Distribution of sea surface temperature and its effect on the *Katsuwonus pelamis* caught by pole and liner in the Savu Sea, Indonesia

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Abstract. The *Katsuwonus pelamis* fishing area in the Savu Sea can be determined by observing oceanographic parameters such as sea surface temperature (SST), because *K. pelamis* is a species whose swimming trajectory is found in the upper layer near the surface. By knowing the optimum SST distribution of *K. pelamis*, fishermen can predict fishing areas in order to save time, costs and effort to carry out fishing operations. The data collection in this study is based on a survey method, while the data analysis method used is a descriptive analysis and linear regression analysis. Observations showed that the most dominant SST in the Savu Sea in the period of November 2019 to March 2020 ranged from 29°C to 31°C, with the highest catch of 1,360 kg at a temperature of 29.2°C. Furthermore, SST has an effect of 22.5% on the catch of *K. pelamis*, while the rest is influenced by other factors.

Key Words: skipjack tuna, AQUAmodis, thermocline, fishing ground, oceanographic parameters.

Introduction. East Nusa Tenggara has a large potential for fish resources that are very diverse in nature. Utilization of fish resources by fishing has a sustainable potential (MSY) of 388.7 tons per year (Edo et al 2020; DKP 2009). In 2016, Kupang Regency produced 1,405 tons of skipjack tuna (*Katsuwonus pelamis*) and became the largest supplier of *K. pelamis* in East Nusa Tenggara (DKP 2018). The Savu Sea in East Nusa Tenggara Province is the location of fishing activities for most fishermen in East Nusa Tenggara (Hermawan et al 2021). One type of economically important fish resources in the Savu Sea is *K. pelamis*. Overall, the total fishing production from 22 city districts of the studied area, in 2017, was of 138,268 tons (Edo et al 2020).

Conditions of fishing areas are usually influenced by oceanographic parameters. One of the oceanographic parameters used in forecasting the availability of pelagic species such as *K. pelamis* is the sea surface temperature (SST) (Simbolon & Limbong 2012; Nugraha et al 2020). Oceanographic parameters such as SST and chlorophyll-a concentration affect various fish activities such as fish growth, spawning, metabolism, and other activities (Demena et al 2017).

Horizontally, the temperature varies according to latitude and vertically according to depth (Akbari et al 2017). To establish the relationship between temperature and parameters, it is shown how the measured parameters (Figure 1) vary as a function of temperature (Jean-Baptiste et al 2017).

Tropical tuna are found in waters with temperatures higher than 18°C (although they can dive to colder waters), while temperate tunas are found in waters as cold as 10°C or colder, but can also be found in tropical waters (Brill 1994; Monllor-Hurtado et al 2017). Detecting changes in the SST value using conventional methods would be difficult because it requires a very large amount of time and cost (Parry et al 2007). This encourages the use of satellite technology in observing oceanographic phenomena, especially SST (Gunarso 1985; Agusliana et al 2016).

