.x_1x_2}$ - correlation of the variables X_1 and X_2 with the variable Y;
ryx_1 - correlation between X_1 and Y;
ryx_2 - correlation between X_2 and Y;
rx_1x_2 - correlation between X_1 and X_2.

Multiple linear regression analysis. When the correlation coefficient is sufficiently high, a multiple linear regression was used to examine the variables relationship, as follows (Sugiono 2005):

$$Y = a + b_1X_1 + b_2X_2$$

Where:
X_1 - variable sea surface temperature;
X_2 - chlorophyll-a variable;
Y - the maximum quantity of certain fish species caught;
a, b_1, b_2 - constants.

Multiple linear statistical test. According to Hasan (2004), multiple linear regression statistical tests are used to test the significance of the relationship of more than two variables through the regression coefficient. The multiple linear regression statistical tests can be divided into two categories, namely:
1. Concurrent test
The test is carried out in multiple linear regressions using the F test, a statistical test for the regression coefficient that together affects Y, namely:

$$F_o = \frac{R^2(n-k-1)}{k(1-R^2)}$$

Where:
n - number of fish caught;

k - number of independent variables;
R^2 - determination coefficient.
2. Individual test
Individual test, namely the regression statistic with only one regression coefficient affecting Y, using the t_{test}:

$$t_o = \frac{b_1 - B_i}{S_{b1}}$$

Where:
b_1 - regression slope coefficient;
B_i - hypothesized slope;
S_{bi} - standard deviation of slope.

Geographical information analysis. The Surfer 13 software was used to map the distribution of *chlorophyll-a* from November 2017 to March 2018, based on time (temporal) and fishing location (spatial), with the aim of producing information about the relationship of these variables.

Results and Discussion

This research was conducted from November 2017 to May 2018 by following a fishing operation using a purse seiner in the Banda Sea, Maluku Indonesia.

Figure 1. Purse seiner (original photo).

Fish catch results. The fishing operation was carried out in seven trips, with a total catch of 56,689 kg and an average of 12,558.17 kg per 34 operations. The number of catches on the 2^{nd} trip (6 operations) was the largest, with a total catch of 11,954 kg (an average of 1,992.33 kg per operation) or 21.1% of the total catch. Meanwhile, the 3^{rd} trip (2 operations) recorded the smallest total catch, namely 5,522 kg or 9.7% of the total catch, but with the highest average per operation, of 2,761 kg (Table 2).

Table 2

The number of fish catch per trip

Trip	*Number of operations*	*Amount (kg)*	*Average (kg)*	*Percentage (%)*
1^{st}	4	8,226	2,056.5	14.5
2^{nd}	6	11,954	1,992.33	21.1
3^{rd}	2	5,522	2,761	9.7
4^{th}	4	7,006	1,751.5	12.4
5^{th}	6	9,607	1,601.16	17
6^{th}	6	7,982	1,330.33	14.1
7^{th}	6	6,392	1,065.33	11.2
Total	34	56,689	12,558.17	100

Catch composition. The catch data consists of seven trips with 34 operations. The main catches are *K. pelamis*, *T. albacares*, *E. affinis* and *D. ~~ruselli~~russelli*. Based on the results obtained, the highest *T. albacares* catches were on the 7^{th} trip and the lowest was on the 5^{th} trip. *K. pelamis* catches reached the highest value on the 2^{nd} trip and the lowest on the 6th trip. The highest *T. albacares* catches were on the 2nd trip and the lowest was on the 7th trip, and the highest *D.* ~~*ruselli*~~*russelli* was on the 6th trip and the lowest was on the 3rd trip. The composition of the catch can be seen in Table 3 below.

Table 3

The composition of the catch based on the type of fish

Trip to-	*Total catch (Kg)*				*Total*
	T. albacares	*K. pelamis*	*E. affinis*	*D.* ~~*ruselli*~~*russelli*	
1st	825	3,018	2,590	1,793	8,226
2nd	230	5,676	4,430	1,618	11,954
3rd	90	4,270	497	665	5,522
4th	569	2,948	1,817	1,672	7,006
5th	0	4,467	4,290	850	9,607
6th	13	2,536	670	4,763	7,982
7th	915	4,323	0	1,154	6,392

Based on the data mentioned above, the highest catch was on the second trip, and the lowest catch was on the 3rd trip. The highest catch of *T. albacares* was on the 7th trip, as much as 915 kg, while the lowest was on the 5th trip, with no catch. The highest catch of *K. pelamis* was on the 2nd trip, as much as 5,676 kg, while the lowest was on the 6th trip, with 2,536 kg. The highest *E. affinis* catch was on the 2nd trip, as much as 4,430 kg, and the lowest on the 7th trip, with no catch. The highest *D.* ~~*ruselli*~~*russelli* catch was on the 6th trip, as much as 4,763 kg, and the lowest was on the 3rd trip, with 665 kg. Based on all catches, *K. pelamis* was the most dominant fish caught compared to other fish (Figure 2).

Commented [e'n1]: We change the fish scientific name

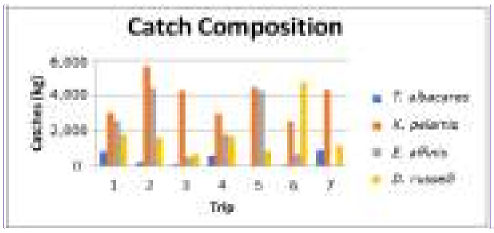

Figure 2. Composition diagram of the catch.

Average K. pelamis per operation. The catch of *K. pelamis* is higher than that of other types. The total catch of *K. pelamis* from the 1st trip to the 7th trip was 27,238 kg. The average highest catch per operation of *K. pelamis* was recorded on the 3rd trip, with 1,495 kg, while the lowest catch per operation was recorded on the 6th trip, with 422.67 kg. The catch of the 1st trip was 3,018 kg, the 2nd trip was 5,676 kg, the 3rd trip was 4,270 kg, the 4th trip was 2,948 kg, the 5th trip was 4,467 kg, the 6th trip was 2,536 kg, the 7th trip was 4,323 kg (Figure 3).

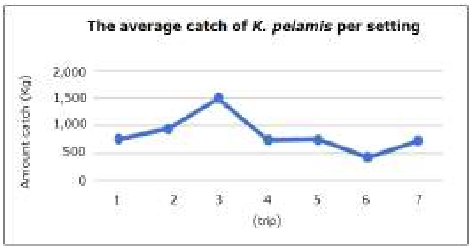

Figure 3. Diagram of the average catch of *Katsuwonus pelamis.*

Chlorophyll-a. Because fertile waters contain high chlorophyll-a concentrations, the chlorophyll-a is eligible as an indicator of fertility in waters. The chlorophyll-a concentration is also influenced by other factors such as currents. Chlorophyll-a image data were downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). The research data was processed using Seadas to produce chlorophyll-a data. Furthermore, the data was processed using Surfer 13 into JPEG format images that display the distribution of chlorophyll-a with different colors. The distribution of chlorophyll-a was taken based on the time and position of the capture operation. Figure 4 shows the chlorophyll-a distribution over the 7 fishing trips.

