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submission Journal 28

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erick nugraha <nugraha_eriq1@yahoo.co.id>
Kepada: Miklos Botha

Rab, 2 Sep 2020 jam 21.13

Dear Miklos,
I send you our third journal with title..

The Effect of Moon Phases to the Pelagic Fish Catches Purse Seine in Fisheries Management Area (FMA) 716, Indonesia

thank you.

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The Effect of Moon Phases to the Pelagic Fish Catches Purse Seine in Fisheries Management Area (FMA) 716, Indonesia

[1]Suharyanto, [1]M Khaydar Arifin, [1]Jerry Hutajulu, [1]Ali S Waluyo, [1]Yusrizal, [1]M Handri, [1]Aman Saputra, [1]Abdul Basith, [1]Erick Nugraha, [2]Sepri

[1]Faculty of Fishing Technology, Jakarta Fisheries Institute, South Jakarta, Indonesia; [2]Faculty of Fishing Technology, Sorong Fisheries Institute, West Papua, Indonesia; Indonesia; Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

Abstract. The purse seine is a fishing tool whose main part is a net whose target catch is pelagic fish. Many factors influence the amount of catch and one of them is the Moon Phases. Changes in the moon phases can identify best times for fishing operations. The purpose of this study was to analyze the effect of the moon phases on the total catch of *K. pelamis*. The data was collected by following the fishing operation directly. The data analysis method used was descriptive to understand how the purse seine operation process and to classify the number of catches based on 4 moon phases. The results of the analysis of differences in the number of catches in each moon phases showed that the highest number of catches occurred in the first crescent cycle 8.575 kg (35%) and the smallest number of catches was during the dark moon phases 1.877 kg (8%). For the results of the analysis of the influence of the moon carried out by the ANOVA test, the value was 0.577>0.05, which means that the moon phases did not have a significant effect on the number of catches.

Kata Kunci : Sulawesi sea, *Pelagic Schooling Species*, Hunter's Moon, Skipjack tuna

Introduction. Indonesia is an archipelagic country that has natural wealth and has potential for fishery resources, both in capture fisheries, marine cultivation, public waters and others (KKP, 2017). Potential fishery resources in North Gorontalo Regency are estimated to have the potential for capture fisheries of 590.970 tons consisting of 175.260 tons of large pelagic fish, 384.750 tons of small pelagic fish, and other types of fish of 30.960 tons. Measured from the utilization rate, it is estimated that it has only reached 46% (Department of Fisheries and Marine Affairs of Gorontalo Province, 2012). To take advantage of the potential of capture fisheries in North Gorontalo, there are several ways and one of them is using a purse seine. (Center for Marine and Fisheries Education, 2012).

Fishing boats are boats or other floating means that are used for fishing (Fachrussyah, 2017). The purse seine boat used for fishing activities in Gorontalo waters uses a *two boat system*. The purse seine is a fishing gear from a net that is operated by circling a group of fish to a bowl-shaped tool at the end of the fishing process (Salencer, 2018). The operation of this fishing gear basically consists of 4 stages of activities which include setting, pursing, hauling and brailling (Santoso H & Bawole F. 2014).

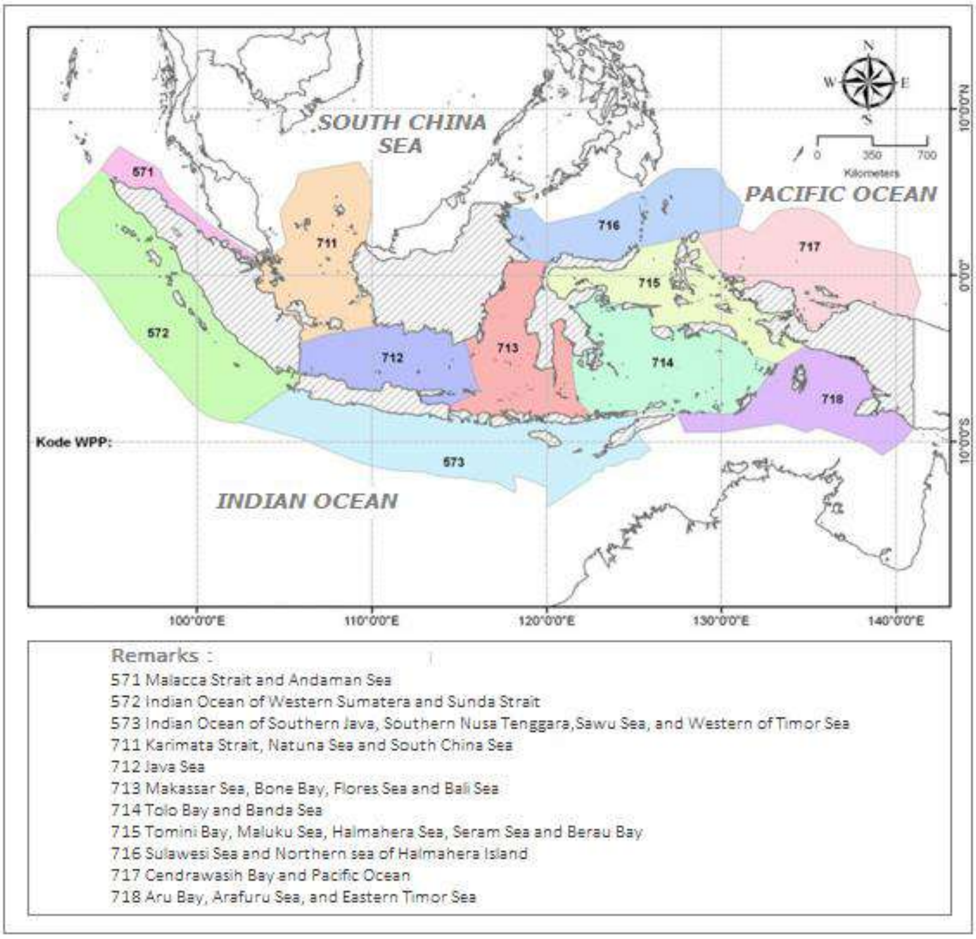
In the operation of a purse seine, there are several factors that affect its operation, one of which is the moon phases. Changes in the moon phases can indicate a good time in fishing operations because there is a difference in light intensity in each moon phases and will affect fish that have positive or negative phototaxis properties of light so that differences in intensity will affect the volume of the catch when fishermen operate (Jatmiko, 2015).

The principle of catching fish with a purse seine is to purse a school of fish with a net. After that the lower net is drained like a bowl, so that the fish collect in the codend and cannot escape. (Syamsuddin et al., 2014). The net is operated in the morning starting at 05.00 AM, setting time lasts half an hour. In 1 trip, the purse seine is operated 1 to 2 times the setting, depending on the catch (Rahmat & Witdiarso, 2017).

Fish that are the main purpose of catching from purse seine are fish that are "Pelagic Schooling Species" (Gatut Bintoro, 2011). According to Telussa (2006), fishing operations with purse seine around FADs with the target of catching small pelagic fish include scad (Decapterus spp), yellowstripe scad (*Selaroides leptolepis*), large pelagic fish such as skipjack (*Katsuwonus pelamis*), frigate tuna (*Auxis rhocei*) and baby tuna (*Thunnus spp*). A fishing ground is where fish that is the target of fishing are caught in maximum numbers and fishing gear can be operated as well as economically (Nusantara et al, 2014).

According to Gatut Bintoro (2011) The first step in operating this fishing gear is to find a fishing ground. Because the fish that are targeted by the purse seine are clustered fish living in palagics, generally the catching area is in the form of seas in offshore areas with water depths of about 50 meters or more.

The distribution of demersal fish resources in FMA-716 is relatively narrow covering the coastal areas of Tarakan, Belinyu and Nunukan in East Kalimantan and Likupang Bay and around the Sangihe Talaud islands in North Sulawesi (Suman A. et al 2014).



Gambar 1. Fisheries Management Areas (FMA) in Indonesia (FAO, 2018)

Moon Phases

Optimization of fishing will work well if fishermen can find out the factors that influence it. These factors include suitability in using fishing gear. The fishing gear used should be adjusted to the fishing ground and the type of fish that is the main target. In addition to the suitability of using fishing gear, fish resources will affect the catch obtained. The factor of the period of the day of the month will indirectly have an impact on the availability of fish resources, so fishermen need to know the changes in each period of the day of the month (Jatmiko, 2015).

Gambar 2. Siklus bulan wilayah Gorontalo (timeanddate.com/moon/phase/)

The catch of fish is strongly influenced by natural factors, one of which is the moon phases. The catch is also affected by changes in the intensity level of the moonlight. Changes in the amount and type of fishermen's catch in each lunar cycle (dark moon, dark to first crescent, first crescent to light moon, bright moon to last crescent) greatly impact the amount of catch and also the income level of fishermen (Nurlindah et al., 2017).

The changing conditions of the lunar period are divided into four phases. New or dark moon phase (new moon), moon phase quadrant 1 (first quarter), full moon phase (full moon), and moon phase quadrant 3 (third quarter). The period of change in the conditions of the month on average occurs every seven days. This division is based on the time or period of the appearance of the month. The condition of a bright moon occurs when the appearance of the moon is more than 8 hours in one day, while the moon bright occurs when the appearance of the moon is between 4 hours-7.5 hours, and the dark moon period occurs when the appearance of the moon only appears between 0 hours - 3.5 hours (Lee, 2010).

The use of light as a fishing aid is closely related to the behavior of fish towards light. In the lift net fishing, the light sources are natural and artificial. Natural light sources come from the sun and moon, when the moon is full, the moonlight will spread over the surface of the water so that the fish will also spread on the surface of the water. This makes it very difficult for fishermen to carry out fishing operations with a purse seine, because it is difficult for fishermen to collect fish into one catchable area. The catch of the boat chart is a group of small pelagic fish that are reactive to light. There are patterns of fish arrival around the light source that go directly to the light source and some are only around the light source. The moon phases is an indication for determining fishing time for fishermen (Siahainenia, 2017).

Material and Method

This research was conducted from November 2019 to May 2020 by participating in the fishing operation of the purse seine vessels operating in North Gorontalo waters.

Figure 3. The purse seine fishing boat used during the study

The tools and materials needed in this research are camera, calculator, laptop, stationery and *Moon Phase Calendar* application.

Method of collecting data

The author uses several methods in data collection, including by way of: observation, interviews and documentation.

1. Primary data, obtained by making direct observations on the ship by participating in ship fishing operations, the data includes; (1) preparation, (2) setting, (3) pursing, (4) hauling, (5) brailing, (6) fish handling, (7) date of each moon phases.
2. Secondary data, is data from fishing owners or companies. The data collection method used was a survey method.

Table 3

The Emergence of Moon Phases

Third Quarter		New Moon	
Date	Time	Date	Time
20/11/2019	05:10	26/11/2019	23:05
19/12/2019	07:14	26/12/2019	13:13
17/01/2020	20:58	25/01/2020	05:42
First Quarter		**Full Moon**	
Date	Time	Date	Time
04/12/2019	14:58	12/12/2019	13:02
03/1/2020	12:45	11/1/2020	03:21
02/2/2020	09:41	09/2/2020	15:33

Data Processing Methods

The data that have been obtained during the study are grouped and classified using tables. Data for each trip of fishing activities are grouped according to the catch, type of fish obtained, income and the moon phases.

Data analysis method

Using descriptive analysis that describes the process of operating fishing gear and to determine the composition of the catch related to the moon phases, a quantitative research was carried out. Furthermore, to observe the effect of the moon phases, the composition of the catch was grouped into 4 moon phases. To find out the percentage comparison of fishing results between 4 moon phases, namely by using the following approach (Susaniati et al., 2013):

$$\mathrm{p} = \frac{\mathrm{ni}}{n}\, x\, 100\%$$

Information:

p = Percentage

ni = value of catch per species

n = Value of Total Catch

Then,

$$\text{Percentage of dark moons } = \frac{\text{total new moon catch}}{\text{total moon phases catches}}\, x\, 100\%$$

$$\text{Percentage of dark moons } = \frac{\text{total first quarter catch}}{\text{total moon phases catches}}\, x\, 100\%$$

$$\text{Percentage of dark moons } = \frac{\text{total full moon catch}}{\text{total moon phases catches}}\, x\, 100\%$$

$$\text{Percentage of dark moons } = \frac{\text{total third quarter catch}}{\text{total moon phases catches}}\, x\, 100\%$$

Then to find out whether the moon phases affects the number of catches, the authors conducted a One Way Anova test using SPSS 22 software. Before carrying out the One Way Anova test, the normality and homogeneity tests must be passed first. The basis for decision making is as follows:

- Normality test
  If the value is Sig. > 0.05, then the data is normally distributed
  If the value is Sig. <0.05, then the data is not normally distributed
- Homogeneity Test
  If the value is Sig. > 0.05, then the data is the same or homogeneous
  If the value is Sig. <0.05, then the data is not the same or not homogeneous
- Anova test
  If the value is Sig. > 0.05, then the average is equal or has no effect
  If the value is Sig. <0.05, then the average is different or influential

Fishing Ground

The fishing operation area at the time of the research was in the Fisheries Management Area of the Republic of Indonesia (FMA-RI) 716, namely in the Sulawesi Sea region as in the map below:

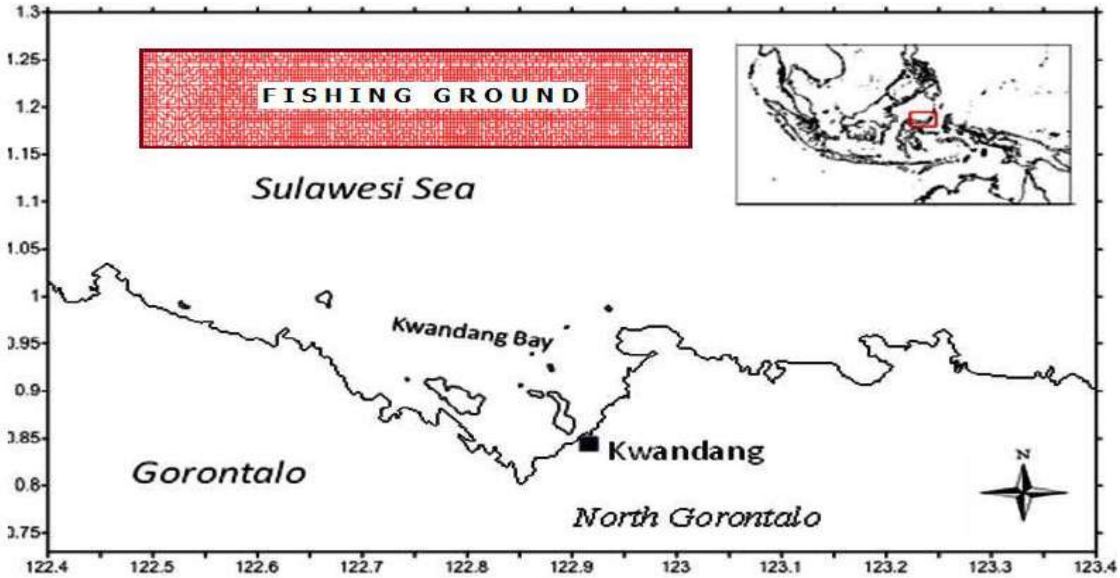


Figure 4. *Fishing Ground* (Tegoeh et al. 2018)

The setting position is as in the table below:

Table 4

Position at the time of the arrest operation

No	Latitude	Longitude
1	01°19′ 54″ U	123°19′ 36″ T
2	01°15′ 54″ U	122°28′ 18″ T
3	01°11′ 18″ U	122°34′ 36″ T
4	01°22′ 42″ U	122°39′ 12″ T
5	01°21′ 36″ U	122°36′ 00″ T
6	01°15′ 54″ U	122°28′ 18″ T
7	01°21′ 48″ U	122°36′ 42″ T
8	01°20′ 36″ U	122°13′ 54″ T
9	01°12′ 00″ U	122°14′ 30″ T
10	01°12′ 48″ U	122°35′ 48″ T

Result.
Catched Fish

The dominant target fish caught in the waters of North Gorontalo are Skipjack Tuna (*Katsuwonus pelamis*), Frigate Tuna (*Euthynnus affinis*), Yellowfin Tuna (*Thunnus albacares*), Indian Scad (*Decapterus sp*).

Number of fish caught during 16 trips

The moon phases is divided into 4 cycles, namely the *first quarter*, the *new moon*, the *third quarter* and the *full moon*. The grouping of the number of catches according to the moon cycle is based on the number of trips as many as 16 trips which are then subdivided into 4 moon phases. The following is data on the number of catches of 16 trips:

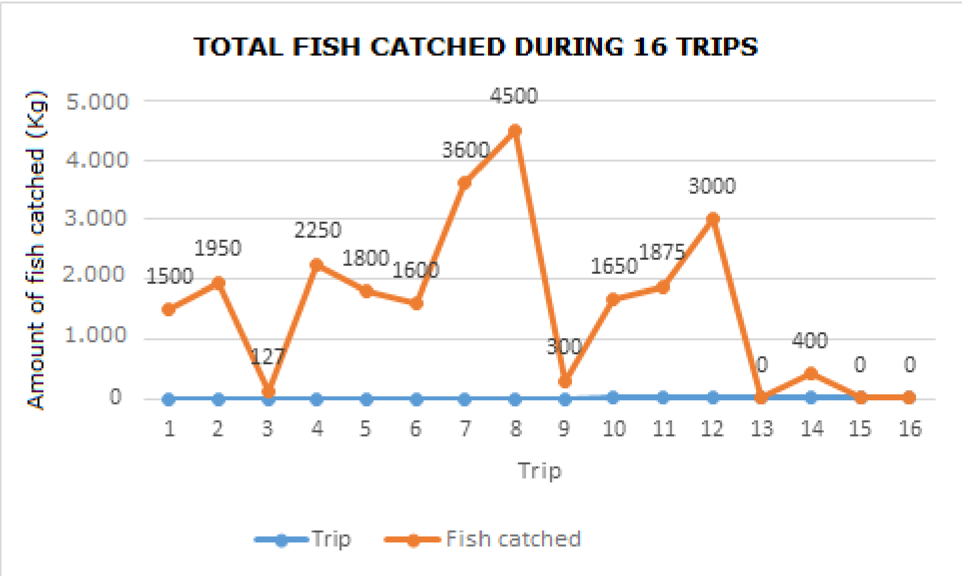


Figure 5. Graph of the number of fish caught during 16 trips

It can be seen that based on the results of the research, the fish caught the most was on the 8th trip with the number of fish caught as much as 4.500 kg consisting of *Katsuwonus pelamis* are 1.500 kg, *Decapterus sp.* are 2.000 kg and *Euthynus affinis* are 1.000 kg.

In Figure 6, you can see the graph of the composition of the fish caught during 16 trips.

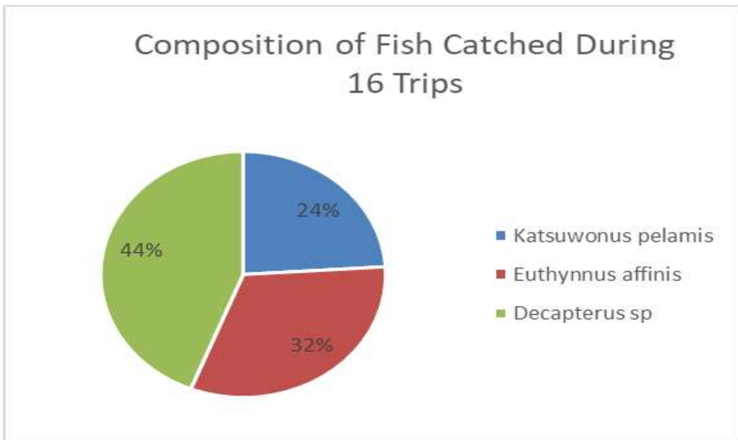


Figure 6. Composition of catched fish

The total number of catches is 24.552 kg, with details of *Decapterus sp.* 10.852 kg, *Euthynus affinis* 7.850 kg and *K. pelamis* 5.850 kg. It can be seen that the most fish species obtained are *Decapterus sp*. 44% (10.852 kg) and the smallest was *K. pelamis* 24% (5.850 kg).

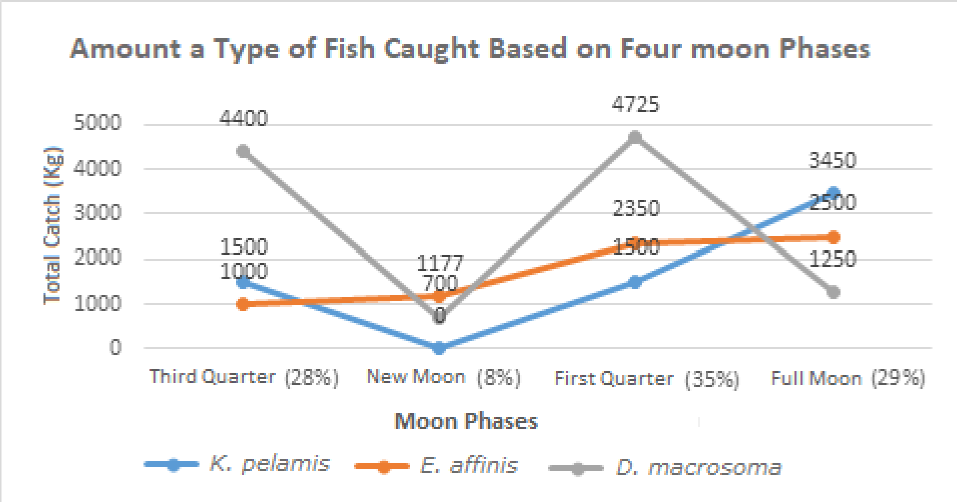


Figure 7. Graph of the number per type of catch based on 4 month cycles

Effect of the moon phases to the number of catches

For grouping based on moon phases, the highest results were obtained in the *first quarter* of 35% (8.575 kg) and the smallest results were 8% (1.877 kg) of the *new moon* phases as shown in Figure 8 below:

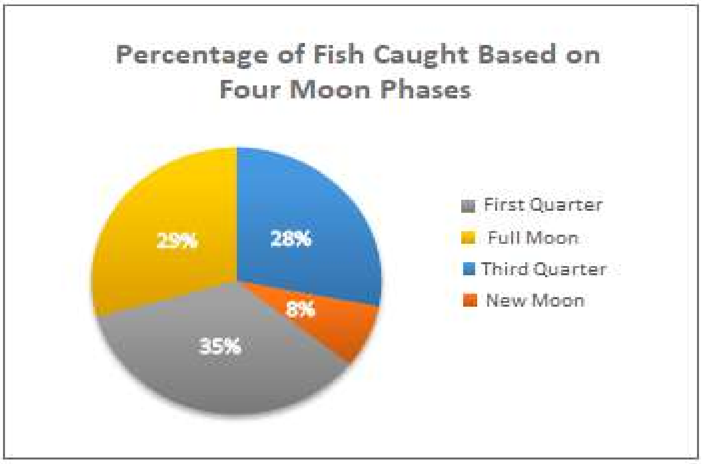


Figure 8. Percentage of fish caught based on four moon phases

To determine whether or not the moon cycle affects the number of catches using SPSS software for the *One Way Anova* test.

- Normality test

Table 8

Normality test

Phase	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Amount Third Quarter	.224	3	.	.984	3	.759
New Moon	.318	3	.	.887	3	.344
First Quarter	.268	3	.	.950	3	.571
Full Moon	.276	3	.	.942	3	.537

From the normality test above, it can be concluded that the Sig. >0.05 so that the data is normally distributed and can be continued to the homogeneity test

- Homogeneity Test

Table 9

Homogeneity test

Levene Statistic	df1	Df2	Sig.
1.093	3	8	.406

For the homogeneity test, the Sig. 0.406>0.05 so that it can be said to be homogeneous and it can be continued to the last stage, namely the anova test.

- Anova test

Table 10

Anova test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8601192.667	3	2867064.222	.701	.577
Within Groups	32720469.33	8	4090058.667		
Total	41321662.00	11			

From the ANOVA test results above, it can be seen that the Sig. 0.577> 0.05, which means that the lunar cycle has a weak or insignificant effect on the amount of catch.

Conclusion

1. From the results of the study it can be concluded that the total number of fish caught is 24.552 kg with the largest composition are *Decapterus sp*. was 10.852 kg.
2. The largest amount was obtained during *the first quarter phase*, namely as much as 8.575 kg (35%).
3. The smallest amount is during the *new moon phases*, which is 1.877 kg (8%).
4. For the *one way ANOVA* test results, the Sig. 0.577>0.05, which means that the moon phases has no significant effect on the amount of catch.

Acknowledgment. We would like to thank to all skipper and crew of FB. DOA RESTU 01 who have allowed us to do research on purse seine 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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Authors:

Suharyanto, Jakarta Institute of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: suharyanto.jfu@gmail.com

Jerry Hutajulu, Jakarta Institute of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: jerryhutajulu15@gmail.com

Ali Syamsudin Waluyo, Jakarta Institute of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: aliswaluyo6@gmail.com

Aman Saputra, Jakarta Institute of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: amansaputra@yahoo.com

Yusrizal, Jakarta Institute of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: buyung_trc@yahoo.co.id

M Handri, Jakarta Institute of Fisheries, Faculty of Fisheries Extension, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: handrimuhammad@gmail.com

Erick Nugraha, Jakarta Institute of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: nugraha_eriq@yahoo.co.id

Abdul Basith, Jakarta Institute of Fisheries, Faculty of Fisheries Machinary, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: abdulbasith_ppsstp63@gmail.com

Mohammad Khaidar Arifin, (Student). Jakarta Institute of Fisheries, Faculty of Fisheries Machinary, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: arifinkhaydar@gmail.com

Sepri, Sorong Fisheries Institute, Faculty of Fishing Technology, Jl. K. Pattimura, Tanjung Kasuari, Sorong - West Papua, Indonesia, e-mail: sepri.papua31@gmail.com

Submission letter

Article title:

The Effect of Moon Phases to the Pelagic Fish Catches Purse Seine in Fisheries Management Area (FMA) 716, Indonesia

Name of the authors: Erick Nugraha

Hereby I would like to submit the manuscript entitled "**article title**" 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.

Corresponding author

Erick Nugraha

Date, September 02, 2020

erick nugraha <nugraha_eriq1@yahoo.co.id>

Kepada: Miklos Botha

Min, 27 Des 2020 jam 11.47

Dear sir,
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thank you.

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[1]Suharyanto, [1]Mohammad K. Arifin, [1]Jerry Hutajulu, [1]Ali Syamsudin Waluyo, [1]Yusrizal, [1]Muhammad Handri, [1]Aman Saputra, [1]Abdul Basith, [1]Erick Nugraha, [2]Sepri

[1] Faculty of Fishing Technology, ~~Jakarta Fisheries Institute~~ Jakarta Technical University of Fisheries, South Jakarta, Indonesia; [2] Faculty of Fishing Technology, Sorong Fisheries Institute, West Papua, Indonesia. Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

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Commented [A1]: Title suggestion: **The effect of moon phases upon purse seine pelagic fish catches in fisheries management area (FMA) 716, Indonesia**

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Commented [EN5]: I changed our college name. thank you.

Commented [A6]: 590 tones or 590 thousand tones?

Commented [EN7R6]: 590,970 tons and 384,750 tons

Commented [A8]: Department of Marine Affairs and Fisheries, 2010?

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Fish that are the main purpose of catching from purse seine are fish that are "Pelagic Schooling Species" ~~(Gatut Bintoro, 2011).~~ (Gatut and Sukandar, 2011). According to Telussa (2006), fishing operations with purse seine around FADs with small pelagic fish as target species include *Decapterus* spp., *Selaroides leptolepis*, large pelagic fish such as *K. pelamis*), *Auxis* ~~*rhocei*~~ *rochei* and *Thunnus* spp.. A fishing ground is where fish that is the target of fishing are caught in maximum amount and fishing gear can be operated economically as well (Nusantara et al 2014).