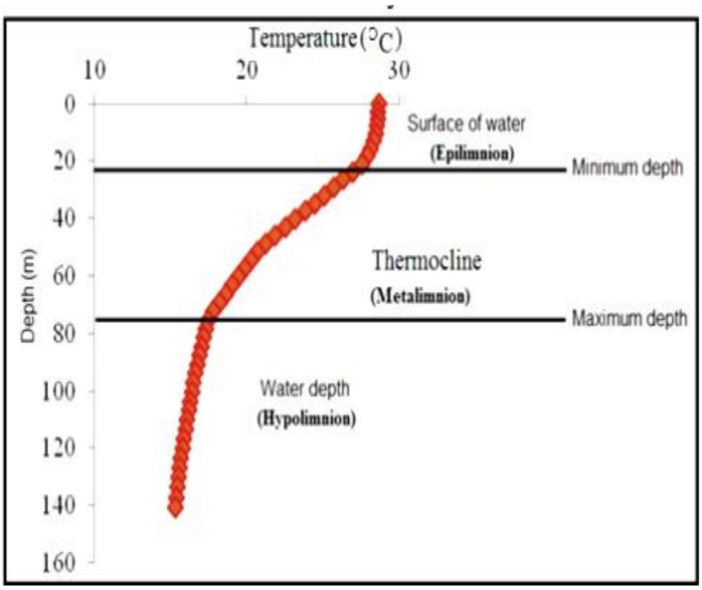


Figure 1. The thermocline layer of sea surface temperature (Jean-Baptiste et al 2017).

Remote sensing is an instrumentation-based technique to obtain information about objects, areas or symptoms, by analyzing the data obtained using a tactile device (sensor), without direct contact with the object, area or symptom to be studied (Lillesand et al 2008; Purbowaseso 1995; Prayogo & Basith 2021). SST images from a wide area of water can be used to determine the SST distribution pattern. By obtaining information on the SST variability, it can increase the effectiveness of fishing activities in the sea (Panggabean et al 2018).

This follow-up study aims to assess the relationship between SST and the catch of *K. pelamis* in the Savu Sea. By detecting the changes in SST, the potential areas for fishing can be identified by fishermen, so that fishing will become more effective and efficient.

Material and Method. The material used during the research included: pole and liner, fishing gear, GPS, compass, watches, digital thermometer, meter, camera, calculator, stationeries, some supporting software. Materials used include: (1) sea water for SST measurement during each fishing operation activity carried out, (2) *K. pelamis* captured samples and (3) satellite imaging periodic data from http://oceancolor.gsfc.nasa.gov.

Method of collecting data. The data series collection is carried out by observing pole and liner operations and also from literature studies.

Analysis of the relationship between Sea Surface Temperature (SST) and catches. Linear regression is a statistical method used to model the relationship between the dependent variable (dependent; response; Y) and one or more independent variables (independent, predictor, X) (Kurniawan 2008). Simple regression is carried out in stages, namely by connecting the independent variable (SST) with the dependent variable (*K. pelamis* catch volume). The regression model used is as follows (Walpole 1995):

$$Y = a + bX$$

Where:
x - sea surface temperature (SST);
y - catch;
a - constant (intercept); value of Y, when X=0
b - regression coefficient.

To get the regression formula above, it is necessary to determine the regression coefficient values, namely the values of a and b. The formula to determine the value mentioned above is as follows (Agustian et al 2021):

$$b = \frac{n \sum x_i y_i - (\sum x_i)(\sum y_i)}{n (\sum x_i^2) - (\sum x_i)^2} \quad \text{and} \quad a = \bar{y} - b\bar{x}$$

To find out the significant relationship between Y (catch) and X (SST), t_{count} was determined, then compared with the value of t_{table}. Provided that if $t_{count} > t_{table}$, there is no significant effect and the null hypothesis, H_0, is rejected.

The series of formulas to find the value of t_{count} is as follows:

$$Se = \sqrt{\frac{\sum y_i^2 - a\sum y_i - b\sum x_i y_i}{n-2}}$$

$$Sb = \frac{Se}{\sqrt{\sum x_i^2 - \left(\frac{(\sum x_i)^2}{n}\right)}}$$

$$t\ count = \frac{b}{Sb}$$

Where:
a - y value when x = 0 (constant value);
b - regression coefficient, which shows the regression curve slope;
x - independent variable;
y - dependent variable;
n - number of subjects studied;
Σ - amount.

H_0 : SST has no significant effect on the catch;
H_1 : SST has a significant effect on the catch.

Results and Discussion. The current research was carried out for five months starting from November 2019 to April 2020 by participating in fishing operations on pole and liner operating in the Savu Sea.

Figure 2. Pole and liner.

Fishing grounds. The fishing ground is concentrated by Fish Aggregation Devices (FAD) that have been installed and scattered in the Savu Sea, at the locations shown in Table 1 and Figure 3 below.