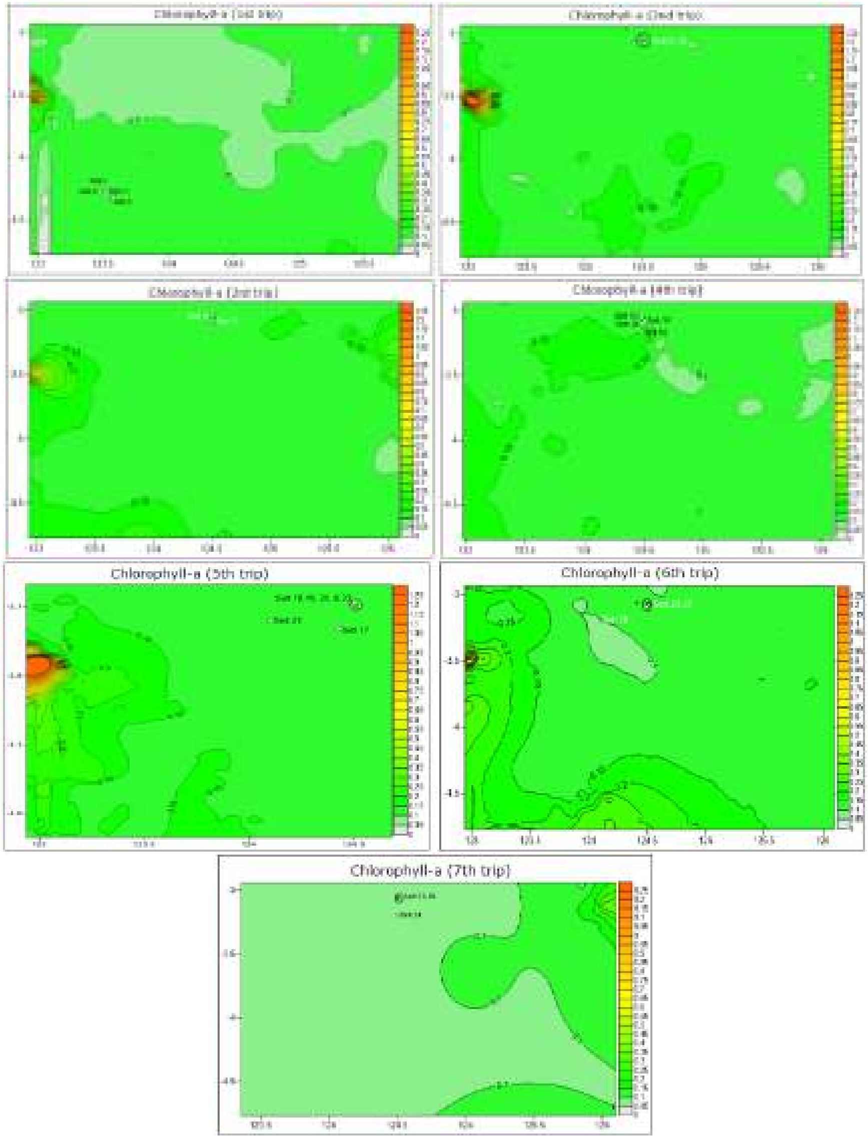

Figure 4. Distribution of chlorophyll-a over the 7 fishing trips.
The chlorophyll-a concentration values can be seen in Table 4 below.

Table 4

Chlorophyll-a concentration values

Trips	*Chlorophyll-a concentration value (mg m^3)*						
	1st operation	*2nd operation*	*3rd operation*	*4th operation*	*5th operation*	*6th operation*	*Average*
Trip 1	0.1308[a]	0.1292	0.1273	0.1268[b]	-	-	0.1285
Trip 2	0.1176	0.1176	0.1173[b]	0.1266	0.1176	0.1266[a]	0.1205
Trip 3	0.1399[a]	0.1342[b]	-	-	-	-	0.1370
Trip 4	0.1046[b]	0.1080	0.1077	0.1632[a]	-	-	0.1209
Trip 5	0.1314	0.1312	0.1312	0.1314[a]	0.1313	0.1258[b]	0.1303
Trip 6	0.1208	0.1288[a]	0.1287	0.1227	0.1281	0.1001[b]	0.1215
Trip 7	0.0895	0.0903	0.0913[a]	0.0880	0.0875[b]	0.0894	0.0893

[a] the distribution of the highest chlorophyll-a concentrations; [b] the distribution of the lowest chlorophyll-a concentrations.

The chlorophyll-a concentration value on the 7th trip decreased significantly, compared to the other trips. The higher the chlorophyll-a concentration value in the waters, the more fertile the waters.

Average chlorophyll-a. The average chlorophyll-a can be seen in Figure 5, where the concentration of the 7th trip decreased, compared to the other trips. The average chlorophyll-a concentration was the highest on trip 3 and the lowest on trip 7. The difference between the highest and lowest concentrations is 0.0477 mg m^{-3}.

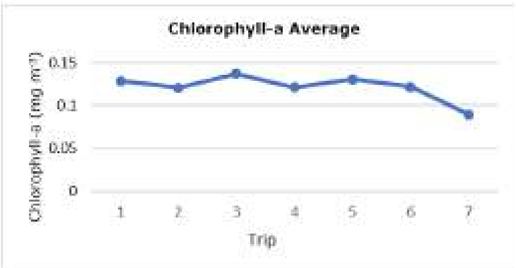

Figure 5. Diagram of average chlorophyll-a for 7 trips.

The relationship between average chlorophyll-a against K. pelamis. The relationship of chlorophyll-a to the catch of *K. pelamis* was calculated using a multiple correlation test. The multiple correlation estimator for the level of chlorophyll-a relationship to *K. pelamis* catch was determined by using SPSS 25.

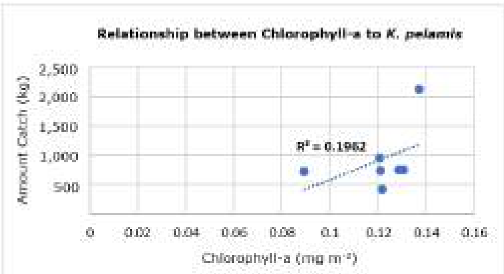

Figure 6. Graph of chlorophyll-a relationship to *Katsuwonus pelamis.*

Based on Figure 6 above, the coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents.

The value of the correlation coefficient using SPSS 25 can be seen in table 4. The correlation coefficient value was obtained at 0.443, which means that the positive relationship between chlorophyll-a and the catch of *K. pelamis* is moderate, because the correlation coefficient value is in the correlation interval 0.40-0.599. This relationship is positive: if the value of one variable is increased, it will increase the value of the other variables and vice versa (Sugiono 2007), while if the chlorophyll-a decreases, it will decrease the catch of *K. pelamis*.

Hypothesis testing via the t test is used to determine whether the hypothesis is accepted or rejected, based on the coefficients table (Table 7). Based on this table, the t_{count} value of chlorophyll-a is 3,320, $t_{count}>t_{table}$ (3,320>2.77, respectively) and the sig value of 0.029 (<0.05), therefore the null hypothesis is rejected, due to the significant effect of chlorophyll-a on the catch of *K. pelamis*, in accordance with a previous research conducted by Demena et al (2017), which states that chlorophyll-a and the number of catches *K. pelamis* have a unidirectional relationship and the chlorophyll-a concentration affects the presence of *K. pelamis*.