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Fish catches are multispecies in nature comprising demersal and pelagic species. The Indonesian fisheries administration records the catch divided to eleven statistical areas also called "management areas" (http://www.fao.org/fishery/facp/IDN/en). These are shown in Figure 1.

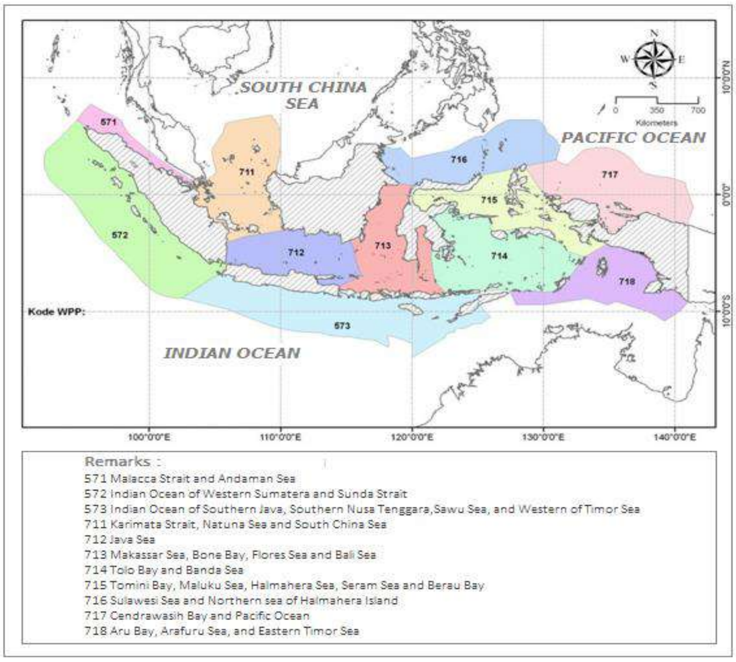

Figure 1. Fisheries Management Areas (FMA) in Indonesia (http://www.fao.org/fishery/facp/IDN/en).

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Moon phases. Optimization of fishing will work well if fishermen can find out the factors that influence it. These factors include suitability in using fishing gear. The fishing gear used should be adjusted to the fishing ground and the type of fish that is the main target. In addition to the suitability of using fishing gear, fish resources will affect the catch obtained. The factor of the phases of the day of the moon will indirectly have an impact on the availability of fish resources, so fishermen need to know the changes in each phases of the day of the moon (Jatmiko 2015).

The catch of fish is strongly influenced by natural factors, one of which is the moon phases. The catch is also affected by changes in the intensity level of the moonlight. Changes in the amount and type of fishermen's catch in each moon phases (dark moon, dark to first crescent, first crescent to light moon, bright moon to last crescent) greatly impact the amount of catch and also the income level of fishermen (Nurlindah et al 2017).

The changing conditions of the moon phases are divided into four phases. New or dark moon phase (new moon), moon phase quadrant 1 (first quarter), full moon phase (full moon), and moon phase quadrant 3 (third quarter) (Figure 2). The phases of change in the conditions of the moon on average occurs every seven days. This division is based on the time or phases of the appearance of the moon. The condition of a bright moon occurs when the appearance of the moon is more than 8 hours in one day, while the moon bright occurs when the appearance of the moon is between 4 hours-7.5 hours, and the dark moon phases occurs when the appearance of the moon only appears between 0 hours - 3.5 hours (Lee 2010).

Figure 2. ~~Siklus bulan wilayah Gorontalo~~ Gorontalo region of moon phase (timeanddate.com/moon/phase/).

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The use of light as a fishing aid is closely related to the behavior of fish towards light. In the lift net fishing, the light sources are natural and artificial. Natural light sources come from the sun and moon, when the moon is full, the moonlight will spread over the surface of the water so that the fish will also spread on the surface of the water. This makes it very difficult for fishermen to carry out fishing operations with a purse seine, because it is difficult for fishermen to collect fish into one catchable area. The catch of the boat chart is a group of small pelagic fish that are reactive to light. There are patterns of fish arrival around the light source that go directly to the light source and some are only around the light source. The moon phases are an indication for determining fishing time for fishermen (Siahainenia 2017).

Material and Method. The present research was conducted from November 2019 to May 2020 by participating in the fishing operations of the purse seine vessels operating in North Gorontalo waters. In Figure 3 below we can shown the purse seine vessel used during the study.

Figure 3. The purse seine fishing boat used during the study.

The tools and materials needed in this research were camera, calculator, laptop, stationery and Moon Phase Calendar application.

Data collection method. ~~The author~~ We uses several methods in data collection, including by way of: observation, interviews and documentation.

1. Primary data were obtained by making direct observations on the ship by participating in ship fishing operations, the data includes; (1) preparation, (2) setting, (3) pursing, (4) hauling, (5) brailing, (6) fish handling, (7) date of each moon phases (Table 3).
2. Secondary data were data from fishing owners or companies. The data collection method used was a survey method.

Table 3

The emergence of moon phases

Third Quarter		**New Moon**	
Date	Time	Date	Time
20/11/2019	05:10	26/11/2019	23:05
19/12/2019	07:14	26/12/2019	13:13
17/01/2020	20:58	25/01/2020	05:42
First Quarter		**Full Moon**	
Date	Time	Date	Time
04/12/2019	14:58	12/12/2019	13:02
03/1/2020	12:45	11/1/2020	03:21
02/2/2020	09:41	09/2/2020	15:33

Data processing. The data that have been obtained during the study were grouped and classified using tables. Data for each trip of fishing activities were grouped according to the catch, type of fish captured, income and the moon phases.

Data analysis. Using descriptive analysis that describes the process of operating fishing gear and to determine the composition of the catch related to the moon phases, a quantitative research was carried out. Furthermore, to observe the effect of the moon phases, the composition of the catch was grouped into four moon phases. To find out the percentage comparison of fishing results between the four moon phases, the approach of Susaniati et al (2013) was applied:

$$\mathrm{p} = \frac{\mathrm{ni}}{n}\, x\, 100$$

Where:
p = percentage
ni = value of catch per species

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Thank you

n = value of total catch

$$\text{Percentage of dark moons } = \frac{\text{total new moon catch}}{\text{total moon phases catches}} x\ 100$$

$$\text{Percentage of dark moons } = \frac{\text{total first quarter catch}}{\text{total moon phases catches}} x\ 100$$

$$\text{Percentage of dark moons } = \frac{\text{total full moon catch}}{\text{total moon phases catches}} x\ 100$$

$$\text{Percentage of dark moons } = \frac{\text{total third quarter catch}}{\text{total moon phases catches}} x\ 100$$

To find out whether the moon phases affects the number of catches, the authors conducted a One Way Anova test using SPSS 22 software. Before carrying out the One Way Anova test, the normality and homogeneity tests must be passed first. The basis for decision making is as follows:

- Normality test
  If the value is Sig. > 0.05, then the data is normally distributed
  If the value is Sig. <0.05, then the data is not normally distributed
- Homogeneity Test
  If the value is Sig. > 0.05, then the data is the same or homogeneous
  If the value is Sig. <0.05, then the data is not the same or not homogeneous
- Anova test
  If the value is Sig. > 0.05, then the average is equal or has no effect
  If the value is Sig. <0.05, then the average is different or influential

Fishing ground. The fishing operation area at the time of the research was in the Fisheries Management Area of the Republic of Indonesia (FMA-RI) 716, namely in the Sulawesi Sea region (Figure 4).

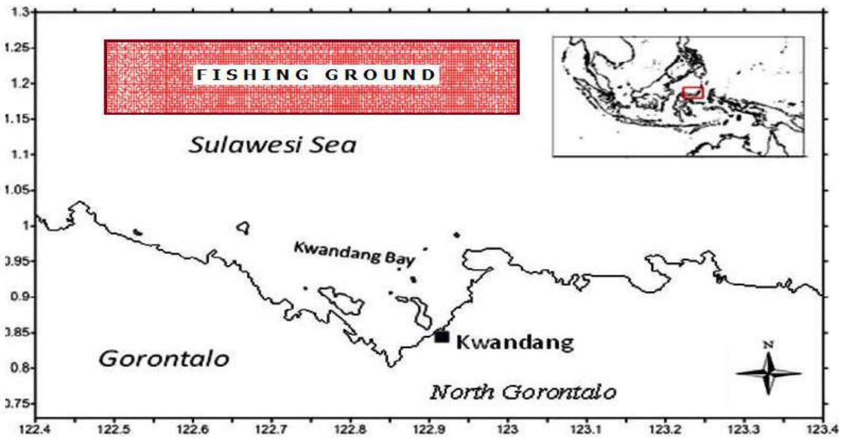

Figure 4. Fishing ground (Tegoeh et al 2018).

The setting (catching) positions were as it is presented in Table 4.

Table 4

Position at the time of the catching operation

No	Latitude	Longitude
1	01°19′ 54″ U	123°19′ 36″ T
2	01°15′ 54″ U	122°28′ 18″ T

3	01°11′ 18″ U	122°34′ 36″ T
4	01°22′ 42″ U	122°39′ 12″ T
5	01°21′ 36″ U	122°36′ 00″ T
6	01°15′ 54″ U	122°28′ 18″ T
7	01°21′ 48″ U	122°36′ 42″ T
8	01°20′ 36″ U	122°13′ 54″ T
9	01°12′ 00″ U	122°14′ 30″ T
10	01°12′ 48″ U	122°35′ 48″ T

Results

Catched fish. The dominant target fish caught in the waters of North Gorontalo were ~~skipjack tuna (*Katsuwonus pelamis*)~~ *K. pelamis*, *Euthynnus affinis*, *Thunnus albacares*, *Decapterus* sp..

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Amount of fish caught during 16 trips. The moon phases are divided into 4 phases, namely the *first quarter*, the *new moon*, the *third quarter* and the *full moon*. The grouping of the amount of catches according to the moon phases is based on the number of trips as many as 16 trips which were then subdivided into 4 moon phases. Figure 5 preents the amount of catch of 16 trips.

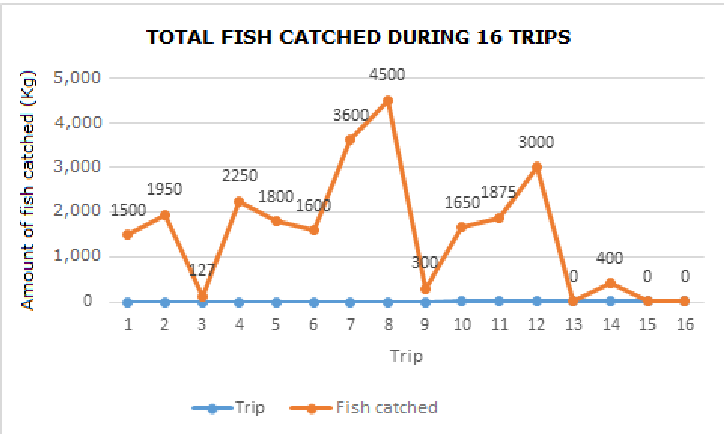

Figure 5. Amount of fish catching during 16 trips.

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It can be seen that based on the results of the research, the most fish caught was on the 8th trip with the amount of fish of 4.500 kg consisting of *Katsuwonus pelamis* with 1,500 kg, *Decapterus* sp. with 2,000 kg and *Euthynus affinis* with 1,000 kg.

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The total amount of catches was 24,552 kg, with 10,852 kg of *Decapterus sp.*, *Euthynus affinis* 7,850 kg and *K. pelamis* 5,850 kg. It can be seen that the highest catch consisted of *Decapterus* sp. 44% (10,852 kg) and the lowest was recorded for *K. pelamis* 24% (5,850 kg) (Figure 6).

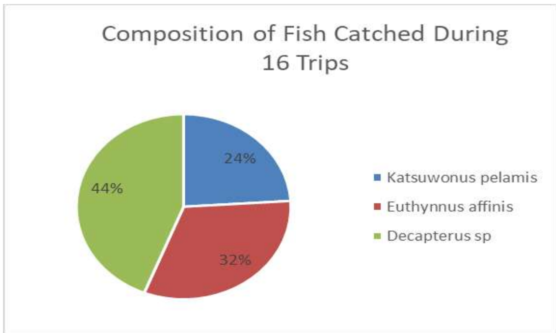

Figure 6. Composition of catched fish.

The total number per type of fish catches based on four moon phases can be seen in the graph 7 below:

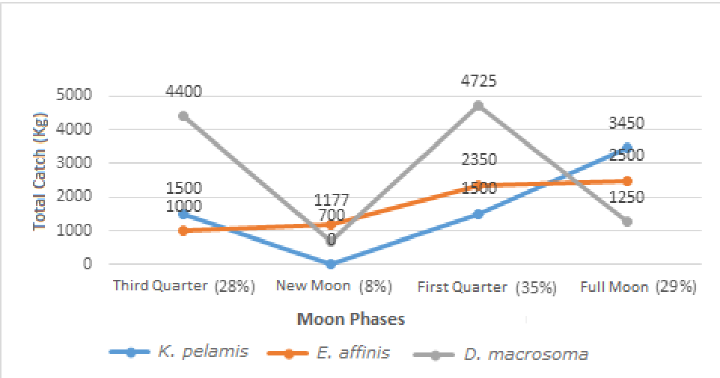

Figure 7. Amont of catch according species based on four moon phases.

Effect of the moon phases upon the catches amount. Grouping based on moon phases revealed the best results for the *first quarter* of 35% (8.575 kg) and the weekest results 8% (1.877 kg) in the *new moon* phases as shown in Figure 8.

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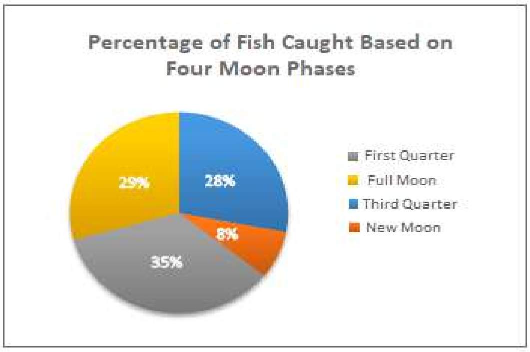

Figure 8. Percentage of fish caught based on four moon phases.

