The relationship between sea surface temperature and catching time of skipjack tuna (*Katsuwonus pelamis*) in FMA-715, Seram Sea, Indonesia

[1]Sepri, [2]Agus Hartoko, [3]Jerry Hutajulu, [3]Hari Prayitno, [3]Eddy S. Husen, [3]Heru Santoso, [3]Erick Nugraha, [4]Sopiyan Danapraja, [5]Muhammad Y. Syam

[1] Faculty of Fishing Technology, Sorong Fisheries Institute, West Papua, Indonesia; [2] Department of Fisheries, Faculty of Fisheries and Marine Science, Diponegoro University, Semarang, Indonesia; [3] Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia; [4] Faculty of Fisheries Extension, Jakarta Technical University of Fisheries, South Jakarta, Indonesia North Sulawesi, Indonesia; [5] Faculty of Fishing Machinery, Jakarta Technical University of Fisheries, South Jakarta, Indonesia. Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

Abstract. Skipjack tuna (*Katsuwonus pelamis*) has a wide distribution in the tropics, especially in eastern Indonesia. The types of fishing gear used consist of purse seines, pole and line, tuna longlines, hand lines and trolling lines. The purpose of this study was to determine the relationship between sea surface temperature (SST) and fishing time on the amount and size of tuna catches. This research is an associative study which aims to determine the relationship between the variable fishing time and SST on the amount of catch and size of *K. pelamis*. These relationships were analyzed using correlation and simple linear regression. The results showed that SST had an effect on the yield and size of the fish caught. The largest catch and the largest *K. pelamis* size were found at SST 28.0-29.9^{0}C and decreased with increasing temperature. Catching time affects the yield and size of the fish caught. The largest catch and the largest *K. pelamis* size were found in the time range 05.00-08.59 AM and decreased with advancing in time.
Key Words: pole and line, tuna (*Thunnus* sp.), oceanographic characteristics, fish size.

Introduction. Indonesia plays an important role in the world's Tuna (*Thunnus* sp.), bullet tuna (*Auxis rochei*) and skipjack tuna (*Katsuwonus pelamis*) fisheries, which have supplied more than 16% of world production (Firdaus 2019). *Thunnus* sp. and *K. pelamis* rank third among marine resources that support global fisheries (Soukotta et al 2017).

Matsumoto et al (1984) in (Kiyofuji et al 2019) said that tuna and *K. pelamis* are highly migratory species with a wide geographical distribution from the equatorial zone to temperate areas. Anderson et al (2012) in (Waileruny et al 2014) explains that *K. pelamis* is present in all tropical oceans, has a large population size, relatively fast growth, and high reproductive potential. As a result, in general, the ability to withstand fishing pressure is relatively high and it is relatively difficult to over fishing and is considered to constantly change places.

The distribution area of *Thunnus* sp. and *K. pelamis* in Indonesia is mainly in the Eastern Indonesia region (Supriatna et al 2014). The results of the parameters of oceanographic characteristics indicate that West Papua waters have good marine resource potential for the survival of pelagic fish, especially *K. pelamis.*

K. pelamis fishing can be done along the year, and the fishing ground that are most often carried out fishing are in the Seram Sea and Fakfak waters (Tjarles et al 2019). Fish distribution is very wide, such as in the waters of Tomini Bay and Seram Sea waters. The movement of water masses from the Pacific Ocean towards the Indian Ocean is characterized by high salinity (33.9-34.2 psu), warm temperatures (28-30°C), high chlorophyll (1-2.5 mg m^{-3}) and dissolved oxygen (5.6-6.2 mg m^{-3}) content. Such conditions are preferred by large pelagic groups compared to small pelagic fish (Ma'mun et al 2018). The exploitation of *K. pelamis* in the Banda Sea has been going on for a long time. Currently the *K. pelamis* resource has shown signs of overfishing. This indication, among others, is marked by a decrease in the catch and individual size, changes in the composition of the catch, and the tendency to increase in the proportion of several types of small fish (Nugraha et al 2010).