The effect of chlorophyll-a on the catch of K. pelamis. Chlorophyll-a is an indicator that greatly influences the presence of fish in the waters, especially *K. pelamis*, a migratory species. The effect of chlorophyll-a on the catch of *K. pelamis* is calculated using the multiple linear regression, with the SPSS 25, and manual calculations were performed using a computer device.

Based on the results obtained in Table 5, the coefficient of determination (R^2)=0.779 or 77.9%. This shows an influence of 77.9% of the chlorophyll-a on the catch of *K. pelamis*, so that the remaining 22.1% are influenced by other factors such as currents and salinity. The correlation coefficient (R) in the model summary table above is 0.882. Based on table 5, the relationship level, given by the correlation coefficient (R), is included in the interval at 0.80-1.00, which means that the level of chlorophyll-a relationship to the catch of *K. pelamis* is very strong.

Table 5

Model summary

Model	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*
1	0.882[a]	0.779	0.668	320.54745

[a]Predictors: (Constant), Chlorophyll-a.

The hypothesis test used is the F test, carried out to test the effect of SST and chlorophyll-a on *K. pelamis* catches which will determine whether the results of the hypothesis are accepted or rejected. Hypothesis testing used SPSS 25 and manually obtained the value of F_o=7.030 and value=6.94 (Table 6). The results obtained in the ANOVA table have a sign value of 0.049<0.05. If H_o is rejected and H_1 is accepted, it means that there is a significant effect between SST and chlorophyll-a on *K. pelamis* catches, this is in accordance with the research conducted by Demena et al (2017) which stated that SST and chlorophyll-a are two indicators that greatly affect the presence of fish in the waters, especially *K. pelamis.*

Table 6

ANOVA regression table

Model	*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*
Regression	1,444,657.089	2	722,328.544	7.030	0.049[b]
Residual	411,002.672	4	102,750.668		
Total	1,855,659.760	6			

[b] Predictors: Constant, Chlorophyll-a, Sea Surface Temperature (SST).

Relationship of average SST to K. pelamis. SST can be used as an indicator to determine the presence of a fish species in waters. Each fish species has a certain temperature tolerance value so that it affects the presence and distribution of fish in the waters. To see the relationship between SST and the presence of *K. pelamis*, the catch data (in-situ) and SST data on the position and time of catching (ex-situ) were taken with SPSS 25 using a computer device. The relationship of SST to the catch of *K. pelamis* was calculated using the multiple correlation test, as an estimator (Figure 7).

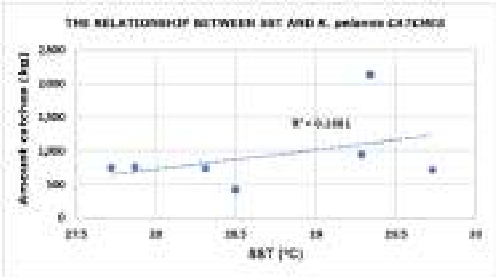

Figure 7. Graph of the relationship between SST and *Katsuwonus pelamis.*

Based on the graph above, the coefficient of determination (R_2) is 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%.

The assessment of the value of the correlation coefficient using SPSS 25 can be seen in Table 7. The correlation coefficient value obtained is 0.410, which means that the positive relationship between SST and the catch of *K. pelamis* is moderate, because the correlation value is in the correlation interval of 0.40-0.599.

Table 7

Correlations

Correlations				
Model		*K. pelamis*	*SST*	*Chlorophyl-a*
Pearson correlation	*K. pelamis*	1.000	0.410	0.443
	SST	0.410	1.000	-0.532
	Chlorophyl-a	0.443	-0.532	1.000
Sig. (1-tailed)	*K. pelamis*	0	0.180	0.160
	SST	0.180	0	0.109
	Chlorophyl-a	0.160	0.109	0
N	*K. pelamis*	7	7	7
	SST	7	7	7
	Chlorophyl-a	7	7	7

Based on Table 8, the results obtained the $t_{count}>t_{table}$ and sig value 0.032<0.05, it was found that H_o was rejected and H_1 accepted, there was a significant effect between SST and the catch of *K. pelamis*. A previous research conducted by Fajrianti (2016) stated that SST had a significant effect on the catch.

Based on the output of SPSS 25 (the coefficients matrix), the multiple linear regression equation could be expressed as follows:

$$Y = -21,557.333 + 642.160\ X_1 + 33,535.607\ X_2$$

The multiple linear regression equation above can be interpreted as follows:

- if the variables X_1 (SST) and X_2 (chlorophyll-a) have a value of 0, then the variable Y is -21,557.33 kg (intercept).

- if the variable X_1 (SST) increases by 1ºC and the other variables are constant, then the variable Y will increase by 642,160 kg.
- if the X_2 variable (chlorophyll-a) increases by 1 mg m^{-3} and the other variables are constant, then the Y variable will increase by 33,535.607 kg.

Table 8

Coefficients

	Coefficients[a]					
Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. error	Beta		
	(Constant)	-21,557.333	6,416.374		-3.360	0.028
1	SST	642.160	198.028	0.902	3.243	0.032
	Chlorophyl-a	33,535.607	10,100.263	0.923	3.320	0.029

Distribution of chlorophyll-a with K. pelamis catch. The graph of the relationship between chlorophyll-a and the catch of *K. pelamis* shows that the concentration of chlorophyll-a and the catch of *K. pelamis* have a unidirectional relationship (Figure 8).

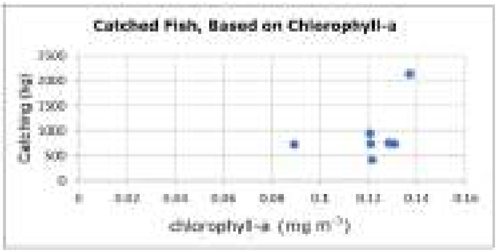

Figure 8. Catch based on chlorophyll-a.

In the figure above, the highest catch occurs at a concentration of 0.137 mg m^{-3}. The results showed that the *K. pelamis* maximum fishing potential occurs at an optimal chlorophyll-a concentration of 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a chlorophyll-a in the optimal range of 0.12-0.22 mg m^{-3}.

Conclusions. From the results of the research, it can be concluded that the main catches were *T. albacares*, *K. pelamis*, *E. affinis* and *D. ~~ruselli~~russelli*, *K. pelamis* being the most caught type of fish. The relationship between the sea surface temperature and *K. pelamis* catches was obtained in the form of a coefficient of determination (R_2) of 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%. There was a positive relationship between chlorophyll-a and *K. pelamis* catches, meaning that if the chlorophyll-a is higher, it will increase the catch, and vice versa if chlorophyll-a is lower, it will decrease the catch of *K. pelamis*. The results of the study concluded that the potential area for *K. pelamis* catching based on the optimum sea surface temperature was around 29°C and the optimum concentration for chlorophyll-a was around 0.13 mg m^{-3}.

Conflict of interest. The authors declare no conflict of interest.