To determine whether or not the moon phases affects the number of catches SPSS software for the *One Way Anova* test was used (Tables 8-10).

- Normality test

Table 8

Normality test

Phase	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Amount Third Quarter	.224	3	.	.984	3	.759
New Moon	.318	3	.	.887	3	.344
First Quarter	.268	3	.	.950	3	.571
Full Moon	.276	3	.	.942	3	.537

From the normality test above, it can be concluded that the Sig. >0.05 so that the data is normally distributed and can be continued to the homogeneity test

- Homogeneity Test

Table 9

Homogeneity test

Levene Statistic	df1	Df2	Sig.
1.093	3	8	.406

For the homogeneity test, the Sig. 0.406>0.05 so that it can be said to be homogeneous and it can be continued to the last stage, namely the anova test.

- Anova test

Table 10

Anova test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8601192.667	3	2867064.222	.701	.577
Within Groups	32720469.33	8	4090058.667		
Total	41321662.00	11			

From the ANOVA test results above, it can be seen that the Sig. 0.577> 0.05, which means that the moon phases has a weak or insignificant effect on the amount of catch.

Conclusions

1. From the results of the study it can be concluded that the total number of fish caught was 24,552 kg with the highest catch consisting in *Decapterus* sp. (10,852 kg).
2. The highest amount of catch was obtained during *the first quarter phase*, namely as much as 8,575 kg (35%).
3. The lowest amount of catch was recorded during the *new moon phases* (1,877 kg; 8%).
4. For the one way ANOVA test results, the Sig. 0.577>0.05, revealed that the moon phases has no significant effect on the amount of catch.

Acknowledgements. We would like to thank to all ~~skipper~~ Captain and crew of FB. DOA RESTU 01 who has allowed us to do research on purse seine 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.

Commented [A31]: What is a skipper? Please explain.

Commented [EN32R31]: Skipper, is a captain on fishing boat. Captain/Master is a captain on merchant marine. (IMO rule)

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http://www.fao.org/fishery/facp/IDN/en.
http://www.timeanddate.com/moon/phase

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Authors:
Suharyanto, ~~Jakarta Institute of Fisheries~~ Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: suharyanto.jfu@gmail.com

Mohammad Khaidar Arifin, (Student). ~~Jakarta Institute of Fisheries~~ Jakarta Technical University of Fisheries, Faculty of Fishing Technology. Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: arifinkhaydar@gmail.com
Jerry Hutajulu, ~~Jakarta Institute of Fisheries~~ Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: jerryhutajulu15@gmail.com
Ali Syamsudin Waluyo, ~~Jakarta Institute of Fisheries~~ Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: aliswaluyo6@gmail.com
Yusrizal, ~~Jakarta Institute of Fisheries~~ Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: buyung_trc@yahoo.co.id
Muhammad Handri, ~~Jakarta Institute of Fisheries~~ Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: handrimuhammad@gmail.com
Aman Saputra, ~~Jakarta Institute of Fisheries~~ Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: amansaputra@yahoo.com
Abdul Basith, ~~Jakarta Institute of Fisheries~~ Jakarta Technical University of Fisheries, Faculty of Fishing Technology., Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: abdulbasith_ppsstp63@gmail.com
Erick Nugraha, ~~Jakarta Institute of Fisheries~~ Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: nugraha_eriq1@yahoo.co.id
Sepri, Sorong Fisheries Institute, Faculty of Fishing Technology, Jl. K. Pattimura, Tanjung Kasuari, Sorong - West Papua, Indonesia, e-mail: sepri.papua31@gmail.com

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Miklos Botha <miklosbotha@yahoo.com>
Kepada: erick nugraha

Sen, 28 Des 2020 jam 18.46

Dear Erick Nugraha,

thank you for your prompt response!

Please find attached the 4th manuscript reviewed.

Looking forward for your kind response!

Kind regards,
Editor AACL Bioflux
Senior Researcher
Miklos Botha, PhD.

The effect of moon phases upon purse seine pelagic fish catches in fisheries management area (FMA) 716, Indonesia

[1]Suharyanto, [1]Mohammad K. Arifin, [1]Jerry Hutajulu, [1]Ali S. Waluyo, [1]Yusrizal, [1]Muhammad Handri, [1]Aman Saputra, [1]Abdul Basith, [1]Erick Nugraha, [2]Sepri

[1] Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia; [2] Faculty of Fishing Technology, Sorong Fisheries Institute, West Papua, Indonesia. Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

Abstract. The purse seine is a fishing tool whose main part is a net whose target catch is pelagic fish. Many factors influence the amount of catch and one of them is the Moon Phases. Changes in the moon phases can identify best times for fishing operations. The purpose of this study was to analyze the effect of the moon phases on the total catch of *K. pelamis*. The data was collected by following the fishing operation directly. The data analysis method used was descriptive to understand how the purse seine operation process and to classify the number of catches based on 4 moon phases. The results of the analysis of differences in the number of catches in each moon phases showed that the highest number of catches occurred in the first crescent cycle 8.575 kg (35%) and the smallest number of catches was during the dark moon phases 1.877 kg (8%). For the results of the analysis of the influence of the moon carried out by the ANOVA test, the value was 0.577>0.05, which means that the moon phases did not have a significant effect on the number of catches.

Key Words: Sulawesi sea, pelagic schooling species, hunter's moon, skipjack tuna.

Introduction. Indonesia is an archipelagic country that has natural wealth and high fishery resources, both in capture fisheries, marine cultivation, public waters and others (KKP 2017). Fishery resources in North Gorontalo Regency are estimated to have the potential for capture fisheries of 590,970 tons consisting of 175,260 tons of large pelagic fish, 384,750 tons of small pelagic fish, and other types of fish of 30,960 tons. Concerning the utilization rate, it is estimated that capture fishery it has only reached 46% of its potential (Department of Marine Affairs and Fisheries 2010). To take advantage of the potential of capture fisheries in North Gorontalo, there are several ways and one of them is using purse seine fishing (Center for Marine and Fisheries Education 2012).

Fishing boats are boats or other floating means that are used for fishing (Fachrussyah 2017). The purse seine boat used for fishing activities in Gorontalo waters uses a "two boat system". The purse seine is a net fishing gear from that is operated by circling a group of fish to a bowl-shaped tool at the end of the fishing process (Salencer 2018). The operation of this fishing gear basically consists of 4 stages of activities which include setting, pursing, hauling and brailling (Santoso & Bawole 2014).

In the operation of a purse seine, there are several factors that affect its operation, one of which is the moon phases. Changes in the moon phases can indicate a good time in fishing operations because there is a difference in light intensity in each moon phases and will affect fish that have positive or negative phototaxis properties of light so that differences in intensity will affect the volume of the catch when fishermen operate (Jatmiko 2015).

The principle of catching fish with a purse seine is to purse a school of fish with a net. After that the lower net is drained like a bowl, so that the fish is collected in the codend and cannot escape (Syamsuddin et al 2014). The net is operated in the morning starting at 05.00 AM, setting time lasts half an hour. In one trip, the purse seine is operated 1 to 2 times (setting), depending on the catch (Rahmat & Witdiarso 2017).

Fish that are the main purpose of catching from purse seine are fish that are "Pelagic Schooling Species" (Gatut & Sukandar 2011). According to Telussa (2006), fishing operations with purse seine around FADs with small pelagic fish as target species include scad (*Decapterus* spp.), yellowstripe scad (*Selaroides leptolepis*), large pelagic fish such as skipjack tuna (*Katsuwonus pelamis*), frigate tuna (*Auxis rochei*) and baby tuna (*Thunnus* spp.). A fishing ground is where fish that is the target of fishing are caught in maximum amount and fishing gear can be operated economically as well (Nusantara et al 2014).

According to Gatut & Sukandar (2011) the first step in operating this fishing gear is to find a fishing ground. Because the fish that are targeted by the purse seine are clustered fish living in palagics, generally the catching area is in the form of seas in offshore areas with water depths of about 50 meters or more.

The distribution of demersal fish resources in FMA-716 is relatively narrow covering the coastal areas of Tarakan, Belinyu and Nunukan in East Kalimantan and Likupang Bay and around the Sangihe Talaud islands in North Sulawesi (Suman et al 2014).

Fish catches are multispecies in nature comprising demersal and pelagic species. The Indonesian fisheries administration records the catch is divided to eleven statistical areas also called "management areas" (FAO 20128) (Figure 1).

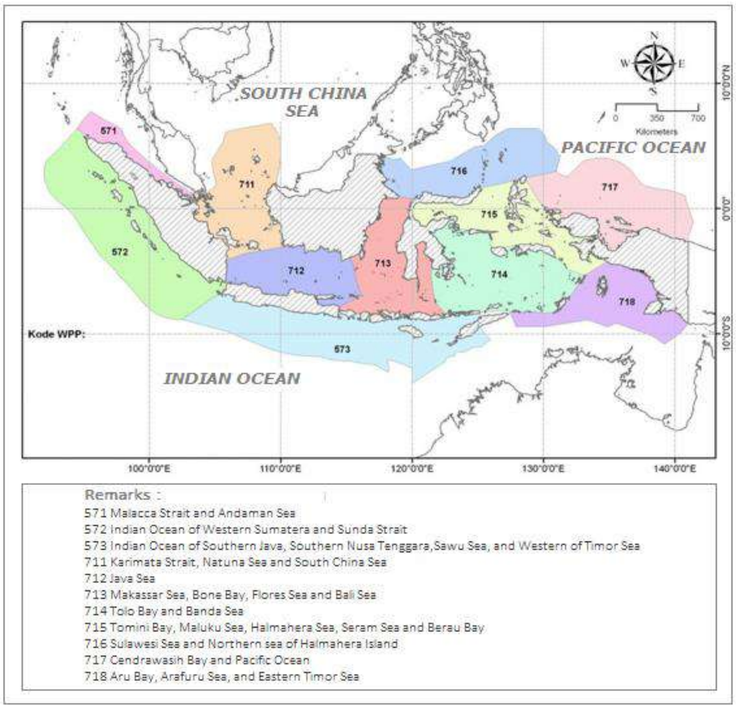

Figure 1. Fisheries management areas (FMA) in Indonesia (FAO 2018).

Moon phases. Optimization of fishing will work well if fishermen can find out the factors that influence it. These factors include suitability in using fishing gear. The fishing gear used should be adjusted to the fishing ground and the type of fish that is the main target. In addition to the suitability of using fishing gear, fish resources will affect the catch obtained. The factor of the period of the day of the month will indirectly have an impact on the availability of fish resources, so fishermen need to know the changes in each period of the day of the month (Jatmiko 2015).

The catch of fish is strongly influenced by natural factors, one of which is the moon phases. The catch is also affected by changes in the intensity level of the moonlight. Changes in the amount and type of fishermen's catch in each lunar cycle (dark moon, dark to first crescent, first crescent to light moon, bright moon to last crescent) greatly impact the amount of catch and also the income level of fishermen (Nurlindah et al 2017).

The changing conditions of the lunar period are divided into four phases. New or dark moon phase (new moon), moon phase quadrant 1 (first quarter), full moon phase (full moon), and moon phase quadrant 3 (third quarter) (Figure 2). The period of change in the conditions of the month on average occurs every seven days. This division is based on the time or period of the appearance of the month. The condition of a bright moon occurs when the appearance of the moon is more than 8 hours in one day, while the moon bright occurs when the appearance of the moon is between 4 hours-7.5 hours, and the dark moon period occurs when the appearance of the moon only appears between 0 hours - 3.5 hours (Lee 2010).

Figure 2. Moon phases of Gorontalo region (timeanddate.com/moon/phase/).

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The tools and materials used in the present research were camera, calculator, laptop, stationery and Moon Phase Calendar application.


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2. Secondary data were data from fishing owners or companies. The data collection method used was a survey method.

Table 1

The emergence of moon phases

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17/01/2020	20:58	25/01/2020	05:42
First quarter		Full moon	
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04/12/2019	14:58	12/12/2019	13:02
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$$\mathrm{p} = \frac{\mathrm{ni}}{n}\ x\ 100$$

Where:

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To find out whether the moon phases affects the number of catches, the authors conducted a One Way Anova test using SPSS 22 software. Before carrying out the One Way Anova test, the normality and homogeneity tests must be passed first. The basis for decision making is as follows:

- Normality test
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  If the value is Sig. > 0.05, then the average is equal or has no effect
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Fishing ground. The fishing operation area at the time of the research was in the Fisheries Management Area of the Republic of Indonesia (FMA-RI) 716, namely in the Sulawesi Sea region (Figure 4). The setting (catching) positions were as it is presented in Table 2.

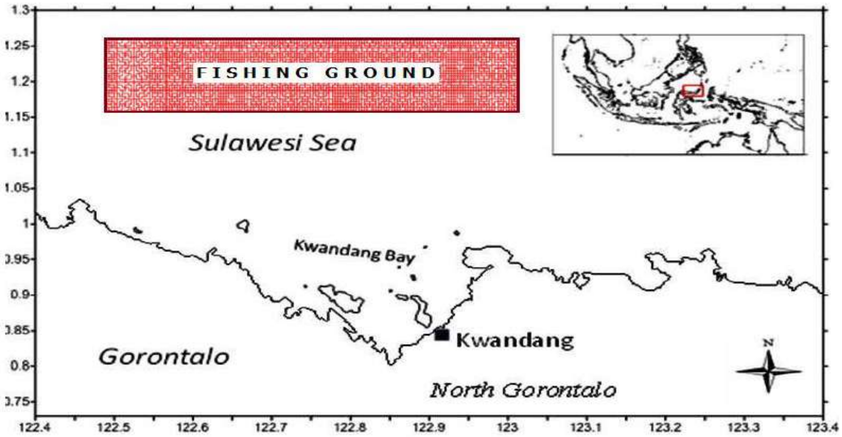

Figure 4. Fishing ground (Tegoeh et al 2018).