The Banda Sea is one of the potential tuna fishing areas in Indonesia. The types of fishing gear used consist of purse seine, pole and line, tuna longlines, hand lines and trolling lines (Widodo et al 2015). Pole and line catch consists of *K. pelamis*, *Thunnus albacares* and *A. rochei* (Nainggolan et al 2017).

The purpose of the present study was to determine the relationship between sea surface temperature (SST) and fishing time on the amount and size of tuna catches and to determine the SST and the most ideal fishing time to carry out fishing activities of *K. pelamis* with pole and line fishing boats.

Material and Method. The research lasted for approximately 6 months, from 24 November 2018 to 05 May 2019. The the research location is in the Seram sea at the position 02°18'47" - 02°40'51" S and 130°03'35" - 130°35'33" E. Seram Sea is included in the Fisheries Management Area of the Republic of Indonesia (FMA-RI) 715 which includes the waters of Tomini Bay, Maluku Sea, Halmahera Sea, Seram Sea and Berau Bay (Figure 1).

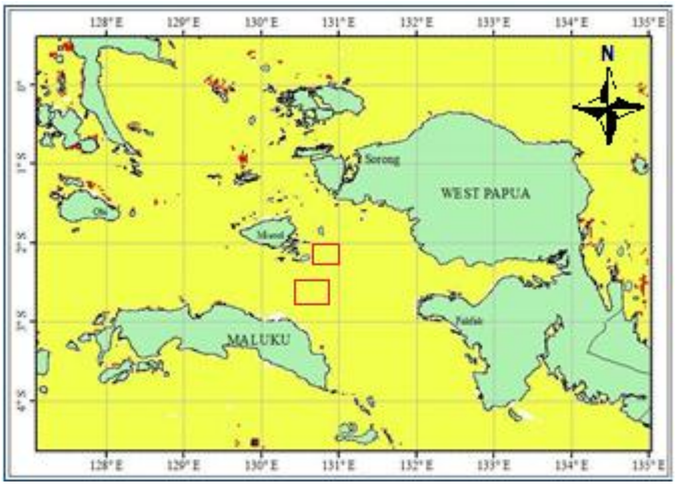

Figure 1. Map of research location (Tjarles et al 2019).

The equipment used was pole and line vessel with a ship size of 60 GT, length overall (LOA) of 25.68 m, width 4.86 m, within 2.20 m (Figure 2). Other equipment used were such as marine maps no 210, magnetic compass, GPS (Global Positioning System), binocular, digital thermometer, roll meter, watch, camera and calculator.

The data collection was carried out by following the fishing operation which lasted 6 fishing trips and 50 settings. The data collected included: setting position, number of catch according to fish species, setting time, SST at setting time, data on the size of the *K. pelamis* sample. The data was recorded in the log fishing operation journal. SST measurements were carried out in situ, which is according to where the setting is made. SST was measured using a digital thermometer. Seawater samples were taken using a bucket, then a digital thermometer was directed to the sea water. Scan button was pressed for 5 seconds. The temperature automatically appears on the thermometer screen. The measurement results were recorded in the capture journal. The setting position was measured using the Global Positioning System (GPS). The measured latitude and longitude position data was at the time of the fishing gear setting. Measuring the size of *K. pelamis* was performed by taking a sample of 30 *K. pelamis* after each setting. The sample fish were measured from head to tip of tail (fork length) using a roll meter.

Figure 2. Pole and line fishing boat.

The amount of catches was recorded when handling the fish caught. After finishing the fishing activity, the catch was arranged in baskets with a size of 50 kg basket^{-1}. The amount of catch per setting was done by counting the number of baskets filled with fish.

This research is an associative study, namely research that aims to determine the relationship between two or more variables. The relationship to be studied is the time of catching and SST to the amount of catches and to the size of *K. pelamis*.