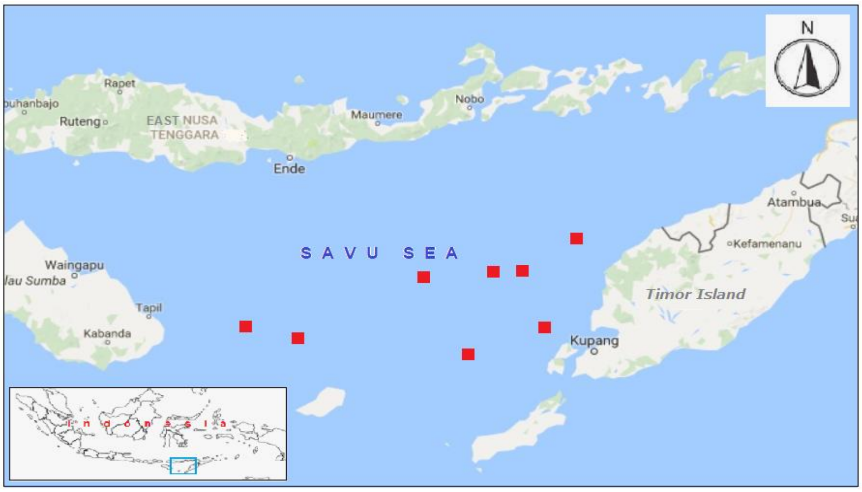


Figure 3. Fish Aggregation Devices (FAD's) position in Savu Sea.

Table 1

Fish Aggregation Devices (FAD's) position

FAD No.	*FAD's position*	
	Latitude (S)	*Longitude (E)*
1	10º 02′ 40″	121º 32′ 26″
2	10º 04′ 17″	121º 37′ 16″
3	09º 49′ 21″	122º 59′ 14″
4	09º 51′ 26″	122º 23′ 58″
5	09º 49′ 11″	122º 46′ 28″
6	09º 40′ 08″	123º 22′ 31″
7	10º 09′ 36″	123º 08′ 22″
8	10º 09′ 45″	122º 38′ 22″

Catch composition. Pole and liner catches target large pelagic fish, such as *K. pelamis*, *Thunnus albacares* and *Auxis rochei* (Nainggolan et al 2017). The composition of the fish caught is shown in the Table 2 and Figure 4 below.

Table 2

Catch compositions

No	*Name of fish*	*Catch quantity (kg)*	*Catch percentage (%)*
1	*Katsuwonus pelamis*	32,980	52
2	*Thunnus albacares*	21,250	33
3	*Coryphaena hippurus*	4,590	7
4	*Elagatis bipinnulata*	5,100	8
	Total catch	63,920	
	Average catch rate by setting	734.71	

Based on the table above, the average catch is 734.71 kg by setting, with a total of 87 settings. The dominant fish caught was *K. pelamis* with a total catch of 32,980 kg.

(a) *Katsuwonus pelamis*

(b) *Thunnus albacares*

(c) *Elagatis bipinnulata*

(d) *Coryphaena hippurus*

Figure 4. Pole and liner catches target large pelagic fish.

The percentage of catch can be seen in the diagram below (Figure 5).

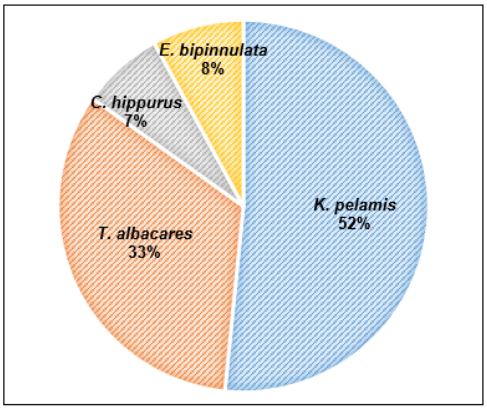


Figure 5. Diagram of catch percentage.