Table 2

Position at the time of the caching operation

No	*Latitude*	*Longitude*
1	01°19′ 54″ U	123°19′ 36″ T
2	01°15′ 54″ U	122°28′ 18″ T
3	01°11′ 18″ U	122°34′ 36″ T
4	01°22′ 42″ U	122°39′ 12″ T
5	01°21′ 36″ U	122°36′ 00″ T
6	01°15′ 54″ U	122°28′ 18″ T
7	01°21′ 48″ U	122°36′ 42″ T
8	01°20′ 36″ U	122°13′ 54″ T
9	01°12′ 00″ U	122°14′ 30″ T
10	01°12′ 48″ U	122°35′ 48″ T

Results and Discussion

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Catched fish. The dominant target fish caught in the waters of North Gorontalo were *K. pelamis*, frigate tuna (*Euthynnus affinis*), yellowfin tuna (*Thunnus albacares*), Indian scad (*Decapterus* sp.).

Amount of fish caught during 16 trips. The moon phases are divided into 4 cycles, namely the *first quarter*, the *new moon*, the *third quarter* and the *full moon*. The grouping of the amount of catches according to the moon cycle is based on the number of trips as many as 16 trips which were then subdivided into 4 moon phases. Figure 5 preents the amount of catch of 16 trips.

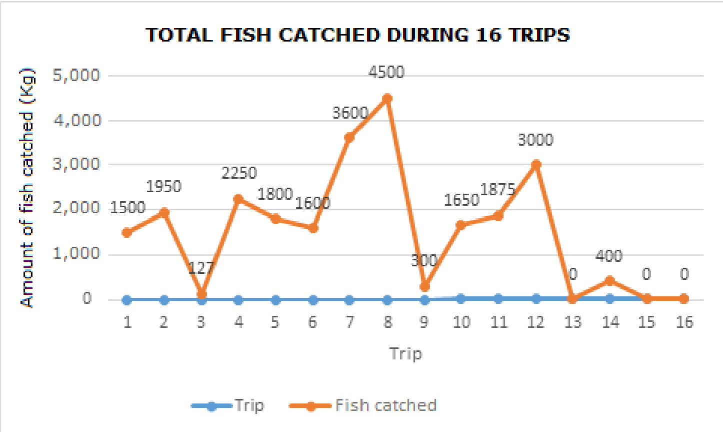

Figure 5. Amount of fish caught during 16 trips.

It can be seen that based on the results of the research, the most fish caught was on the 8^{th} trip with the amount of fish of 4,500 kg consisting of *K. pelamis* with 1,500 kg, *Decapterus* sp. with 2,000 kg and *E. affinis* with 1,000 kg.

The total amount of catches was 24,552 kg, with 10,852 kg of *Decapterus sp.*, *Euthynus affinis* 7,850 kg and *K. pelamis* 5,850 kg. It can be seen that the highest catch consisted of *Decapterus* sp. 44% (10,852 kg) and the lowest was recorded for *K. pelamis* 24% (5,850 kg) (Figure 6).

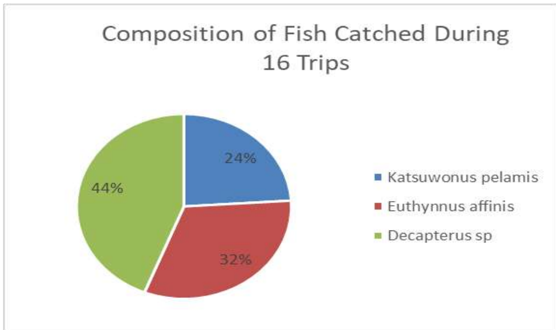

Figure 6. Composition of catched fish.

The total amount of catches according species, based on four moon phases can be seen in the Figure 7.

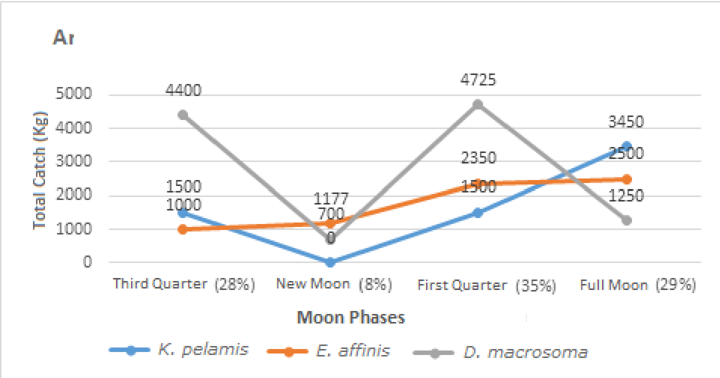

Figure 7. Amont of catch according species based on 4 month cycles.

Effect of the moon phases upon the catches amount. Grouping based on moon phases revealed the best results for the *first quarter* of 35% (8,575 kg) and the weekest results 8% (1,877 kg) in the *new moon* phases as shown in Figure 8.

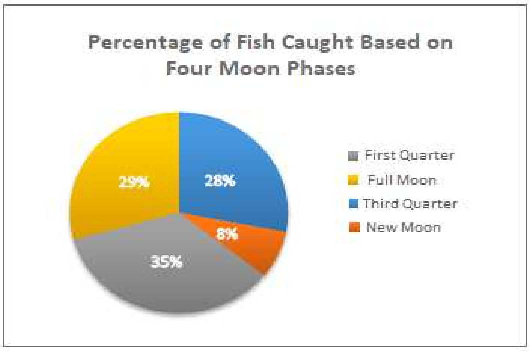

Figure 8. Percentage of fish caught based on four moon phases.

To determine whether or not the moon cycle affects the number of catches SPSS software for the *One Way Anova* test was used (Tables 3-5).

- Normality test

Table 3

Normality test

Phase	*Kolmogorov-Smirnov*[a]			*Shapiro-Wilk*		
	Statistic	*df*	*Sig.*	*Statistic*	*df*	*Sig.*
Third quarter	.224	3	.	.984	3	.759
New moon	.318	3	.	.887	3	.344
First quarter	.268	3	.	.950	3	.571
Full moon	.276	3	.	.942	3	.537

From the normality test above, it can be concluded that the Sig. >0.05 so that the data is normally distributed and can be continued to the homogeneity test

- Homogeneity Test

Table 4

Homogeneity test

Levene statistic	*df1*	*Df2*	*Sig.*
1.093	3	8	.406

For the homogeneity test, the Sig. 0.406>0.05 so that it can be said to be homogeneous and it can be continued to the last stage, namely the anova test.

- Anova test

Table 5

Anova test

	Sum of squares	*df*	*Mean square*	*F*	*Sig.*
Between groups	8601192.667	3	2867064.222	.701	.577
Within groups	32720469.33	8	4090058.667		
Total	41321662.00	11			

From the ANOVA test results above, it can be seen that the Sig. 0.577> 0.05, which means that the lunar cycle has a weak or insignificant effect on the amount of catch.

Conclusions
1. From the results of the study it can be concluded that the total number of fish caught was 24,552 kg with the highest catch consisting in *Decapterus* sp. (10,852 kg).
2. The highest amount of catch was obtained during *the first quarter phase*, namely as much as 8,575 kg (35%).
3. The lowest amount of catch was recorded during the *new moon phases* (1.877 kg; 8%).
4. For the one way ANOVA test results, the Sig. 0.577>0.05, revealed that the moon phases has no significant effect on the amount of catch.

Acknowledgements. We would like to thank to all captains and crew of FB. DOA RESTU 01 who has allowed us to do research on purse seine 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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Authors:
Suharyanto, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: suharyanto.jfu@gmail.com
Mohammad Khaidar Arifin, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: arifinkhaydar@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
Ali Syamsudin Waluyo, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: aliswaluyo6@gmail.com
Yusrizal, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: buyung_trc@yahoo.co.id
Muhammad Handri, Jakarta Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: handrimuhammad@gmail.com
Aman Saputra, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: amansaputra@yahoo.com
Abdul Basith, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: abdulbasith_ppsstp63@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
Sepri, Sorong Fisheries Institute, Faculty of Fishing Technology, Indonesia, Sorong - West Papua, Tanjung Kasuari, Jl. K. Pattimura, e-mail: sepri.papua31@gmail.com

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Sel, 29 Des 2020 jam 12.40

Dear Erick Nugraha,

concerning your 3rd manuscript there are some minor unsolved issues, please see attachment.

Looking forward for your kind response!

Kind regards,

Editor AACL Bioflux
Senior Researcher
Miklos Botha, PhD.

The effect of moon phases upon purse seine pelagic fish catches in Fisheries Management Area (FMA) 716, Indonesia

[1]Suharyanto, [1]Mohammad K. Arifin, [1]Jerry Hutajulu, [1]Ali S. Waluyo, [1]Yusrizal, [1]Muhammad Handri, [1]Aman Saputra, [1]Abdul Basith, [1]Erick Nugraha, [2]Sepri

[1] Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia; [2] Faculty of Fishing Technology, Sorong Fisheries Institute, West Papua, Indonesia. Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

Abstract. The purse seine is a fishing tool whose main part is a net whose target catch is pelagic fish. Many factors influence the amount of catch and one of them is the Moon Phases. Changes in the moon phases can identify best times for fishing operations. The purpose of this study was to analyze the effect of the moon phases on the total catch of *K. pelamis*. The data was collected by following the fishing operation directly. The data analysis method used was descriptive to understand how the purse seine operation process and to classify the number of catches based on 4 moon phases. The results of the analysis of differences in the number of catches in each moon phases showed that the highest number of catches occurred in the first crescent cycle 8.575 kg (35%) and the smallest number of catches was during the dark moon phases 1.877 kg (8%). For the results of the analysis of the influence of the moon carried out by the ANOVA test, the value was 0.577>0.05, which means that the moon phases did not have a significant effect on the number of catches.
Key Words: Sulawesi sea, pelagic schooling species, hunter's moon, skipjack tuna.

Introduction. Indonesia is an archipelagic country that has natural wealth and high fishery resources, both in capture fisheries, marine cultivation, public waters and others (KKP 2017). Fishery resources in North Gorontalo Regency are estimated to have the potential for capture fisheries of 590,970 tons consisting of 175,260 tons of large pelagic fish, 384,750 tons of small pelagic fish, and other types of fish of 30,960 tons. Concerning the utilization rate, it is estimated that capture fishery it has only reached 46% of its potential (Department of Marine Affairs and Fisheries 2010). To take advantage of the potential of capture fisheries in North Gorontalo, there are several ways and one of them is using purse seine fishing (Center for Marine and Fisheries Education 2012).

Fishing boats are boats or other floating means that are used for fishing (Fachrussyah 2017). The purse seine boat used for fishing activities in Gorontalo waters uses a "two boat system". The purse seine is a net fishing gear from that is operated by circling a group of fish to a bowl-shaped tool at the end of the fishing process (Salencer 2018). The operation of this fishing gear basically consists of 4 stages of activities which include setting, pursing, hauling and brailling (Santoso & Bawole 2014).

In the operation of a purse seine, there are several factors that affect its operation, one of which is the moon phases. Changes in the moon phases can indicate a good time in fishing operations because there is a difference in light intensity in each moon phases and will affect fish that have positive or negative phototaxis properties of light so that differences in intensity will affect the volume of the catch when fishermen operate (Jatmiko 2015).

The principle of catching fish with a purse seine is to purse a school of fish with a net. After that the lower net is drained like a bowl, so that the fish is collected in the codend and cannot escape (Syamsuddin et al 2014). The net is operated in the morning starting at 05.00 AM, setting time lasts half an hour. In one trip, the purse seine is operated 1 to 2 times (setting), depending on the catch (Rahmat & Witdiarso 2017).

Fish that are the main purpose of catching from purse seine are fish that are "Pelagic Schooling Species" (Gatut & Sukandar 2011). According to ~~Telussa~~ MS Baskoro et al (2006), fishing operations with purse seine around FADs with small pelagic fish as target species include scad (*Decapterus* spp.), yellowstripe scad (*Selaroides leptolepis*), large pelagic fish such as skipjack tuna (*Katsuwonus pelamis*), frigate tuna (*Auxis rochei*) and baby tuna (*Thunnus* spp.). A fishing ground is where fish that is the target of fishing are caught in maximum amount and fishing gear can be operated economically as well (Nusantara et al 2014).

According to Gatut & Sukandar (2011) the first step in operating this fishing gear is to find a fishing ground. Because the fish that are targeted by the purse seine are clustered fish living in palagics, generally the catching area is in the form of seas in offshore areas with water depths of about 50 meters or more.

The distribution of demersal fish resources in FMA-716 is relatively narrow covering the coastal areas of Tarakan, Belinyu and Nunukan in East Kalimantan and Likupang Bay and around the Sangihe Talaud islands in North Sulawesi (Suman et al 2014).

Fish catches are multispecies in nature comprising demersal and pelagic species. The Indonesian fisheries administration records the catch is divided to eleven statistical areas also called "management areas" (FAO 20128) (Figure 1).

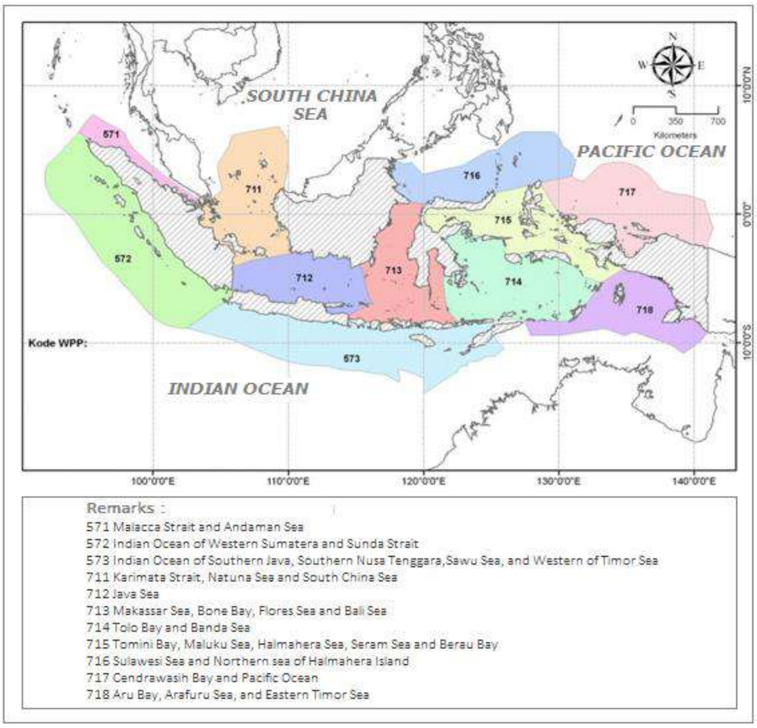

Figure 1. Fisheries management areas (FMA) in Indonesia (FAO 2018).