The hypothesis of this study is that fishing time and SST have an effect on the amount of catch and on the size of *K. pelamis*. To measure the presence or absence of correlation between variables, it is analyzed by simple linear regression with the following regression line equation (Hasan 2001):

$$Y = a + bX$$

$$a = \frac{(\sum Y)(\sum X^2) - (\sum X)(\sum XY)}{(n)(\sum X^2) - (\sum X)^2}$$

$$b = \frac{(n)(\sum XY) - (\sum X)(\sum Y)}{(n)(\sum X^2) - (\sum X)^2}$$

To measure the closeness of the relationship between two variables, the Pearson correlation coefficient using the least squere method was used:

$$r = \frac{n\sum XY - (\sum X)(\sum Y)}{\sqrt{(n\sum X^2 - (\sum X)^2)(n\sum Y^2 - (\sum Y)^2)}}$$

Where:
Y = amount of catch or size of *K. pelamis*
X = SST

To determine the closeness of the relationship or correlation between these variables, the benchmark value "r" was used as follows:

0 <r ≤ 0.20, very weak correlation
0.20 <r ≤ 0.40, weak correlation
0.40 <r ≤ 0.70, significant correlation
0.70 <r ≤ 0.90, strong correlation
0.90 <r <1.00, very strong correlation
r = 1, perfect correlation

For the purpose of testing the model parameter values hypothesis, the linear regression model also assumes what is known as the classic assumption test, namely the normality test, heteroscedasticity test, linearity test and autocorrelation test for time series data (Janie 2012). The normality test aims to test whether the data used in the study is normally distributed or not. The linearity test aims to determine whether the predictor or independent variable has a significant linear relationship with the criterion or dependent variable. Multicollinearity test aims to test whether the regression model found a strong correlation or relationship between the independent variables or the independent variables. The heteroscedasticity test aims to test whether in the regression model there is an unequal variance from the residual value of one observation to another. If the variance from the residual value from one observation to another is constant, it is called homoscedasticity, conversely if the variance from the residual value from one observation to another is different, it is called heteroscedasticity. A good regression model should not have heteroscedasticity symptoms.

Results and Discussion

Composition of catch. Pole and line catch targets are large pelagic fish such as *Thunnus* sp. and *K. pelamis*. There are also by-catch such as Mahi Mahi (*Coryphaena hippurus*), mackerel (*Scomberomorus commerson*) and others. The amount of bycatch is insignificant and is not caught every time. Table 1 show that the catch during 6 fishing trips consisting of 50 settings is 83.57 kg with an average of 1.672 kg/setting. The composition of the catch was dominated by *K. pelamis* as much as 75.480 kg or 90%, while yellowfin tuna (*Thunnus albacares*) represented only 8.095 kg or 10%. The highest catch of *K. pelamis* was 5.000 kg/setting and the lowest is 20 kg/setting. The higest catch of tuna was 1,200 kg/setting and the lowest 0 kg/setting.

Table 1

Composition of fish catch

No	*Species*	*Total catch for 6 fishing trips (kg)*	*%*	*Average catch per setting (kg)*	*Highest catch per setting (kg)*	*Lowest catch per setting (kg)*
1	*K. pelamis*	75,480	90	1,510	5,000	20
2	*T. albacares*	8,095	10	162	1,200	0
	Total	83,575	100	1,672	-	-

Relationship between sea surface temperature (SST) and total K. pelamis catch. There is a strong relationship between the dynamics of oceanographic conditions with fluctuations in the catch of large pelagic fish (Safruddin et al 2018) and SST is the most important predictor of habitat for *K. pelamis* migration (Mugo et al 2010). The relationship between SST and amount of *K. pelamis* catches was analyzed using simple linear regression.

Normality test of data distribution was carried out by using the Kolmogorov-Smirnov normality test and the Asymp significance value was obtained. Sig. (2-tailed) of 0.559>0.05. It can be concluded that the data is normally distributed. The results of the linearity test obtained the Deviation from linearity sig. amounting to 0.598>0.05, it can be concluded that there is a significant linear relationship between the independent variable and the dependent variable. Heteroscedasticity test used the Glejser test and obtained a significance value of the SPL variable of 0.560. This variable has a significant value higher than 0.05, therefore it can be concluded that there is no symptom of heteroscedasticity in the regression model. Thus the assumptions or requirements to perform simple linear regression analysis have been met.

To find out whether or not there is a relationship between the catch time variable (X) and the *K. pelamis* fishing yield variable (Y), the t test was applied as shown in Table 2. The t test results obtained a significance value of 0.000<0.05 and a t-count value of -

4.835> t_{table} -2.029, it can be concluded that there is a relationship between the SPL (X) variable and the catch variable (Y).