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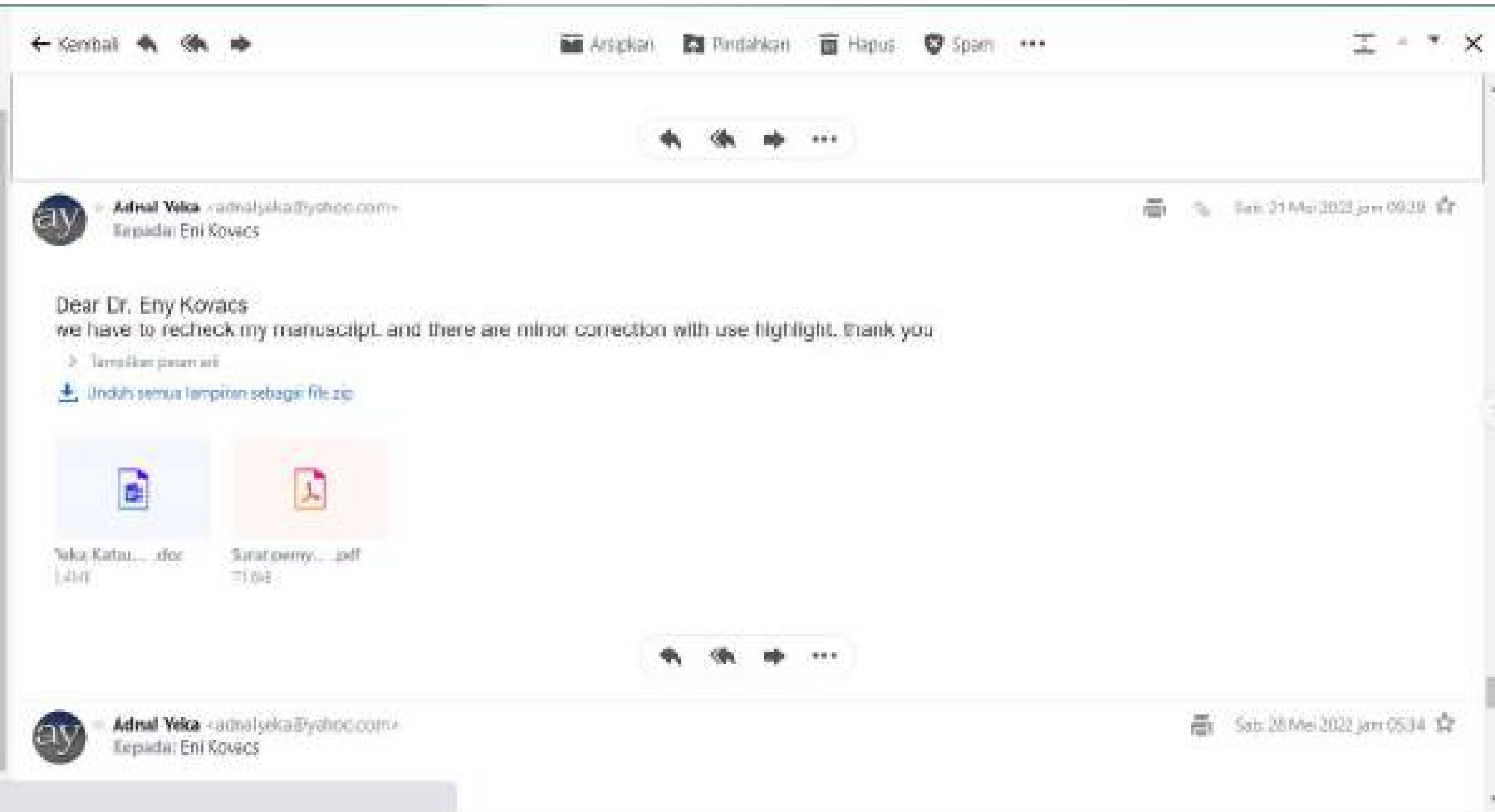

Kembali
Arsipkan
Pindahkan
Hapus
Spam
Adnal Yeka <adnalyeka@yahoo.com>
Kepada: Eni Kovacs
Sab, 21 Mei 2022 jam 09:29
Dear Dr. Eny Kovacs
we have to recheck my manuscipt. and there are minor correction with use higlight. thank you
Tampilkan pesan asli
Unduh semua lampiran sebagai file zip
Yeka Katu... .doc
Surat peny... .pdf
Adnal Yeka <adnalyeka@yahoo.com>
Kepada: Eni Kovacs
Sab, 28 Mei 2022 jam 05:34

STATEMENT LETTER

Hereby we declare our article with the title:

The effect of chlorophyll-a on the catches of skipjack tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

It has gone through several editing processes and we agreed to publish it. Thank you.

Name of the authors:

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Deni Sarianto	Yulia Fitri	Eli Nurlaela
Bongbongan Kusmedy	Erick Nugraha	Jerry Hutajulu

May 21, 2022

The effect of chlorophyll-a on the catches of skipjack tuna *(Katsuwonus pelamis)* in Banda Sea, Maluku, Indonesia

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Abstract. The Banda Sea is located in the waters of Central Maluku Regency, Maluku Province. The topography of the seabed is very complex with a basin in the west and a trough in the east. The shape of the topography is also decisive in controlling the exchange of water masses. The purpose of this study was to analyze the relationship of chlorophyll-a and the effect of its distribution on the catch of skipjack tuna (*Katsuwonus pelamis*). The study used the data analysis method, namely the multiple linear regression (computerized data processing using the SPSS 25 program). Primary data was obtained by following fishing operations and secondary data was collected from chlorophyll-a images downloaded from the NASA database in the form of an average per trip. The results of the study showed that the coefficient of determination (R2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents. The results of the t-test obtained a t_count chlorophyll-a value of 3.320, sig value of 0.029 and t_table value of 2.77. Based on the value of t_count>t_table and the value of sig 0.029<0.05, there was a significant effect between chlorophyll-a and *K. pelamis*; the ANOVA table showed the value of R^2=0.779 or 77.9% the effect of chlorophyll on *K. pelamis*, so the remaining 22.1% was influenced by other factors. Based on the results obtained, chlorophyll-a had a significant effect on *K. pelamis*.

Key Words: purse seine, remote sensing, sea surface temperature (SST), catch season.

Introduction. The Banda Sea owes its abundance to a high nutrient load. The distribution of these nutrients can be seen by the upwelling phenomenon in the Banda Sea (Putra et al 2017). The topography of the seabed is very complex, with a basin in the west and a trough in the east (Suyarso 1999; Tapilatu 2016). This complex topographical shape also determines the mass exchange of water. The circulation of different water massesvaries between seasons and is influenced by the monsoon system's wind pattern. The circulation of water mass in Indonesian waters differs between the west monsoon and the east monsoon. In the west monsoon, water masses generally flow to the east of Indonesian waters. The eastern monsoons develop perfectly, supplying water masses originating from the upwelling areas in the Arafura and Banda Seas (Hasanudin 1998). The upwelling process that occurs in the Banda Sea results in a decrease of temperatures, an increase of salinity and the removal of nutrients, so that their availability will affect the abundance of plankton in the waters (Baars et al 1990; Armus et al 2019).

The potential area for catching skipjack tuna (*Katsuwonus pelamis*) has a close relationship with the environmental parameters, especially the chlorophyll-a, whose optimum ranges from 0.12 to 0.22 mg m^3 (Zainuddin 2011; Hidayat et al 2019; Wangi et al 2019). Almost all fish populations that live in marine waters, including *K. pelamis*, require optimal sea surface temperature (SST) range and chlorophyll-a values for their survival (Jufri et al 2014). Remote sensing technology helps observing the oceanographic

parameters of the surrounding waters in the Banda Sea, so that it can determine the effect of chlorophyll-a on the catch of *K. pelamis* in the Banda Sea.