From the diagram above, it can be seen that the percentage of catches with the most types of fish caught was *K. pelamis* with a percentage of 52%, then *T. albacares* with a percentage of 33%, *C. hippurus* with a percentage of 7%, and *E. bipinnulata* with a percentage of 8%. The catch quantities and operations distribution by month is shown in Table 3 and Figure 6.

Table 3

Average catch per month

	Catch rate a month				
	November	*December*	*January*	*February*	*March*
Amount setting (times)	*2*	*43*	*14*	*15*	*13*
K. pelamis (kg)	1,020	15,300	2,890	6,290	7,480
T. albacares (kg)	0	9,520	2,040	5,440	4,250
C. hippurus (kg)	0	1,870	1,870	0	1,360
E. bipinnulata (kg)	0	1,530	1,190	0	1,870
Total catch (kg)	1,020	28,220	7,990	11,730	14,960
Catch rate a setting (kg)	510	656.28	570.71	782	1,150.77

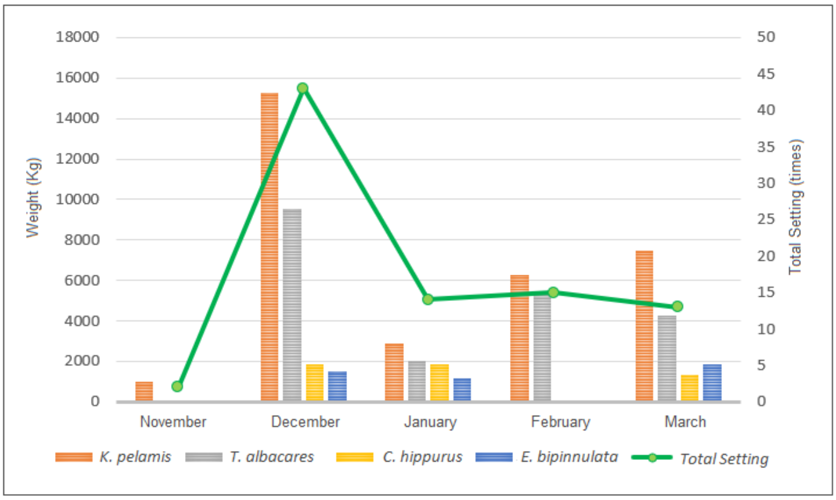


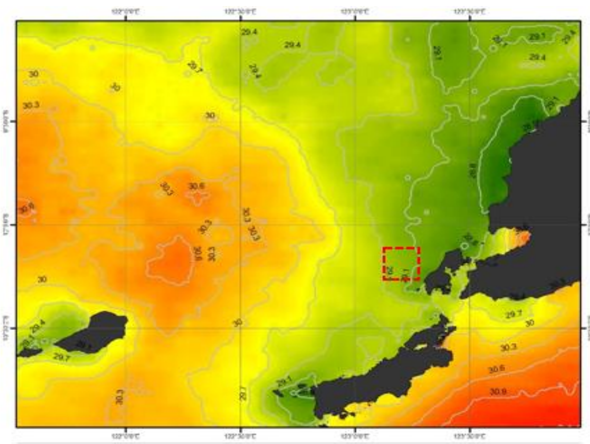
Figure 6. Graph of monthly catch.

Based on Figure 6 above, there was a decrease in the number of settings and catches during the 4 months of operation. The operations were mostly carried out in December: 43 times (settings), with a total catch of 28,220 kg, dominated by *K. pelamis* and *T. albacares*. The highest average catch by setting was obtained in March: 1,150.77 kg.