Table 2
Regression analysis of the relationship between SST and catch of *Katsuwonus pelamis*

Variable	*Regression coefficient*	T_{count}	*Sig.*
Constant	25.518.091		
SST	- 805.762	- 4.835	.000

r = - 0.572
r_{square} = 0.327
t_{table} = 2.029

The coefficient of determination or R square was 0.327 or 32.7%, which means that the SST (X) variable is related to the *K. pelamis* catch amount variable of 32.7% while the rest (67.3%) is connected by other variables outside this regression equation. Furthermore, the value of r = -0.572 which means an increase in SST followed by a decrease in catch and the closeness of the relationship or correlation between the two variables can be categorized as having a significant correlation. Our findings are in contrast to what have been reported by Nugraha et al (2020) that SST does not have a significant relationship with the amount and size of *K. pelamis* caught in the Banda Sea.

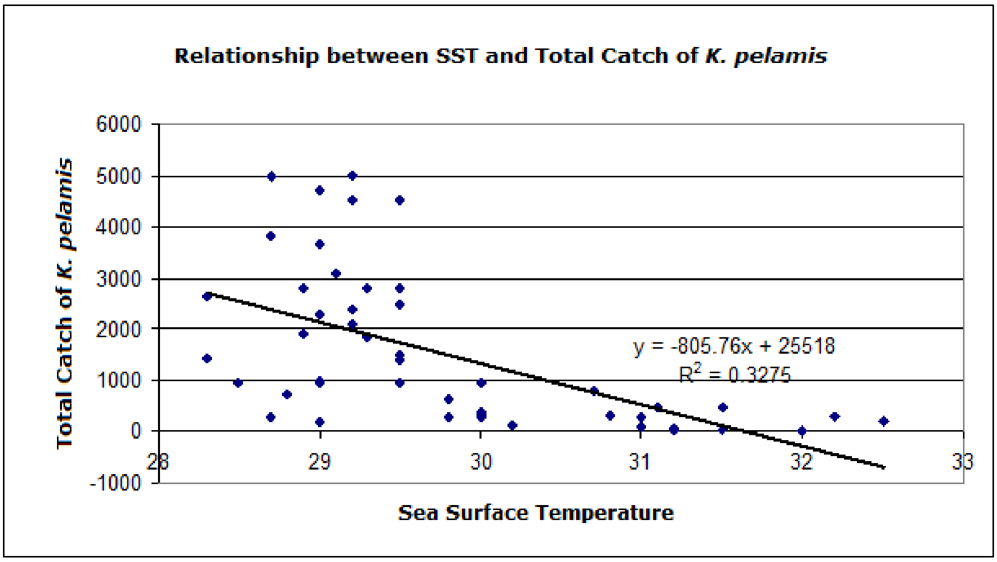

Figure 3. Relationship between sea surface temperature (SST) and total catch of *Katsuwonus pelamis*.

The relationship between SST and total catch of *K. pelamis* is shown in Figure 3, and formulated the regression equation as follows:

$$Y = 25,518,091 - 805,762\ X$$

Where:
Y = amount of *K. pelamis* catch
X = SST

The regression equation above shows that each increase in temperature of 1^0C will reduce the catch by 805,762 kg, or in other words, an increase in temperature will reduce the amount of tuna catches. Thus it can be concluded that to obtain the highest catch, the low SST is favorable. In contrast to what Wyrtki (1961) in (Baskoro et al 2011) reported, the relationship of temperature to fisheries in Indonesian waters which are tropical waters is unclear. This is because tropical waters have low annual temperature variations compared to subtropical waters.

Relationship between sea surface temperature (SST) and K. pelamis size. The relationship of SST to *K. pelamis* size was also analyzed using simple linear regression. SST was considered as independent variable or independent variable or X variable, while *K. pelamis* size as dependent variable or dependent variable or Y variable.