Moon phases. Optimization of fishing will work well if fishermen can find out the factors that influence it. These factors include suitability in using fishing gear. The fishing gear used should be adjusted to the fishing ground and the type of fish that is the main target. In addition to the suitability of using fishing gear, fish resources will affect the catch obtained. The factor of the period of the day of the month will indirectly have an impact on the availability of fish resources, so fishermen need to know the changes in each period of the day of the month (Jatmiko 2015).

The catch of fish is strongly influenced by natural factors, one of which is the moon phases. The catch is also affected by changes in the intensity level of the moonlight. Changes in the amount and type of fishermen's catch in each lunar cycle (dark moon, dark to first crescent, first crescent to light moon, bright moon to last crescent) greatly impact the amount of catch and also the income level of fishermen (Nurlindah et al 2017).

The changing conditions of the lunar period are divided into four phases. New or dark moon phase (new moon), moon phase quadrant 1 (first quarter), full moon phase (full moon), and moon phase quadrant 3 (third quarter) (Figure 2). The period of change in the conditions of the month on average occurs every seven days. This division is based on the time or period of the appearance of the month. The condition of a bright moon occurs when the appearance of the moon is more than 8 hours in one day, while the moon bright occurs when the appearance of the moon is between 4 hours-7.5 hours, and the dark moon period occurs when the appearance of the moon only appears between 0 hours - 3.5 hours (Lee 2010).

Figure 2. Moon phases of Gorontalo region (timeanddate.com/moon/phase/).

The use of light as a fishing aid is closely related to the behavior of fish towards light. In the lift net fishing, the light sources are natural and artificial. Natural light sources come from the sun and moon, when the moon is full, the moonlight will spread over the surface of the water so that the fish will also spread on the surface of the water. This makes it very difficult for fishermen to carry out fishing operations with a purse seine, because it is difficult for fishermen to collect fish into one catchable area. The catch of the boat chart is a group of small pelagic fish that are reactive to light. There are patterns of fish arrival around the light source that go directly to the light source and some are only around the light source. The moon phases are an indication for determining fishing time for fishermen (Siahainenia 2017).

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  If the value is Sig. > 0.05, then the average is equal or has no effect
  If the value is Sig. <0.05, then the average is different or influential

Fishing ground. The fishing operation area at the time of the research was in the Fisheries Management Area of the Republic of Indonesia (FMA-RI) 716, namely in the Sulawesi Sea region (Figure 4). The setting (catching) positions were as it is presented in Table 2.

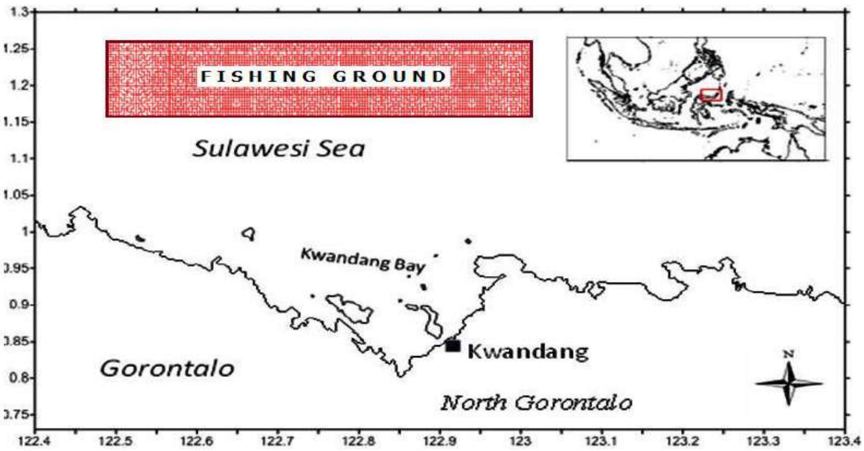

Figure 4. Fishing ground (Tegoeh et al 2019).

Table 2

Position at the time of the caching operation

No	*Latitude*	*Longitude*
1	01°19′ 54″ U	123°19′ 36″ T
2	01°15′ 54″ U	122°28′ 18″ T
3	01°11′ 18″ U	122°34′ 36″ T
4	01°22′ 42″ U	122°39′ 12″ T
5	01°21′ 36″ U	122°36′ 00″ T
6	01°15′ 54″ U	122°28′ 18″ T
7	01°21′ 48″ U	122°36′ 42″ T
8	01°20′ 36″ U	122°13′ 54″ T
9	01°12′ 00″ U	122°14′ 30″ T
10	01°12′ 48″ U	122°35′ 48″ T

Results ~~and Discussion~~

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Catched fish. The dominant target fish caught in the waters of North Gorontalo were *K. pelamis*, frigate tuna (*Euthynnus affinis*), yellowfin tuna (*Thunnus albacares*), Indian scad (*Decapterus* sp.).

Amount of fish caught during 16 trips. The moon phases are divided into 4 cycles, namely the *first quarter*, the *new moon*, the *third quarter* and the *full moon*. The grouping of the amount of catches according to the moon cycle is based on the number of trips as many as 16 trips which were then subdivided into 4 moon phases. Figure 5 preents the amount of catch of 16 trips.

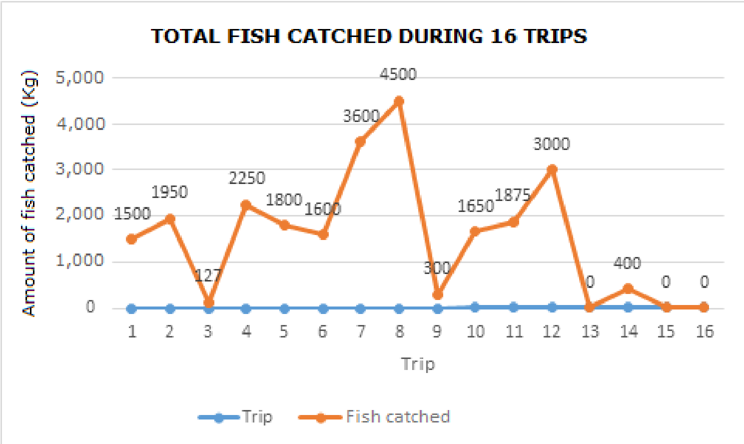

Figure 5. Amount of fish caught during 16 trips.

It can be seen that based on the results of the research, the most fish caught was on the 8th trip with the amount of fish of 4,500 kg consisting of *K. pelamis* with 1,500 kg, *Decapterus* sp. with 2,000 kg and *E. affinis* with 1,000 kg.

The total amount of catches was 24,552 kg, with 10,852 kg of *Decapterus sp.*, *Euthynus affinis* 7,850 kg and *K. pelamis* 5,850 kg. It can be seen that the highest catch consisted of *Decapterus* sp. 44% (10,852 kg) and the lowest was recorded for *K. pelamis* 24% (5,850 kg) (Figure 6).

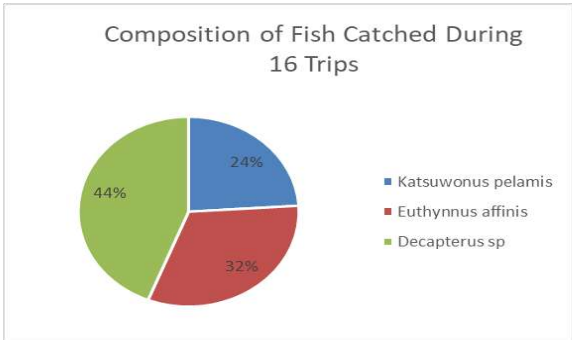

Figure 6. Composition of catched fish.

The total amount of catches according species, based on four moon phases can be seen in the Figure 7.

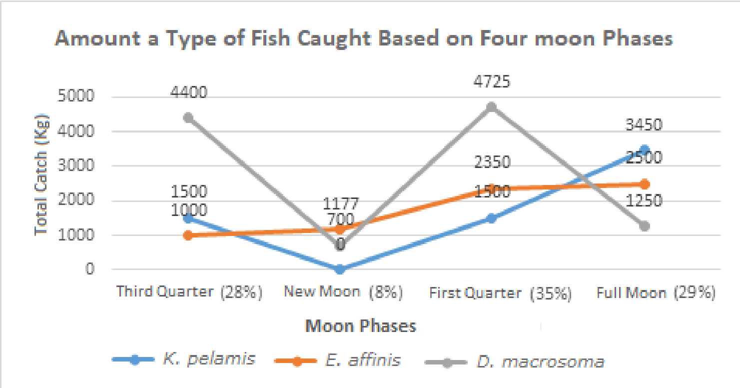

Figure 7. Amont of catch according species based on 4 month cycles.

Effect of the moon phases upon the catches amount. Grouping based on moon phases revealed the best results for the *first quarter* of 35% (8,575 kg) and the weekest results 8% (1,877 kg) in the *new moon* phases as shown in Figure 8.

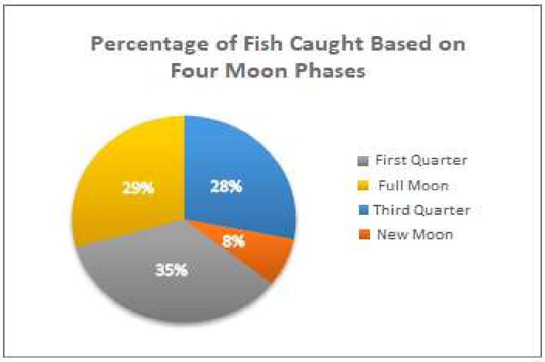

Figure 8. Percentage of fish caught based on four moon phases.

To determine whether or not the moon cycle affects the number of catches SPSS software for the *One Way Anova* test was used (Tables 3-5).

- Normality test

Table 3

Normality test

Phase	*Kolmogorov-Smirnov*[a]			*Shapiro-Wilk*		
	Statistic	*df*	*Sig.*	*Statistic*	*df*	*Sig.*
Third quarter	.224	3	.	.984	3	.759
New moon	.318	3	.	.887	3	.344
First quarter	.268	3	.	.950	3	.571
Full moon	.276	3	.	.942	3	.537

From the normality test above, it can be concluded that the Sig. >0.05 so that the data is normally distributed and can be continued to the homogeneity test

- Homogeneity Test

Table 4

Homogeneity test

Levene statistic	*df1*	*Df2*	*Sig.*
1.093	3	8	.406

For the homogeneity test, the Sig. 0.406>0.05 so that it can be said to be homogeneous and it can be continued to the last stage, namely the anova test.

- Anova test

Table 5

Anova test

	Sum of squares	*df*	*Mean square*	*F*	*Sig.*
Between groups	8601192.667	3	2867064.222	.701	.577
Within groups	32720469.33	8	4090058.667		
Total	41321662.00	11			

From the ANOVA test results above, it can be seen that the Sig. 0.577> 0.05, which means that the lunar cycle has a weak or insignificant effect on the amount of catch.

Conclusions

1. From the results of the study it can be concluded that the total number of fish caught was 24,552 kg with the highest catch consisting in *Decapterus* sp. (10,852 kg).
2. The highest amount of catch was obtained during *the first quarter phase*, namely as much as 8,575 kg (35%).
3. The lowest amount of catch was recorded during the *new moon phases* (1.877 kg; 8%).
4. For the one way ANOVA test results, the Sig. 0.577>0.05, revealed that the moon phases has no significant effect on the amount of catch.

Acknowledgements. We would like to thank to all captains and crew of FB. DOA RESTU 01 who has allowed us to do research on purse seine 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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Authors:
Suharyanto, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: suharyanto.jfu@gmail.com
Mohammad Khaidar Arifin, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: arifinkhaydar@gmail.com
Jerry Hutajulu, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: jerryhutajulu15@gmail.com
Ali Syamsudin Waluyo Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: aliswaluyo6@gmail.com
Yusrizal, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: buyung_trc@yahoo.co.id
Muhammad Handri, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: handrimuhammad@gmail.com
Aman Saputra, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: amansaputra@yahoo.com

Abdul Basith, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: abdulbasith_ppsstp63@gmail.com
Erick Nugraha, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: nugraha_eriq1@yahoo.co.id
Sepri, Faculty of Fishing Technology, Sorong Fisheries Institute, Indonesia, Sorong - West Papua, Tanjung Kasuari, Jl. K. Pattimura, e-mail: sepri.papua31@gmail.com

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Thank You

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Study of tunas (*Thunnus* spp.*)* swimming layer using tuna longliner in the Northern Indian Ocean, Indonesia

Bongbongan Kusmedy, Jerry Hutajulu, Eddy S. Husen, Heru Santoso, Hari Prayitno, Rahmat Mualim, Maman Hermawan, Tonny E. Kusumo, Erick Nugraha, Aldhy Oktavildy

Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia. Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

Abstract. Research on the depth of the tuna swimming layer was carried out from November 2016 to May 2017 in the Indian Ocean. The present study aims to obtain information about tuna long liner operating techniques, determine the composition of the main catch and determine the depth of the tuna swimming layer in the Indian Ocean. This research is a case study of tuna fishing activities on tuna long liner. The catch obtained in this study consisted of 85 Bigeye tuna (*Thunnus obesus*), 45 Albacore (*Thunnus alalunga*), 23 Yellowfin tuna (*Thunnus albaceras*) (15%), and 7 (4%) Southern bluefin tuna (*Thunnus maccoyii*). The Bigeye (*Thunnus obesus*) swimming layer was at a depth of 41–327.48 m. The swimming layer of albacore tuna (*Thunnus alalunga*) was found at a depth of 41–327.48 m. Yellowfin tuna (*Thunnus albacares*) swimming layer was found at a depth of 41–327.48 m. The swimming layer of the southern bluefin tuna (*Thunnus maccoyii*) was found at a depth of 189-310.54 m.
Key Words: Swimming layer depth, tuna, Thunnus spp., South Savu Sea

Introduction. Tuna longline is one of the most effective fishing gears to catch tuna. In addition, this fishing gear is selective to catch tuna (Nugraha & Setyadji 2013). Tuna longline is a combination of several lines with branch line and is equipped with buoys and hook (Subani & Barus 1989). Tuna longline consists of a series of main lines, and on the main line at a certain distance there are several branch lines that are shorter and smaller in diameter. At the end of the branch line is linked a hook with bait (Sjarif & Mulyadi 2004) (Figure 1). This bait includes sardine (*Sardenilla longiceps*), Indian mackerel (*Rastrelliger kanagurta*), scad mackerel (*Decapterus* spp.), bigeye scad (*Selar crumenophthalmus*), squid (*Loligo* spp.) and milkfish (*Chanos chanos*) (Santoso 1995). Milkfish (*Chanos chanos*) life are also used for longline fishing, especially by Taiwanese vessels (Beverly et al 2003).