K. pelamis likes areas where there is a convergence of currents that mostly occur in areas with many islands. The vertical distribution of *K. pelamis* starts from the surface to a depth of 260 m during the day, while at night it will go to the surface (diurnal migration) (Ekayana et al 2017). *K. pelamis* specimens from the small size category tend to be caught at a more homogeneous (warm) SST, while large *K. pelamis* are caught in a wider range of SST (cold and warm) (Simbolon & Limbong 2012). *K. pelamis* congregate at low chlorophyll-a concentrations and water depths of ≥500 m, because *K. pelamis* is a carnivorous fish with the main prey of small pelagic fish such as *Stelophorus sp.* and *Sardinella sp*., which are abundant in the continental shelf and sloping waters (Bubun et al 2015).

Remote sensing technology is an alternative method that is very beneficial if it is used in a country with a very large area such as Indonesia (Syah 2010). Remote sensing is a technique for collecting information about objects and their environment from a distance without physical touch (Lo 1986). The use of remote sensing methods to detect oceanographic parameters including sea surface temperature (SST), salinity, chlorophyll-a index, currents and other oceanographic conditions is a very appropriate alternative (Tangke 2016; Mashita & Lumban-Gaol 2019). Remote sensing technology has several advantages including cheap and easily accessible data prices, wide area coverage, high temporal resolution and digitalized data supply, making it a potential source for the geographic information system (GIS) data (Louhenapessy & Waas 2009). One of the sensing satellites equipped with sensors that can detect the chlorophyll-a content is the Aqua MODIS satellite (Utari 2013). The variables measured by the Aqua satellite include the aerosols, land-covering plants, phytoplankton and dissolved organic matter in the oceans, as well as the air, land and water temperature (Putra et al 2012). The Aqua MODIS satellite has a polar sun-synchronous orbit. The satellite crosses the equator at noon, approaching at 13:30 local time (Karif 2011).

Changes in fishing actually occur when the seasons' change. Seasonal changes directly affect the oceanographic aspects of the waters, especially sea surface temperature and chlorophyll-a, which greatly influence the presence of fish in an area, determining the fishing grounds in that area. Both of these parameters can trigger natural events or phenomena such as upwelling and fronts (Waileruny & Wiyono 2014). The fishing season in Southeast Sulawesi waters can be found in January to April and from July to September, and it can affect the salinity of the habitat of the caught fish species. In the eastern monsoon (June to September), high salinity water masses originating from the Flores Sea and Pacific Ocean flow through the Makassar Strait to the Java Sea. In the western season (December to March) surface currents move from the South China Sea into the Java Sea from west to east (Bubun & Mahmud 2016). The present research aimed to analyze how much influence chlorophyll-a had on the number of *K. pelamis*, knowing the distribution of chlorophyll-a concentrations in the Banda Sea, Maluku. In this way, fishermen can be more effective in determining the area and time of catch.

Material and Method. The tools and materials needed in the implementation of this research include: stationery, cameras, rulers, GPS, MODIS data and the softwares SeaDas, SPSS Statistics 25 and Surfer 13.0.

Method of collecting data. The data collection method uses primary data, carried out *in situ* by direct observation of the fishing operation including operating time, the number of catches and the position of the fishing area, and by using secondary data including the image of the distribution of chlorophyll-a, from the level 3 of the Aqua MODIS, downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). Data were processed using the Seadas to get the chlorophyll value and the Surfer 13 to get the distribution of chlorophyll-a in the form of images.

The chlorophyll-a image data chosen to be processed is a standard 8-day image with a 4 km resolution map of level 3, at night, from November 2017 to March 2018.

Chlorophyll-a data was calculated using chlorophyll-a image data that has been adjusted with both atmospheric and geometrical corrections. Seadas produced the chlorophyll-a distribution data which was reprocessed using a computer device, then using the Surfer 13, which will produced the distribution data of chlorophyll-a in the JPEG image format. The catch used includes the catch weight of *K. pelamis* analyzed by calculating the weight per fishing trip, so that fluctuations in the catch based on time (temporal) and fishing location (spatial) can be observed.

Multiple correlation analysis. The multiple correlations showed the direction and strength of the relationship between the studied variables. To be able to provide an interpretation of the correlation coefficients found, reference values are listed in Table 1 (Sugiono 2007).

Table 1

Assessment of the correlation coefficient (Sugiono 2007)

Coefficient interval	*Relationship level*
0.00–0.199	Very low
0.20–0.399	Low
0.40–0.599	Moderate
0.60–0.799	Strong
0.80–1.00	Very strong

The double correlation formula for two variables is the following (Sugiono 2007):

$$R_{y.x_1x_2} = \sqrt{\frac{r_{yx1}^2 + r_{yx2}^2 - 2r_{yx1}r_{yx2}\ r_{x1x2}}{1-r^2_{x1\,x2}}}$$

Where:
$R_{y.x_1x_2}$ - correlation of the variables X_1 and X_2 with the variable Y;
ryx_1 - correlation between X_1 and Y;
ryx_2 - correlation between X_2 and Y;
rx_1x_2 - correlation between X_1 and X_2.

Multiple linear regression analysis. When the correlation coefficient is sufficiently high, a multiple linear regression was used to examine the variables relationship, as follows (Sugiono 2005):

$$Y = a + b_1X_1 + b_2X_2$$

Where:
X_1 - variable sea surface temperature;
X_2 - chlorophyll-a variable;
Y - the maximum quantity of certain fish species caught;
a, b_1, b_2 - constants.

Multiple linear statistical test. According to Hasan (2004), multiple linear regression statistical tests are used to test the significance of the relationship of more than two variables through the regression coefficient. The multiple linear regression statistical tests can be divided into two categories, namely:
1. Concurrent test
The test is carried out in multiple linear regressions using the F test, a statistical test for the regression coefficient that together affects Y, namely:

$$F_o = \frac{R^2(n-k-1)}{k(1-R^2)}$$

Where:
n - number of fish caught;

k - number of independent variables;
R^2 - determination coefficient.
2. Individual test
Individual test, namely the regression statistic with only one regression coefficient affecting Y, using the t_{test}:

$$t_o = \frac{b_1 - B_i}{S_{b1}}$$

Where:
b_1 - regression slope coefficient;
B_i - hypothesized slope;
S_{bi} - standard deviation of slope.

Geographical information analysis. The Surfer 13 software was used to map the distribution of *chlorophyll-a* from November 2017 to March 2018, based on time (temporal) and fishing location (spatial), with the aim of producing information about the relationship of these variables.

Results and Discussion

This research was conducted from November 2017 to May 2018 by following a fishing operation using a purse seiner in the Banda Sea, Maluku Indonesia.


Figure 1. Purse seiner (original photo).

Fish catch results. The fishing operation was carried out in seven trips, with a total catch of 56,689 kg and an average of 12,558.17 kg per 34 operations. The number of catches on the 2nd trip (6 operations) was the largest, with a total catch of 11,954 kg (an average of 1,992.33 kg per operation) or 21.1% of the total catch. Meanwhile, the 3rd trip (2 operations) recorded the smallest total catch, namely 5,522 kg or 9.7% of the total catch, but with the highest average per operation, of 2,761 kg (Table 2).