Normality test of data distribution was carried out by using the Kolmogorov-Smirnov normality test and the Asymp significance value was obtained. Sig. (2-tailed) 0.194>0.05. It can be concluded that the data is normally distributed. The results of the linearity test obtained the Deviation from linearity sig. amounting to 0.063>0.05, it can be concluded that there is a significant linear relationship between the independent variable and the dependent variable. Heteroscedasticity test used the Glejser test and obtained a significance value of the SST variable of 0.218. This variable has a significance value, higher than 0.05, it can be concluded that there is no heteroscedasticity symptom in the regression model. Thus the assumptions or requirements to perform simple linear regression analysis have been met.

To find out whether or not there is a relationship between the fishing time variable (X) and the *K. pelamis* size variable (Y), the t test was carried out as shown in Table 3. The t test results obtained a significance value of 0.000<0.05 and a $t\text{-}_{count}$ value of -6.125> t_{table} -2.029, it can be concluded that there is a relationship between the SST variable (X) and the catching of *K. pelamis* (Y) variable.

Table 3

Regression analysis of the relationship between SST and *Katsuwonus pelamis* size

Variable	*Regression coefficient*	T_{count}	*Sig.*
Constant	238.92		
SPL	- 6.214	- 6.125	.000

r = - 0.662
r_{square} = 0.439
t_{table} = 2.029

The coefficient of determination or R square was 0.439 or 43.9%, which means that the SPL (X) variable is related to the *K. pelamis* size variable by 43.9% while the rest (56.1%) is related by other variables outside this regression equation. Furthermore, the value of r = 0.662 which means that an increase in SST is followed by a decrease in the size of *K. pelamis* and the closeness of the relationship or correlation between the two variables can be categorized as having a significant correlation.

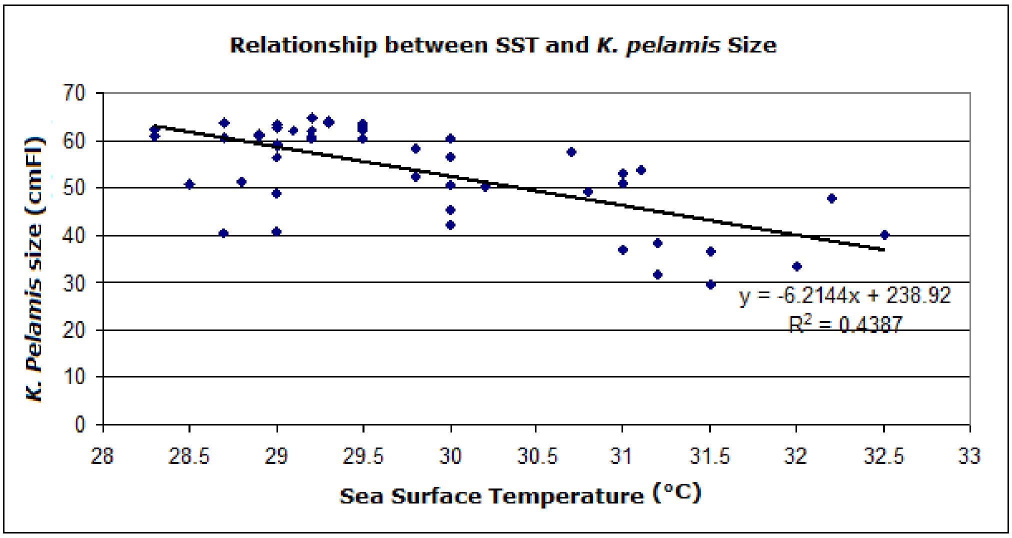

Figure 4. Relationship between sea surface temperature (SST) and *Katsuwonus pelamis* size.

The relationship between SST and *K. pelamis* size as shown in Figure 4, is formulated in the regression equation as follows:

$$Y = 238.92 - 6{,}214\ X$$

Where:

Y = size of *K. pelamis*
X = SPL

The regression equation above shows that each increase in temperature of 1°C will reduce the size of *K. pelamis* by 6.21 cm, or in other words, an increase in temperature will reduce the size of *K. pelamis*. Thus it can be concluded that to obtain the best results the low SST is favorable.