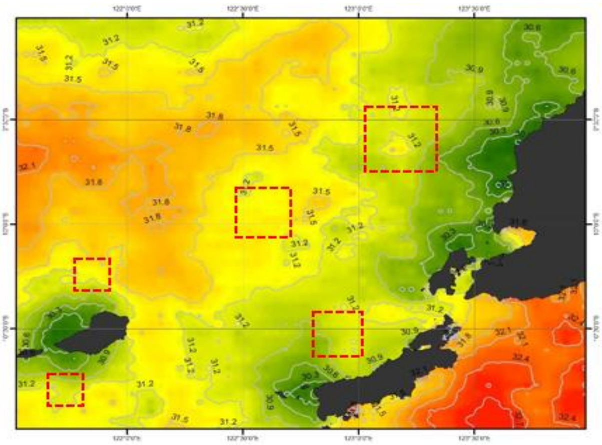
Sea Surface Temperature (SST). SST measurements were carried out *in situ* and *ex situ*. Temperature data was taken every time the setting was carried out starting from November 2019 to March 2020. In May 2018, the results of measuring SST field data in Savu sea ranged from 26.4 to 30.5°C. SST satellite data ranged from 26.7 to 31.4°C (Maro et al 2021). The distribution of SST in the Savu Sea at the positions of Latitude 09°00'00"S to 11°00'00"S and Longitude 121°30'00"E to 124°00'00"E, was determined using MODIS-Aqua satellite data (month period), with a resolution of 4 km, starting from November 2019 to March 2020. Data originated from http://oceancolor.gsfc.nasa.gov. Overall SST images produced from November 2019 to March 2020 vary greatly from the lowest value, 28°C, to the highest one, 35°C. The following is a map of the distribution of SST images in the Savu Sea (Figure 7).

Based on Figure 7, the image for November 2019 shows that SST in the Savu Sea ranges from 28°C to 31°C, with a dominant value of 29°C to 30°C, which is spread throughout the north of Savu Island. The SST image for December 2019 experienced a quite drastic increase, with values ranging from 29°C to 35°C, with a dominant temperature of 31°C to 32°C, which is spread throughout the north of Savu Island. The image for January 2020 shows that SST in the Savu Sea has decreased, ranging from 28°C to 31°C, with a dominant value of 30°C to 31°C, which is spread fairly evenly across the sea surface. The image for February 2020 shows that SST in the Savu Sea experienced a slight increase, ranging from 28°C to 33°C, with a dominant temperature of 30°C to 31°C, which is spread throughout the north towards Flores Island. The image of sea surface temperature in March 2020 has increased again in the range of 29°C to 32°C, with a dominant temperature of 31° to 32°C, which is spread evenly in the middle of the Savu Sea.

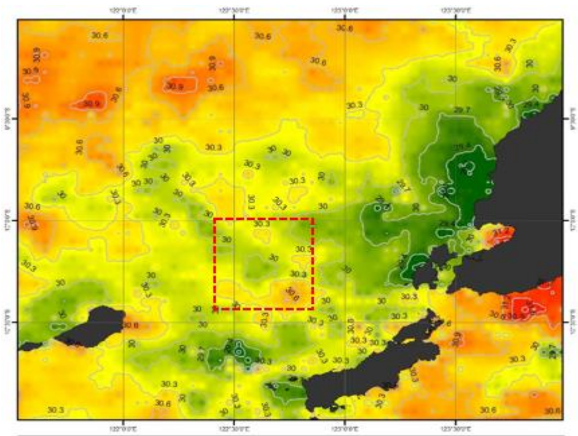
Satellite imagery SST was compared with the SST measured in the fishing areas. SST using MODIS-Aqua imagery and direct retrieval using an infrared thermometer give different values (Table 4). MODIS-Aqua (satellite) images are remote sensing data resulting from observations of ocean conditions. Comparison of SST used the average temperature data for each month starting from November 2019 to March 2020.