Table 2

The number of fish catch per trip

Trip	*Number of operations*	*Amount (kg)*	*Average (kg)*	*Percentage (%)*
1st	4	8,226	2,056.5	14.5
2nd	6	11,954	1,992.33	21.1
3rd	2	5,522	2,761	9.7
4th	4	7,006	1,751.5	12.4
5th	6	9,607	1,601.16	17
6th	6	7,982	1,330.33	14.1
7th	6	6,392	1,065.33	11.2
Total	34	56,689	12,558.17	100

Catch composition. The catch data consists of seven trips with 34 operations. The main catches are *K. pelamis*, *T. albacares*, *E. affinis* and *D. ruselli*. Based on the results obtained, the highest *T. albacares* catches were on the 7th trip and the lowest was on the 5th trip. *K. pelamis* catches reached the highest value on the 2nd trip and the lowest on

the 6th trip. The highest *T. albacares* catches were on the 2nd trip and the lowest was on the 7th trip, and the highest *D. ruselli* was on the 6th trip and the lowest was on the 3rd trip. The composition of the catch can be seen in Table 3 below.

Table 3

The composition of the catch based on the type of fish

Trip to-	*Total catch (Kg)*				*Total*
	T. albacares	*K. pelamis*	*E. affinis*	*D. ruselli*	
1st	825	3,018	2,590	1,793	8,226
2nd	230	5,676	4,430	1,618	11,954
3rd	90	4,270	497	665	5,522
4th	569	2,948	1,817	1,672	7,006
5th	0	4,467	4,290	850	9,607
6th	13	2,536	670	4,763	7,982
7th	915	4,323	0	1,154	6,392

Based on the data mentioned above, the highest catch was on the second trip, and the lowest catch was on the 3rd trip. The highest catch of *T. albacares* was on the 7th trip, as much as 915 kg, while the lowest was on the 5th trip, with no catch. The highest catch of *K. pelamis* was on the 2nd trip, as much as 5,676 kg, while the lowest was on the 6th trip, with 2,536 kg. The highest *E. affinis* catch was on the 2nd trip, as much as 4,430 kg, and the lowest on the 7th trip, with no catch. The highest *D. ruselli* catch was on the 6th trip, as much as 4,763 kg, and the lowest was on the 3rd trip, with 665 kg. Based on all catches, *K. pelamis* was the most dominant fish caught compared to other fish (Figure 2).

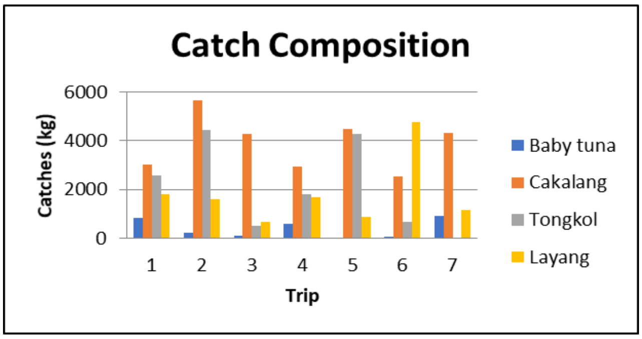

Figure 2. Composition diagram of the catch.

Average K. pelamis per operation. The catch of *K. pelamis* is higher than that of other types. The total catch of *K. pelamis* from the 1st trip to the 7th trip was 27,238 kg. The average highest catch per operation of *K. pelamis* was recorded on the 3rd trip, with 1,495 kg, while the lowest catch per operation was recorded on the 6th trip, with 422.67 kg. The catch of the 1st trip was 3,018 kg, the 2nd trip was 5,676 kg, the 3rd trip was 4,270 kg, the 4th trip was 2,948 kg, the 5th trip was 4,467 kg, the 6th trip was 2,536 kg, the 7th trip was 4,323 kg (Figure 3).

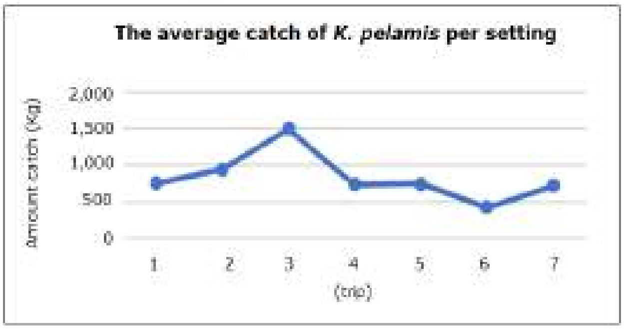

Figure 3. Diagram of the average catch of *Katsuwonus pelamis.*

Chlorophyll-a. Because fertile waters contain high chlorophyll-a concentrations, the chlorophyll-a is eligible as an indicator of fertility in waters. The chlorophyll-a concentration is also influenced by other factors such as currents. Chlorophyll-a image data were downloaded from the NASA database (http://www.oceancolor.gsfc.nasa.gov). The research data was processed using Seadas to produce chlorophyll-a data. Furthermore, the data was processed using Surfer 13 into JPEG format images that display the distribution of chlorophyll-a with different colors. The distribution of chlorophyll-a was taken based on the time and position of the capture operation. Figure 4 shows the chlorophyll-a distribution over the 7 fishing trips.