The relationship between SST and the amount and size of K. pelamis catch. To find the right temperature for obtaining highest amount and larger fish, a line chart analyses was used. The temperature range during the capture operation (setting) was from 28 to 33°C. SST was divided into five classes, with a class interval of 1°C.

In Figure 5, it can be seen that the average catch at a temperature of 28.0-28.9°C was 2,178 kg per setting, increasing to 2,278 kg per setting at a temperature of 29.0-29.9°C then decreased sharply at a temperature of 30.0-30.9°C to 446 kg per setting and 209 kg per setting and at a temperature of 31.0-31.9°C to 173 kg per setting at a temperature of 32.0-32.9°C. Standard error at 28.0-28.9°C was 512 kg, at 29.0-29.9°C 314 kg, at 30.0-30.9°C 98 kg, at 31.0-31.9°C 69 kg and at 32.0-32.9°C 82 kg. The highest catch was obtained at a temperature of 28.0-28.9°C and 29.0-29.9°C reaching 3,000 kg per setting. Meanwhile, at a temperature of 30.0-30.9°C the catch amounted 950 kg per setting, at a temperature of 31.0-31.9°C 500 kg per setting and at a temperature of 32.0-32.9°C 300 kg per setting.

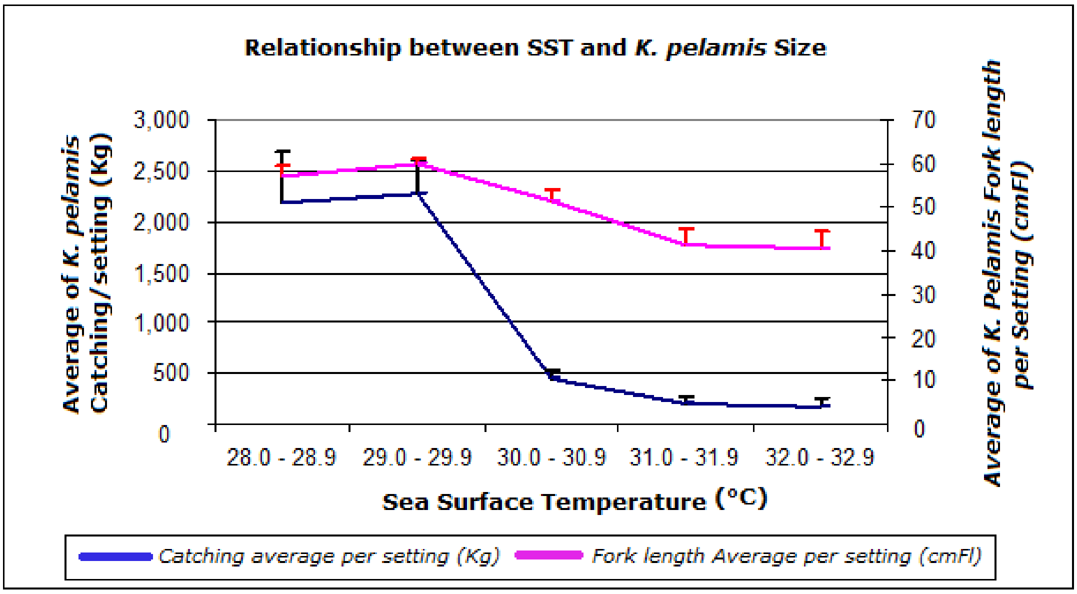

Figure 5. The relationship of sea surface temperature (SST) to the amount and size of *Katsuwonus pelamis* catches.

The average size of *K. pelamis* at 28.0-28.9°C was 56.9 cm Fl per setting, increased to 59.7 cm Fl per setting at 29.0-29.9°C then decreased sharply at 30.0-30.9°C to 51.4 cm Fl per setting and became 41.3 cm Fl per setting and at temperatures of 31.0-31.9°C to 40.4 cm Fl per setting at 32.0-32.9°C. Standard error at 28.0-28.9°C was 2.6 cm, at 29.0-29.9°C 1.2 cm, at 30.0-30.9°C 2.2 cm, at 31.0-31.9°C 3.4 cm and at 32.0-32.9°C 4.1 cm. The highest catch was recorded at a temperature of 28.0-28.9°C and a temperature of 29.0-29.9°C reaching 3,000 kg per setting. Meanwhile, at a temperature of 30.0-30.9°C it was 950 kg per setting, at a temperature of 31.0-31.9°C it was 500 kg per setting and at a temperature of 32.0-32.9°C it was 300 kg per setting. This is in accordance with Nugraha et al (2020) that, there is a pattern or trend that shows that small size fish are caught more at high temperatures. It is also in line with Gunarso (1985) who states that larger and older fish will tend to move towards cooler waters, while smaller fish will remain in their normal distribution area.