November 2019



December 2019



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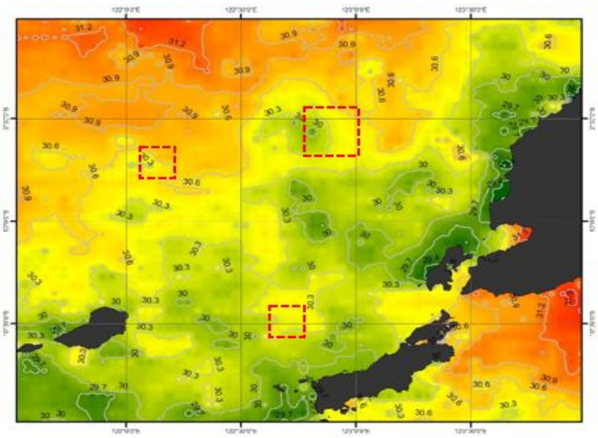
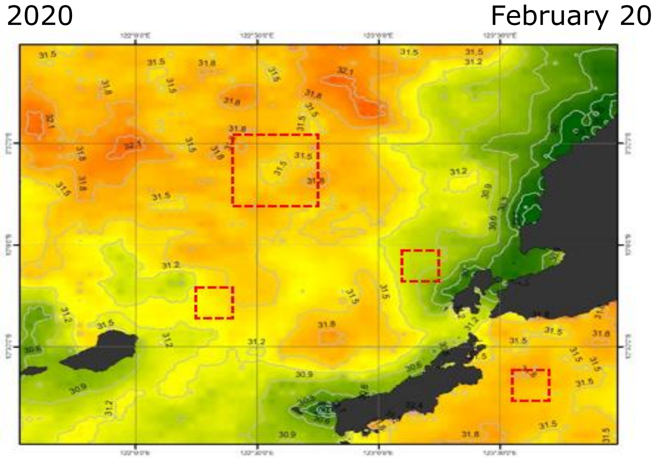


February 2020



March 2020

Figure 7. SST distribution map for November 2019 to March 2020.

Table 4

The difference in average SST every month

Month	*Amount setting (times)*	*SST-satellite (°C)*	*SST-infrared (°C)*	*Difference (°C)*
November	2	29.78	30.85	-1.07
December	43	31.28	30.95	0.33
January	14	30.26	30.14	0.12
February	15	30.42	30	0.42
March	13	31.25	30.52	0.73

The SST comparison is seen once a month with a varying number of setting points starting from the highest number in December 2019, which is 43 points, to the lowest in November 2019, which is 2 points. From the observations made, the lowest temperature difference is 0.12°C in January 2020, with a satellite SST value of 30.26°C and an infrared SST value of 30.14°C. The highest temperature difference is 0.73°C in March 2020, with satellite SST value of 31.25°C, while the infrared SST value is of 30.52°C. This illustrates that the SST difference between SST-satellite and SST-infrared is quite high (Irawan et al 2008). The comparison between MODIS-Aqua and SST can be seen in Figure 8 below.

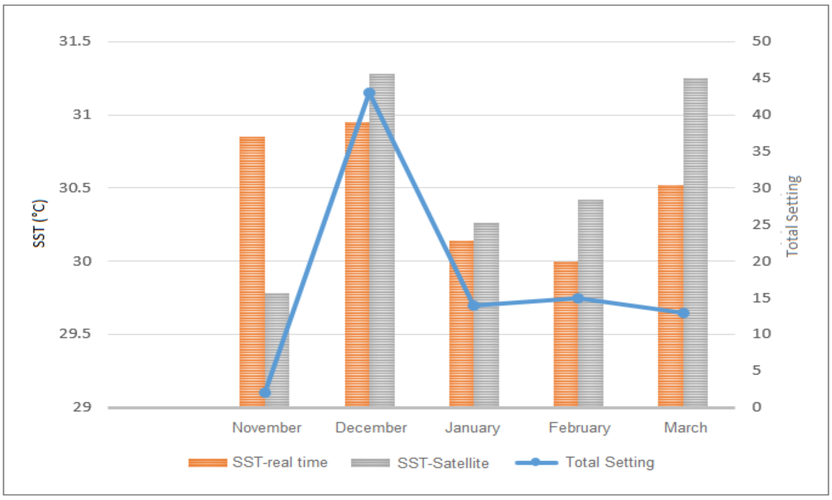


Figure 8. SST comparison diagram of MODIS-Aqua image and measurements from infrared thermometer.