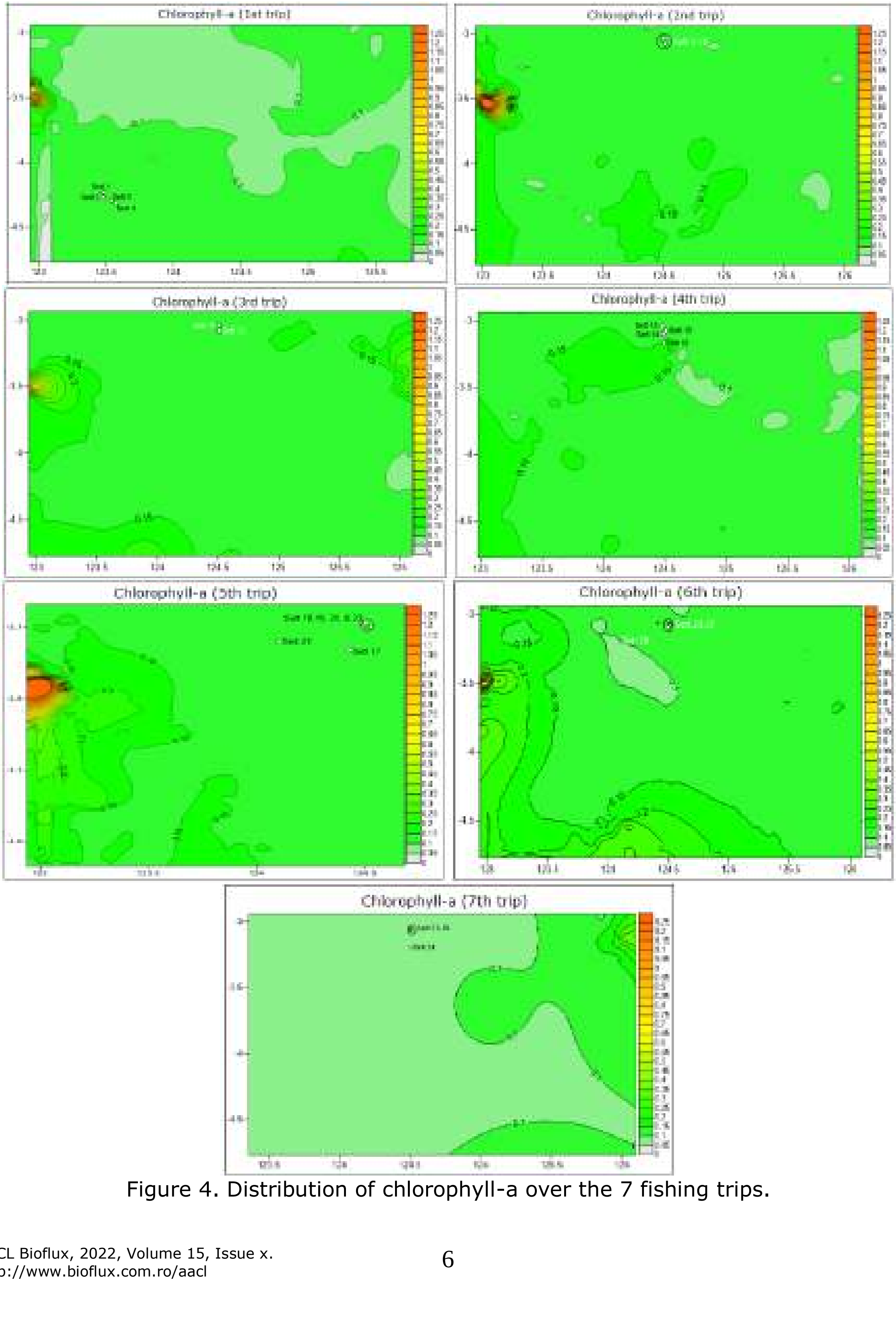

Figure 4. Distribution of chlorophyll-a over the 7 fishing trips.

The chlorophyll-a concentration values can be seen in Table 4 below.

Table 4

Chlorophyll-a concentration values

Trips	*Chlorophyll-a concentration value (mg m³)*						*Average*
	1st operation	*2nd operation*	*3rd operation*	*4th operation*	*5th operation*	*6th operation*	
Trip 1	0.1308[a]	0.1292	0.1273	0.1268[b]	-	-	0.1285
Trip 2	0.1176	0.1176	0.1173[b]	0.1266	0.1176	0.1266[a]	0.1205
Trip 3	0.1399[a]	0.1342[b]	-	-	-	-	0.1370
Trip 4	0.1046[b]	0.1080	0.1077	0.1632[a]	-	-	0.1209
Trip 5	0.1314	0.1312	0.1312	0.1314[a]	0.1313	0.1258[b]	0.1303
Trip 6	0.1208	0.1288[a]	0.1287	0.1227	0.1281	0.1001[b]	0.1215
Trip 7	0.0895	0.0903	0.0913[a]	0.0880	0.0875[b]	0.0894	0.0893

[a] the distribution of the highest chlorophyll-a concentrations; [b] the distribution of the lowest chlorophyll-a concentrations.

The chlorophyll-a concentration value on the 7th trip decreased significantly, compared to the other trips. The higher the chlorophyll-a concentration value in the waters, the more fertile the waters.

Average chlorophyll-a. The average chlorophyll-a can be seen in Figure 5, where the concentration of the 7th trip decreased, compared to the other trips. The average chlorophyll-a concentration was the highest on trip 3 and the lowest on trip 7. The difference between the highest and lowest concentrations is 0.0477 mg m^{-3}.

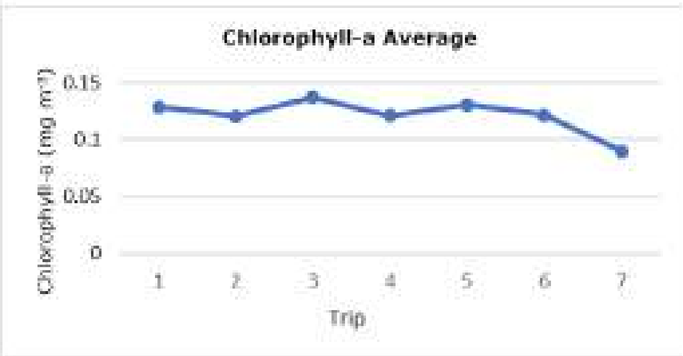

Figure 5. Diagram of average chlorophyll-a for 7 trips.

The relationship between average chlorophyll-a against K. pelamis. The relationship of chlorophyll-a to the catch of *K. pelamis* was calculated using a multiple correlation test. The multiple correlation estimator for the level of chlorophyll-a relationship to *K. pelamis* catch was determined by using SPSS 25.

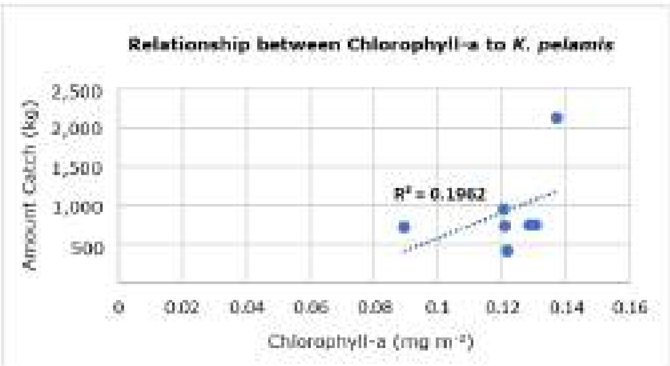

Figure 6. Graph of chlorophyll-a relationship to *Katsuwonus pelamis.*

Based on Figure 6 above, the coefficient of determination (R^2) is 0.196 or 19.6%. This shows that the chlorophyll-a factor used can only explain the actual model by 19.6%, so that the remaining 80.4% are explained by other factors such as salinity and currents.

The value of the correlation coefficient using SPSS 25 can be seen in table 4. The correlation coefficient value was obtained at 0.443, which means that the positive relationship between chlorophyll-a and the catch of *K. pelamis* is moderate, because the correlation coefficient value is in the correlation interval 0.40-0.599. This relationship is positive: if the value of one variable is increased, it will increase the value of the other variables and vice versa (Sugiono 2007), while if the chlorophyll-a decreases, it will decrease the catch of *K. pelamis*.

Hypothesis testing via the t test is used to determine whether the hypothesis is accepted or rejected, based on the coefficients table (Table 7). Based on this table, the t_{count} value of chlorophyll-a is 3,320, $t_{count}>t_{table}$ (3,320>2.77, respectively) and the sig value of 0.029 (<0.05), therefore the null hypothesis is rejected, due to the significant effect of chlorophyll-a on the catch of *K. pelamis*, in accordance with a previous research conducted by Demena et al (2017), which states that chlorophyll-a and the number of catches *K. pelamis* have a unidirectional relationship and the chlorophyll-a concentration affects the presence of *K. pelamis*.

The effect of chlorophyll-a on the catch of K. pelamis. Chlorophyll-a is an indicator that greatly influences the presence of fish in the waters, especially *K. pelamis*, a migratory species. The effect of chlorophyll-a on the catch of *K. pelamis* is calculated using the multiple linear regression, with the SPSS 25, and manual calculations were performed using a computer device.

Based on the results obtained in Table 5, the coefficient of determination (R^2)=0.779 or 77.9%. This shows an influence of 77.9% of the chlorophyll-a on the catch of *K. pelamis*, so that the remaining 22.1% are influenced by other factors such as currents and salinity. The correlation coefficient (R) in the model summary table above is 0.882. Based on table 5, the relationship level, given by the correlation coefficient (R), is included in the interval at 0.80-1.00, which means that the level of chlorophyll-a relationship to the catch of *K. pelamis* is very strong.