The distribution and abundance of tuna is strongly influenced by variations in temperature and water depth parameters. Information concerning the distribution of tuna based on temperature and water depth is very important to support the success of tuna fishing operations (Novianto & Bahtiar 2011).

Pelagic fish are fast swimming fish. Tuna is a fast swimmer that differs in epipelagic waters (>500 m) and can swim as far as 55 km every day (Nurjana 2011). Tuna fish live by navigating the world's great oceans with a swimming speed of up to 50 km hour^{-1} (Baskoro & Wahyu 2004).

The interaction between target fish and bycatch is strongly influenced by the swimming layer (Novianto & Nugraha 2014). The depth of the swimming layer of tuna is influenced by temperature and salinity. The depth of the hook can be determined by changing the distance between two adjacent buoys. In addition, there are still other ways, namely by changing the length of the tuna longline such as main lines, branch line and buoy lines (Djatikusumo 1977).

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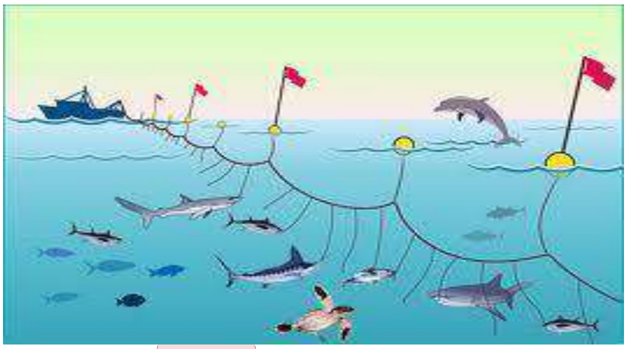

Figure 1. Tuna longline fishing.

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Fishing ground. The fishing areas in Indonesian waters for tuna are Banda Sea, Maluku Sea, waters of south Java Island continuing to the east, as well as south of Sumatra waters, around Andaman and Nicobar, waters of north Irian Jaya, south of Timor waters and so on (Ayodhyoa 1981).

Tunas are special pelagic inhabitants that lies below the thermocline layer during the day, immigrates to the thermocline layer during sunset, spreads between the thermocline layer and the water bed at night, and descends to the deepest layer at sunrise.

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Table 1

Fishing area parameters according to the target catch species

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Species	Depth (m)	Temperature (ºC)
Bigeye tuna (*T. obesus*)	50-600, thermocline layer	10-17
Yellowfin tuna (*T. albacares*)	50-250, top and middle layers	18-28
Albacore (*T. alalunga*)	50-600, thermocline layer	10-17
Blue Marlin (*Macaira nigricans*)	50-150, top and middle layers	18-22

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Fishing season. The fishing season for several types of tuna in Indian Ocean is generally thought to last for six months (Sedana 2004).

Table 2

Season of Indian Ocean tuna fishing (Sedana 2004)

Species	Season (month)	Range of peaks
Southern bluefin tuna (*T. maccoyii*)	January - April	January
Yellowfin tuna (*T. albacares*)	November - January	December
Bigeye tuna (*T. obesus*)	February - June	June
Albacore (*T. alalunga*)	June - August	June
Other large pelagic species	July - December	October

Swimming layer. The distribution of tuna fish (based on depth of water) is most influenced by swimming layer and temperature (Nugraha et al 2010). Several previous research results also showed differences in the depth of the swimming layer of each type of tuna obtained in the Indian Ocean. Bigeye tuna (*T. obesus*) can be found at a depth of 186-285 m, Yellowfin tuna (*T. albacares*) at 149-185 m, and Albacore (*T. alalunga*) at a depth of 161-220 m (Santoso 1999). Bigeye tuna (*T. obesus*) was caught at a depth of 300-399.9 m, Yellowfin tuna (*T. albacares*) 250-299.9 m and Albacore (*T. alalunga*) at 150-199.9 m (Nugraha & Triharyuni 2009).

The purpose of the present study was to find out the types of tuna caught in Indonesian waters and to know the depth of the swimming layer in the Nothern Indian Ocean.

Material and Method. The methods used in data collection consisted of carrying out activities on longliner fishing vessel and using several methods, namely: observation, interview, and literature study.

Data analysis. The data analysis was performed using descriptive method, namely by reducing the data obtained in the field and comparing it with literature studies. Data and information obtained during the implementation of the study was analyzed by descriptive analysis method and qualitative analysis methods. Formula 1 and formula 2 below were used to calculate the depth of the fishing line using the Yoshihara method (1951).

$$D = fl + bl + {}^{1}/_{2}\,BK\ \left\{\sqrt{(1 + Cotg^2\sigma)} - \sqrt{\left(1 - \frac{2j}{n}\right)^2 + Cotg^2\sigma}\right\}$$

Where:
D - depth of hook (m)
Fl - length of the float line
bl - length of branch line
BK - length of play line in 1 basket (m)
j - number of branch line position
n - number of branch lines in 1 basket + 1

K	θ	Cotg²θ
0.47136	79	0.03778
0.48657	78	0.04777
0.51698	77	0.05330
0.60821	69	0.14232
0.54739	75	0.07127
0.51698	77	0.05330
0.63862	66	0.18960
0.77927	54	0.52786
0.60821	69	0.14232
0.56674	73	0.09079

The value of the angle σ was obtained first by finding the curvature coefficient of the main line.

$$K = \frac{Vk\ x\ Ts}{BK\ x \sum b}$$

Where:
K - coefficient of curvature
Vk - ship speed (km h^{-1})
Ts - setting time (hours)
b - number of baskets

Formula 3 below was used to calculate the catch rate in the ratio of the catch to the number of hooks.

$$Hook\ rate = \frac{Number\ of\ fish\ caught/trip}{Number\ of\ hooks\ attached\ /\ trip}\ x\ 100$$

Fishing ground. The area of operation during the voyage was area 1 of the distribution of Southern bluefin tuna (*Thunnus maccoyii*) fishing areas, which is around the south of the islands of Bali, Lombok and Sumbawa (Figure 2).

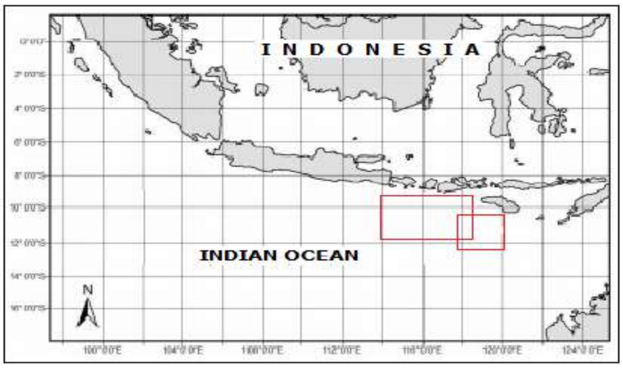

Figure 2. Longliner fishing ground.

Results and Discussion. The research was carried out from November 2016 to May 2017 using longliners operating in the Indian Ocean (Figure 3). The equipment used in this research were: cameras, stationery, calculators, laptops, meters, and tuna caught as research objects.

Picture. 3 Longliners in Bali, Indonesia.

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At the time of research, the catching system used two basket systems, namely basket with thirteen branch lines and basket with six branch lines.

Basket with thirteen branch lines. From the 64 settings, there were 48 settings using basket with thirteen branch lines (Figure 4), the setting time started at 06.00 central Indonesia time (WITA) until it finishes average five hours per setting time, setting using basket with thirteen branch lines is done when the moon is in the dark moon (not in a full moon) and when hauling is at 17.00 central Indonesia time (WITA) until the end of the hauling time is 9-12 hours depending on the weather and the main line is disconnected or not, the more main line decisions the longer the hauling process.

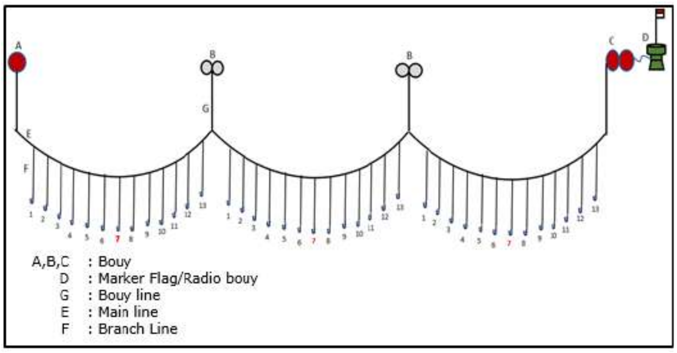

Figure 4. Sketch of basket with 13 branch lines.

The main catch using basket branch line was 90 fish, 56.25% of the total main catch. The tuna caught were albacore tuna (*T. alalunga*), bigeye tuna (*T. obesus*), Yellowfin tuna (*T. albacares*) and Southern bluefin tuna (*T. maccoyii*).

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Basket with six branch lines. From 64 times of the overall settings, for 16 times basket with six branch lines was used (Figure 5). Unlike the thirteen branch line basket, this setting is done at 17.00 central Indonesia time (WITA) until it's finished, the setting takes 6-7 hours because the speed of the main line throwing the speed is slightly reduced when using this basket, because the hooks does not sink too deep due to chasing tuna that swim on the surface of the water, this basket is usually used at full moon, 3 days before full moon and 3 days after full moon.

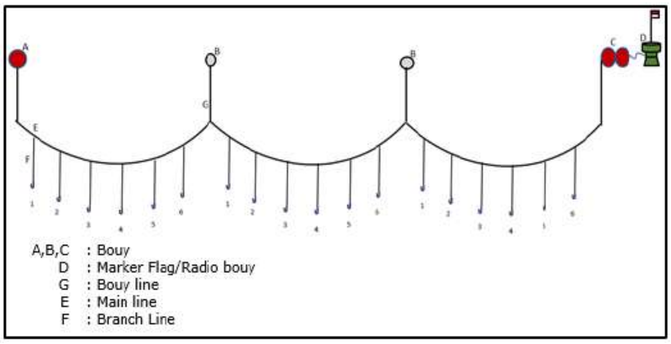

Figure 5. Sketch of basket with 6 branch lines.

The main catch using a basket with six branch lines consisted of 70 fish, 43.75% of the total main catch. From the two types of basket, the highest catches were obtained in basket with 6 branch lines viewed from the catch comparison factor with the number of settings perspective.

Catch composition. The catch obtained was grouped into main catch and bycatch. The main catch was considered to consist of tuna species, while bycatch consisted of any other species.

The total catch obtained during 91 days of fishing operation or 64 settings consisted of 160 fish. The main catch obtained included albacore tuna (*T. alalunga*), bigeye tuna (*T. obesus*), Yellowfin tuna (*T. albacares*) and Southern bluefin tuna (*T. maccoyii*). Comparison of the amount of catch can be seen in Figure 6.

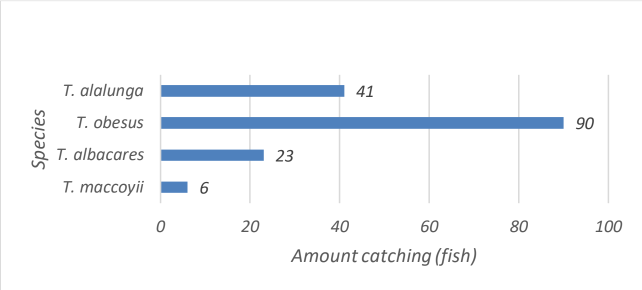

Figure 6. Comparison of the amount of catches.

The picture above shows a comparison of the number of catches during the fishing process. The total catch was dominated by bigeye tuna (*T. obesus*) with a total catch of 90 fish (56%), 41 albacore tuna (*T. alalunga*) (26.54%), 23 Yellowfin tuna (*T. albacares*). (14.20%) while the lowest catch was recorded for Southern bluefin tuna (*T. maccoyii*) amounting 6 fish (4%).

Catch composition of based on size. The tuna species caught had different lengths according to species. The length measurement divided the catch into several categories, namely size 50-100 cm, 100-150 cm, and >150 cm. The distribution of the catch based on length can be seen in Figure 7.

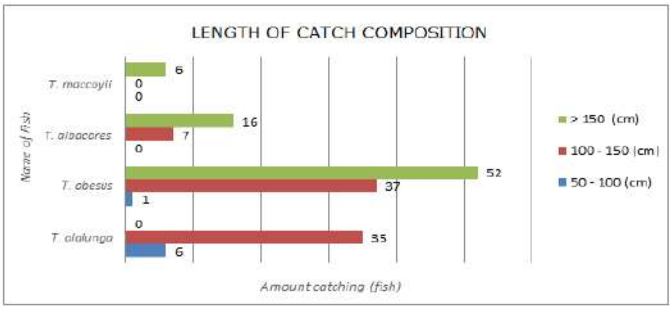

Figure 7. Length of catch composition.