In general, the relationship pattern between SST and *K. pelamis* caught by pole and liner is linear (Zulkhasyni 2015). The highest catch and the largest size of *K. pelamis* were found at an SST of 28.0°C to 29.9°C and it decreased with the temperature increase (Sepri et al 2020).

Catching time affects the yield and size of the fish caught. The pattern of the relationship between SST and the catch of *K. pelamis* is an inverse proportionality, as observed in Table 5.

Table 5

Average *Katsuwonus pelamis* catches based on SST

Temperature (°C)	29.0 - 29.9	30.0 - 30.9	31.0 - 31.9	32.0 - 32.5
Total setting	13	44	27	3
K. pelamis (kg)	8,330	16,575	7,735	340
Average (kg)	640.8	376.7	286.5	113.3

Figure 9 shows that an SST of 29 to 29.9°C determined an average catch of *K. pelamis* of 640.8 kg by setting; a temperature of 30 to 30.9°C with determined an average catch of *K. pelamis* of 376.7 kg by setting; a temperature of 31° to 31.9°C determined an average catch of *K. pelamis* of 286.5 kg by setting; a temperature over 32°C determined the lowest average catch of113.3 kg by setting.

The relationship between SST and the catch of *K. pelamis* was processed by software using a simple linear regression method, where the independent variable (x) was SST and the dependent variable (y) was the catch of K. pelamis (Table 6).

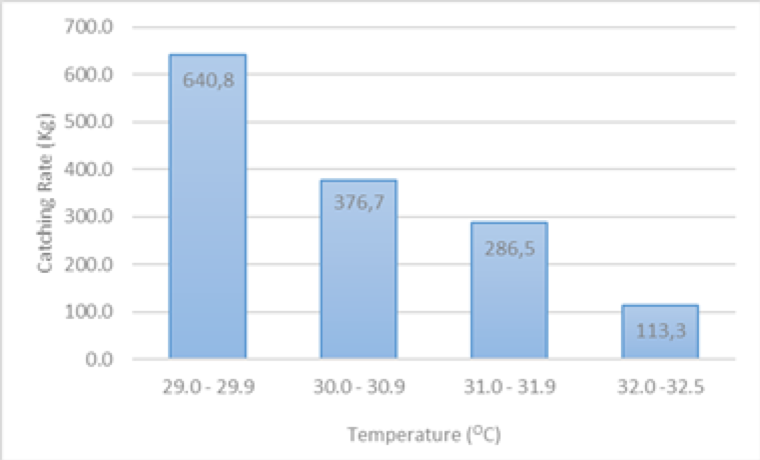


Figure 9. Average *Katsuwonus pelamis* catches based on SST.

Table 6

Summary of the relationship between SST and the catch of *Katsuwonus pelamis*

Model summary				
Model	*R*	*R square*	*Adjusted R square*	*Std. error of the estimate*
1	.474[a]	.225	.215	230.143

a. Predictors: (Constant), Temperature.

Based on table above, the R value or correlation value is 0.474 (medium relationship) and the coefficient of determination or R Square is 0.225 or 22.5%; this value means that SST has an effect of 22.5% on the catch *K. pelamis*, while the remaining 77.5% is influenced by other factors.

Table 7

SST influence coefficient

Coefficients[a]						
Model		*Unstandardized coefficients*		*Standardized coefficients*	*t*	*Sig.*
		B	*Std. error*	*Beta*		
1	(Constant)	6163.231	1166.006		5.286	.000
	Temperature	-188.932	38.078	-.474	-4.962	.000

a. Dependent variable: catching.