From the results description above, it can be seen that the highest catch and the largest *K. pelamis* size were caught at a temperature of 28.0-29.9°C. The same correlation was reported by Gunarso (1985) that the optimum temperature preferred by *K. pelamis* in Indonesia is at a temperature of 28.0-29.0°C. Similar to what Nugraha et al (2020) and Nainggolan et al (2017) noticed that the highest catch of *K. pelamis* is at SST between 29.0 and 30.0°C. The same aspect was stated by Putri et al (2018) that *K. pelamis* is generally caught in the SST range of 28.42-30.73°C. Slightly different values was reported by Angraeni et al (2014), who stated that the waters favored by *K. pelamis* are in the range of 29.5-31.0^{o}C with the highest catch in the range of 31.0-31.4^{o}C.

Thus it can be concluded that SST affects the yield and size of the fish caught. The highest catch and the largest *K. pelamis* size were found at the SST range of 28.0-29.9^{0}C and decreased with increasing temperature. The most ideal SST for conducting *K. pelamis* fishing activities with pole and line is at a temperature of 28.0-29.9^{0}C.

The relationship between catching time and amount and size of K. pelamis catch. To find out the right time to get fish in high quantities and at bigger size, a line chart analysis was used. The arrest operation (setting) took place starting around 05.00 and ending around 17.00. The fishing time was divided into three classes, namely the class in the time range 05.00-8.59 which is then called the morning group and the afternoon group in the time range 09.00-12.59 and the last one is the afternoon group in the time range 13.00-16.59.

In Figure 6, it can be seen that the highest average catch was in the morning, amounting 2,155 kg per setting, then decreased sharply during the day to 416 kg per setting and continued to decline to 175 kg per setting in the afternoon. Standard error in the morning 268 kg, 105 kg during the day and 81 kg in the afternoon. The highest catch in the morning reached 5,000 kg per setting, during the day 1,400 kg per setting and 330 kg per setting in the evening.

The highest average size of *K. pelamis* was captured in the morning, with 58.1 cm Fl per setting, then droped sharply at noon to 47.7 cm Fl per setting and continued to decrease to 40 cm Fl per setting in the afternoon. Standard error was 1.2 cm in the morning, 2.6 cm in the daytime and 5.0 cm in the afternoon. The largest size of fish in the morning was 64.8 cm Fl, 60.3 cm Fl in the daytime and 49.1 cm Fl in the afternoon.