Table 5

Model summary

Model	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*
1	0.882[a]	0.779	0.668	320.54745

[a]Predictors: (Constant), Chlorophyll-a.

The hypothesis test used is the F test, carried out to test the effect of SST and chlorophyll-a on *K. pelamis* catches which will determine whether the results of the hypothesis are accepted or rejected. Hypothesis testing used SPSS 25 and manually obtained the value of F_o=7.030 and value=6.94 (Table 6). The results obtained in the ANOVA table have a sign value of 0.049<0.05. If H_o is rejected and H_1 is accepted, it means that there is a significant effect between SST and chlorophyll-a on *K. pelamis* catches, this is in accordance with the research conducted by Demena et al (2017) which stated that SST and chlorophyll-a are two indicators that greatly affect the presence of fish in the waters, especially *K. pelamis.*

Table 6

ANOVA regression table

Model	*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*
Regression	1,444,657.089	2	722,328.544	7.030	0.049[b]
Residual	411,002.672	4	102,750.668		
Total	1,855,659.760	6			

[b] Predictors: Constant, Chlorophyll-a, Sea Surface Temperature (SST).

Relationship of average SST to K. pelamis. SST can be used as an indicator to determine the presence of a fish species in waters. Each fish species has a certain temperature tolerance value so that it affects the presence and distribution of fish in the waters. To see the relationship between SST and the presence of *K. pelamis*, the catch data (in-situ) and SST data on the position and time of catching (ex-situ) were taken with SPSS 25 using a computer device. The relationship of SST to the catch of *K. pelamis* was calculated using the multiple correlation test, as an estimator (Figure 7).

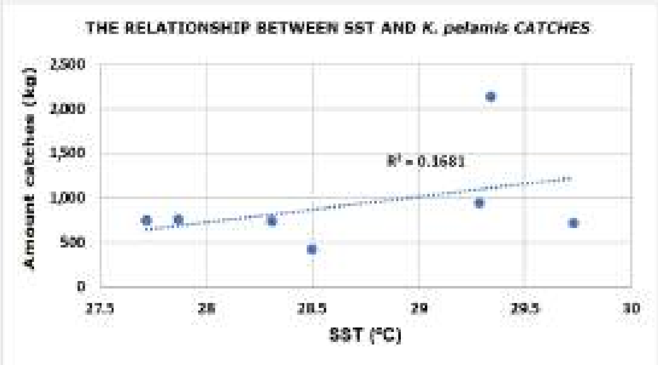

Figure 7. Graph of the relationship between SST and *Katsuwonus pelamis.*

Based on the graph above, the coefficient of determination (R_2) is 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%.

The assessment of the value of the correlation coefficient using SPSS 25 can be seen in Table 7. The correlation coefficient value obtained is 0.410, which means that the positive relationship between SST and the catch of *K. pelamis* is moderate, because the correlation value is in the correlation interval of 0.40-0.599.

Table 7

Correlations

Correlations				
Model		*K. pelamis*	*SST*	*Chlorophyl-a*
Pearson correlation	*K. pelamis*	1.000	0.410	0.443
	SST	0.410	1.000	-0.532
	Chlorophyl-a	0.443	-0.532	1.000
Sig. (1-tailed)	*K. pelamis*	0	0.180	0.160
	SST	0.180	0	0.109
	Chlorophyl-a	0.160	0.109	0
N	*K. pelamis*	7	7	7
	SST	7	7	7
	Chlorophyl-a	7	7	7

Based on Table 8, the results obtained the $t_{count}>t_{table}$ and sig value 0.032<0.05, it was found that H_o was rejected and H_1 accepted, there was a significant effect between SST and the catch of *K. pelamis*. A previous research conducted by Fajrianti (2016) stated that SST had a significant effect on the catch.

Based on the output of SPSS 25 (the coefficients matrix), the multiple linear regression equation could be expressed as follows:

$$Y = -21,557.333 + 642.160\ X_1 + 33,535.607\ X_2$$

The multiple linear regression equation above can be interpreted as follows:

- if the variables X_1 (SST) and X_2 (chlorophyll-a) have a value of 0, then the variable Y is -21,557.33 kg (intercept).
- if the variable X_1 (SST) increases by 1ºC and the other variables are constant, then the variable Y will increase by 642,160 kg.

- if the X_2 variable (chlorophyll-a) increases by 1 mg m^{-3} and the other variables are constant, then the Y variable will increase by 33,535.607 kg.

Table 8

Coefficients

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig.
		B	Std. error	Beta		
1	(Constant)	-21,557.333	6,416.374		-3.360	0.028
	SST	642.160	198.028	0.902	3.243	0.032
	Chlorophyl-a	33,535.607	10,100.263	0.923	3.320	0.029

Distribution of chlorophyll-a with K. pelamis catch. The graph of the relationship between chlorophyll-a and the catch of *K. pelamis* shows that the concentration of chlorophyll-a and the catch of *K. pelamis* have a unidirectional relationship (Figure 8).

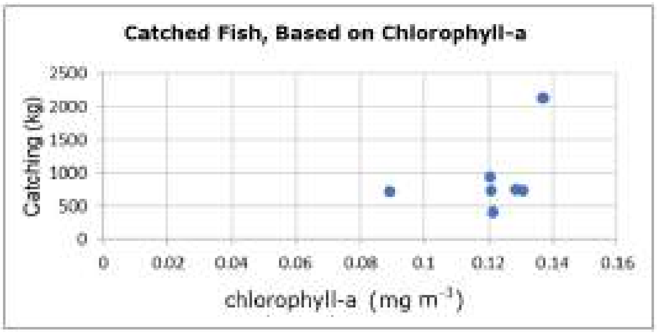

Figure 8. Catch based on chlorophyll-a.

In the figure above, the highest catch occurs at a concentration of 0.137 mg m^{-3}. The results showed that the *K. pelamis* maximum fishing potential occurs at an optimal chlorophyll-a concentration of 0.13 mg m^{-3}. This is in accordance with previous research conducted by Jufri et al (2014) which states that the potential fishing area for *K. pelamis* is closely related to the environmental parameters, especially to a chlorophyll-a in the optimal range of 0.12-0.22 mg m^{-3}.

Conclusions. From the results of the research, it can be concluded that the main catches were *T. albacares*, *K. pelamis*, *E. affinis* and *D. ruselli*, *K. pelamis* being the most caught type of fish. The relationship between the sea surface temperature and *K. pelamis* catches was obtained in the form of a coefficient of determination (R_2) of 0.168 or 16.8%. This shows that the SST factor used can only explain the actual model by 16.8% so that the rest is explained by other factors of 83.2%. There was a positive relationship between chlorophyll-a and *K. pelamis* catches, meaning that if the chlorophyll-a is higher, it will increase the catch, and vice versa if chlorophyll-a is lower, it will decrease the catch of *K. pelamis*. The results of the study concluded that the potential area for *K. pelamis* catching based on the optimum sea surface temperature was around 29°C and the optimum concentration for chlorophyll-a was around 0.13 mg m^{-3}.

Conflict of interest. The authors declare no conflict of interest.

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