There are two references that are used as the basis for making decisions: firstly by looking at the significance value (sig), and secondly comparing the t_{count} value with the t_{table}. Based on the significance value, when (sig) <0.05, then there is an effect of the independent variable (x) on the dependent variable (y) and the hypothesis is accepted. Contrarily, when the value (sig) >0.05 there is no effect of the independent variable (x) on the dependent variable (y) and the null hypothesis is accepted. Based on the comparison of the value of t_{count} with t_{table}. If the value of $t_{count} > t_{table}$ then there is an influence between the independent variable (x) on the dependent variable (y) or the hypothesis is accepted. If the value of $t_{count} < t_{table}$ then there is no effect or the hypothesis is rejected. Based on data analysis, the value (sig) for SST is 0.00 where 0.00 <0.05 so the hypothesis is accepted, SST affects the catch of *K. pelamis*. Based on the comparison of the calculated t_{value} with the t_{table}, the results obtained for the independent variable (x) are 4.962 with a t_{table} value of 1.988; as 4.962 > 1.988 (hypothesis accepted), SST affects the catch.

Simbolon & Limbong (2012) explained that SST does not have a direct influence on catches. Meanwhile, according to Gunawan et al (2019) SST has a greater influence than chlorophyll-a and also that the water depth contribution is of only 17.8%. This study is in accordance with the opinion of various experts who stated that SST had a weak influence on the catch of *K. pelamis.*

Figure 10 shows a pattern: *K. pelamis* tends to be caught at a temperature of 29° to 31°C with the optimum catch at a temperature of 29.2°C.

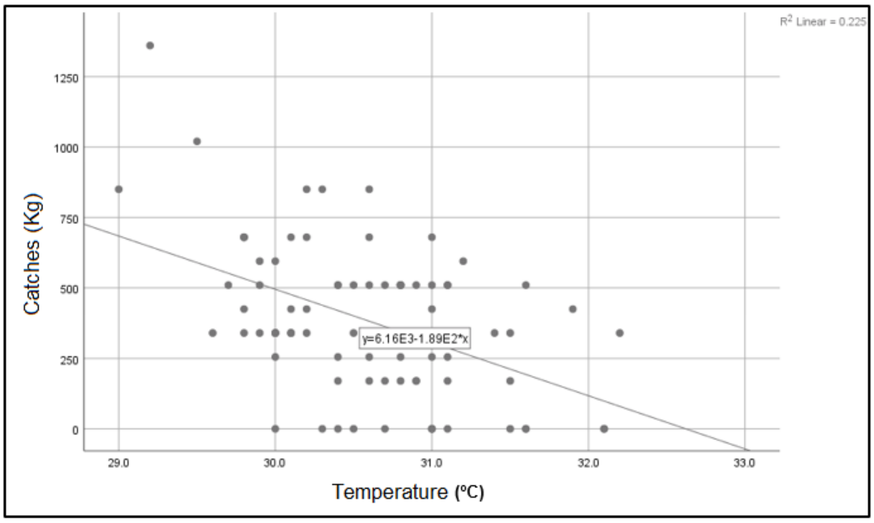


Figure 10. Effect of SST on *Katsuwonus pelamis* catches.

SST for catching *K. pelamis* was in the range of 29.5°C to 31.9°C (Angraeni et al 2014) so that the above data can be used as a reference for catching *K. pelamis* in the Savu Sea from December to March.

Conclusions. Based on field observations made from November 2019 to March 2020 and on the SST from the image of the MODIS-Aqua in the Savu Sea, the range of 29 to 31°C is the most dominant, with an even distribution over the entire surface of the Sawu Sea. The current research confirms that the SST alone has a weak effect on the catch, of only 22.5%, while the remaining influence is due to other factors.

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

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