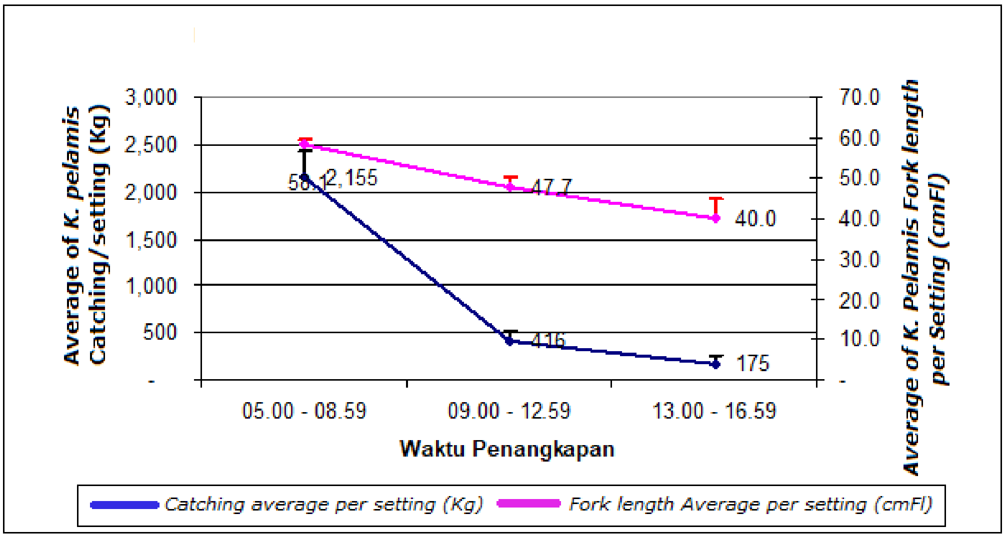

Figure 6. Relationship between catching time and amount and size of *Katsuwonus pelamis* catch.

From the results presented above, it can be seen that the largest catch and the largest *K. pelamis* was caught in the morning. Mardlijah (2008) said that *T. albacares* starts eating at around 07.00 am. Gunarso (1998) states that *T. albacares* generally forage during the day, even though at night they are quite active in hunting prey. Furthermore, Nakamura (1965) in Mardlijah (2008) stated that *K. pelamis* caught in the morning have a larger stomach volume than fish caught at midday.
Thus it can be concluded that the time of catching affects the yield and size of the fish caught. The largest catch and the largest *K. pelamis* size were found in the time range 05.00-08.59 and decreased with time. The ideal time to catch *K. pelamis* with pole and line is in the morning, namely between 05.00 and 08.59.

Conclusions. Composition of pole and line catches in Seram waters at position 02°18'47"-02° 40'51"S and 130°03'35"-130°35'33"E was dominated by *K. pelamis* 90% and the rest of 10% were constituted by *T. albacares*.

SST affects the yield and size of the fish caught. The largest catch and the largest *K. pelamis* size were found at SST 28.0-29.9°C and decreased with increasing temperature. The most ideal SST for conducting *K. pelamis* fishing activities with pole and line is at a temperature of 28.0-29.9°C.

Catching time affects the yield and size of the fish caught. The largest catch and the largest *K. pelamis* size were found in the time range 05.00-08.59 and decreased with increasing time. The most ideal time to do *K. pelamis* fishing activities with pole and line is in the morning, between 05.00 and 08.59.

Acknowledgements. The authors would like to thank to all captains and crew of FV. Mina Fintura 01 who has allowed us to do research on pole and line fishing boat, provided tremendous opportunities, attention and assistance during the research. Thanks also go to all related parties, so that this research can be carried out and published.

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Received: 02 September 2020. Accepted: 12 November 2020. Published online: 19 November 2020.
Authors:
Sepri, Sorong Fisheries Institute, Faculty of Fishing Technology, Indonesia, Sorong - West Papua, Jl. K. Pattimura, Tanjung Kasuari, e-mail: sepri.sumbung31@gmail.com
Agus Hartoko, Diponegoro University, Faculty of Fisheries and Marine Science, Department of Fisheries, Indonesia, Semarang, 50275 Jawa Tengah, e-mail: agushartoko.undip@gmail.com
Jerry Hutajulu, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: jerryhutajulu15@gmail.com
Hari Prayitno, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: hariprayitno46@gmail.com
Eddy Sugriwa Husen, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: sugriwastp@gmail.com
Heru Santoso, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: herustppsm15@gmail.com
Erick Nugraha, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: nugraha_eriq@yahoo.co.id
Sopiyan Danapraja, Jakarta Technical University of Fisheries, Faculty of Fisheries Extension, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: sopiyanraja@gmail.com
Muhammad Yusuf Syam, Jakarta Technical University of Fisheries, Faculty of Fisheries Machinary, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: yusufsyam17@yahoo.co.id

How to cite this article:
Sepri, Hartoko A., Hutajulu J., Prayitno H., Husen E. S., Santoso H., Nugraha E., Danapraja S., Syam M. Y., 2020 The relationship between sea surface temperature and catching time of skipjack tuna (*Katsuwonus pelamis*) in FMA-715, Seram Sea, Indonesia. AACL Bioflux 13(6):3430-3440.