There were 35 *T. alalunga* caught at 100-150 cm size or 44.30%. *T. obesus* was caught mostly at >150 cm in size as many as 52 individuals or about 70.27%. *T. albacares* was mostly caught at a size of >150 cm as many as 16 fish or 21.62%. All individuals of *T. maccoyii* caught were all, over 150 cm amounting 6 fish or 8.11%.

The main catch that is mostly caught is bigeye tuna (*T. obesus*) as many as 90 (56%). Bigeye tuna (*T. obesus*) caught the majority measuring more than 100 cm as much as 58.17%. This shows that more than half of the total catch is catch feasible. Bigeye tuna (*T. obesus*) has a catch size above 100 cm (Pranata 2013).

Albacore tuna (*T. alalunga*) is the second type of tuna caught mostly as many as 41 (26.54%), and as much as 85.38% are catch-worthy. This is because the majority of caught are more than 85 cm in size. At that size, albakora tuna species have experienced gonad maturity (Pranata 2013).

Yellowfin tuna (*T. albacares*) were caught as many as 23 tails or 14.20%. The average that was caught, had a size of more than 105 cm, which was 91.30%.

Southern bluefin tuna (*T. maccoyii*) is the type of tuna caught the least, as many as 6 (4%). However, all the catch of this type has a size of more than 150 cm which means it is catch-worthy. The catch-worthy category of it measures over 120 cm (Pranata 2013).

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I green T. obesus 52 individuals, 70.27%. In this section T. obesus 90 individuals, 56% etc
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This fish is similar to the Southern bluefin tuna (*T. maccoyii*) caught in the northern hemisphere, only smaller in size.

Catch results based on fishing position. The first basket uses thirteen branch lines to catch tuna whose fishing area is deeper, usually performed when it is not a full moon. The second basket uses six branch lines to catch tuna swimming to the surface of the water, six branch lines are used when the full moon is around 7 days.

a. Basket with 13 branch lines

The composition of the catch based on the number of hooks can be seen in the Table 3.

Table 3

Catch based on 13 fishing lines positions

Species	Branch lines							Fish (ind.)
	1, 13	2, 12	3, 11	4, 10	5, 9	6, 8	7	
Albacore (*T. alalunga*)	2	1	3	3	7	3	3	22
Bigeye tuna (*T. obesus*)	6	6	6	11	12	8	6	55
Yellowfin tuna (*T. albacares*)	2	0	2	2	2	3	0	11
Southern bluefin tuna (*T. maccoyii*)	0	0	0	0	0	2	0	2
Number (fish)	10	7	11	16	21	16	9	90
Number hook	10,150	10,150	10,150	10,150	10,150	10,150	5,075	
Hook rate (%)	0.0985	0.0690	0.1084	0.1576	0.2069	0.1576	0.1773	

Based on the Table 3, *T. alalunga* and *T. obesus* were mostly caught on branch line 5 and 9. *T. albacares* was almost evenly caught in each branch lines, but was not caught on lure numbers 2, 7 and 12. *T. maccoyii* was caught on hook number 6 and number 8 only.

b. Basket with 6 branch lines

The composition of the catch based on the number of 6 hooks can be seen in Table 4.

Table 4

Catch based on position of 6 branch lines

Species	Branch lines			Fish (ind.)
	1,6	2,5	3,4	
Albacore (*T. alalunga*)	6	6	7	19
Bigeye tuna (*T. obesus*)	10	11	14	35
Yellowfin tuna (*T. albacares*)	4	4	4	12
Southern bluefin tuna (*T. maccoyii*)	1	2	1	4
Fish (individuals)	21	23	26	70
Number hook	7,180	7,180	7,180	
Hook rate (%)	0.292	0.320	0.362	

Based on Table 4, *T. alalunga* was mostly caught on fishing lines 3 and 4, and were caught evenly on all fishing lines. *T. obesus* was caught mostly in branch line number 3 and 4, and was caught almost evenly on all fishing lines. *T. albacares* was captured evenly on all hooks. *T. maccoyii* was mostly caught on line 2 and 5 and evenly caught on the other hooks.

Hook rate. The hook rate is a real calculation in quantity proportional to the number of fish caught at one time, for tuna longline itself it is calculated every 100 points of the line. So this hook rate determines whether the area still has good fishing potential or not, so that future availability can be calculated.

Figure 8 shows the result of tuna hook rate for 64 settings, these results are for all the four tuna species captured *T. obesus*, *T. albacares*, *T. alalunga*, and *T. maccoyii*. The

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results showed that the average hook rate was 0.18% with the highest hook rate at setting 64, with a hook rate of 0.79%. According to Santoso (1999) the hook rate ranges from 1.17–2.73. The highest hook rate occurred at 9.11 hauling, and 12 was very different from what the researchers found, with a hook rate difference of 0.77%.

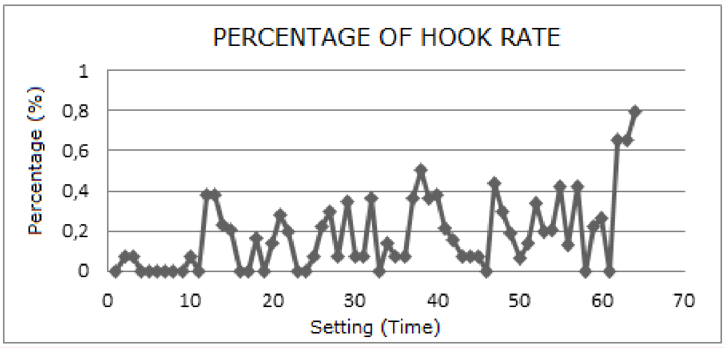

Figure 8. Percentage of hook rate.

Estimated depth of tuna swimming layer

a. Basket with 13 branch lines

The depth of the fishing line in operation with 13 branch lines has different depths as it is shown in Table 5.

Table 5

Calculation of the depth for each fishing line

Branch line number	Depth (m)		
	Upper Limit	Lower Limit	Average
1, 13	41.29	56.87	44.50
2, 12	80.35	113.10	87.49
3, 11	116.25	168.30	128.25
4, 10	147.65	221.56	165.58
5, 9	172.70	270.82	197.47
6, 8	189.14	310.54	220.47
7	194.10	327.49	229.32

The depth of branch line number 8 is the same as of branch line number 6, branch line number 9 is the same as branch line 5, branch line number 10 is the same as branch line 4, branch line number 11 is the same as branch line 3, branch line 12 is the same as branch line number 2, branch line 13 is the same as the number 1.

b. Basket with 6 branch lines

The depth of the branch lines in operation with 6 hooks has different depths, as it is shown in Table 6.

Table 6

The results of the calculation of the depth of each fishing line number

Branch line number	Depth (m)		
	Upper Limit	Lower Limit	Average
1, 6	41.76	52.99	44.71
2, 5	75.47	103.72	82.38
3, 4	95.28	145.11	106.19

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The depth of the branch line number 4 is the same with branch line number 3, branch line number 5 is the same as branch line number 2, branch line number 6 is the same as number 1.

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Swimming layer. The spread of tuna in the sea is determined by two factors, namely internal factors and external factors. Internal factors include genetics, age, size and behavior. Different genetics causes differences in morphology, physiological responses, and adaptability to the environment. External factors are environmental factors, including oceanographic parameters such as temperature, salinity, density, depth of the thermocline layer, currents, water mass circulation, oxygen and food abundance. The swimming depth of tuna varies depending on the species. In general, tuna is caught at a depth of 0-400 meters. The preferred water salinity ranges from 32 to 35 ppt or in oceanic waters. The water temperature ranges from 17-31ºC (Pranata 2013). Tuna catches based on the position of the fishing line (Table 3 and Table 4) and the calculation results of each fishing line number depth value (Table 5 and Table 6) obtained can be used as material for estimating the depth of the swimming layer for each species of tuna.

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T. alalunga was caught in all branch lines, the majority was caught on branch line 5 and 9 (Table 3) as much as 31.82%. It is suspected that *T. alalunga* swimming layer is at a depth of 172.70-270.82 m. The distribution of *T. alalunga* is strongly influenced by temperature and this tuna prefers lower temperatures. According to Nugraha & Triharyuni (2009), the distribution of *T. alalunga* is in a temperature range of 14-24ºC with a catching temperature range of 17-24ºC. At juvenile stage, *T. alalunga* prefers habitat in the area around the equator and its swimming layer is near the surface layer. After maturity (>95 cm), begins to move to a deeper layer (Block & Stevens 2001).

T. obesus catches were recorded almost evenly across the hooks. The depth of the swimming layer of this species is estimated to be at a depth of 41.30–327.49 m, the majority being caught at 172.70–270.82 m depth interval (branch line 5 and 8). *T. obesus* are often caught on deeper branch lines (no. 4, 5, and 6), because *T. obesus* prefer deep water with cooler temperatures (Block & Stevens 2001). The swimming area for *T. obesus* is located just below the thermocline layer, so it is advisable to use the deep sea tuna longline type (Santoso 1999).

T. albacares caught on all hooks were 23 (81.81%). The swimming layer of this species is thought to be at a depth of 189.14–310.54 m. *T. albacares* is often found in fishing lines close to the surface. Mainly this species is generally found above 100 m deep layers which have sufficient oxygen content. In the deeper layers where oxygen levels are low, *T. albacares* individuals are rare, while juvenile *T. albacares* can be found clustered with *K. pelamis* and *T. obesus* in the surface layer. When they are mature, they tend to stay in this water layer. The distribution of *T. albacares* is in the temperature range of 18–31°C (Block & Stevens 2001).

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T. maccoyii was caught in a quantity of 7 individuals and all of them was caught on branch line 2, 3, and 4 but mostly found on branch line number 2 amounting to 42.85%. Tuna which has a large body size has a spreading area with temperatures between 5-20ºC and can be found at depths of up to 1,000 m. This high adaptation behavior to extreme temperatures is due to the fact that *T. maccoyii* can raise its blood temperature above water temperature using its muscle activity (Block & Stevens 2001). *T. maccoyii* caught in the present study were suspected to be spawning individuals.

Figure 9 is an illustration of the swimming depth layer of tuna from the results of the present study. It can be seen the difference in the depth of the swimming layer between the four species of tuna captured. The difference in the vertical distribution of tuna is caused by several factors, one of which is temperature (Pranata 2013). According to the results of research by Nugraha & Triharyuni (2009), in the Indian Ocean *T. obesus* was caught in the temperature range of 10.0-13.9ºC, *T. albacares* at 16.0-16.9ºC, and *T. alalunga* at 20.0-20.9ºC. In addition, differences in location or geographic location also affect the habitat of tuna.

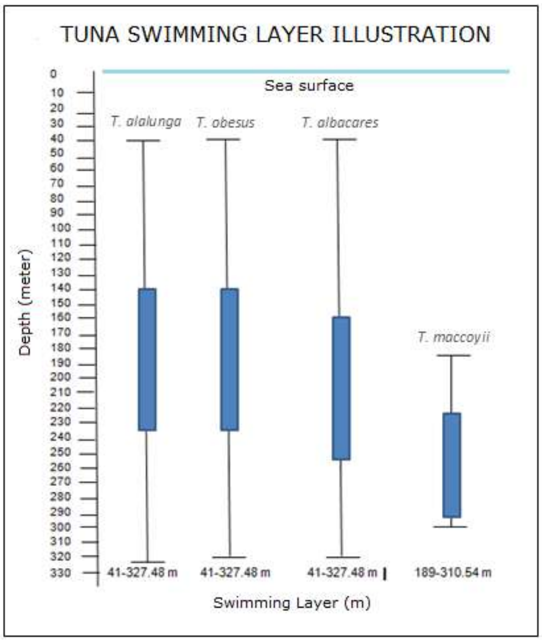

Figure 9. Tuna swimming layer illustration.

Several previous research results also showed differences in the depth of the swimming layer of each type of tuna captured in the Indian Ocean waters. The results of Santoso (1999) research show that *T. obesus* can be found at a depth of 186-285 m, *T. albacares* at 149-185 m, and *T. alalunga* at a depth of 161-220 m. Nugraha & Triharyuni (2009) reported that *T. obesus* was caught at a depth of 300-399.9 m, *T. albacares* at 250.0-299.9 m, and *T. alalunga* at 150.0-199.9 m.

Figure 9 illustrates the overall depth rage of the tuna's swimming layer. *T. alalunga* was caught at a depth range of 41–327.48 m, *T. obesus* was caught at the depth range of 41–327.48 m, *T. albacares* was caught at the depth range of 41–327.48 m and *T. maccoyii* was caught at the depth rage of 189–0 310.54 m.

Conclusions

1. The operation of tuna fishing consists of two processes, namely in setting and hauling. The average setting time was around 5 hours depending on the catch quantity. Hauling was performed from 17.00 until early morning.
2. Overall catches consisted of *T. obesus*, *T. albacares*, *T. alalunga*, and *T. maccoyii*. The average hook rate was 0.18% with the highest hook rate at setting 64, with a hook rate of 0.79%.
3. Concerning the tuna swimming layer, *T. alalunga* was caught at a depth range of 41–327.48 m, *T. obesus* was caught at a depth range of 41–327.48 m, *T. albacares* was caught at a depth range of 41–327.48 m and *T. maccoyii* was caught at a depth range of 189 - 310.54 m.
4. The main catch obtained in the present study consisted of 85 *T. obesus*, 45 *T. alalunga*, 23 *T. albaceras* (15%), and 7 (4%) *T. maccoyii*.

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Authors:
Bongbongan Kusmedy, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: bkhutapea@gmail.com
Jerry Hutajulu, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: jerryhutajulu15@gmail.com
Eddy Sugriwa Husen, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: sugriwastp@gmail.com
Heru Santoso, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: herustppsm15@gmail.com
Hari Prayitno, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: hariprayitno46@gmail.com
Rahmat Mualim, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: rahmatmuallim@gmail.com
Maman Hermawan, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: mhermawan60@gmail.com
Tonny E Kusumo, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: susilobagaswibisono@gmail.com
Erick Nugraha,
Aldhy Oktavildy,

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Miklos Botha <miklosbotha@yahoo.com>
Kepada: erick nugraha

Rab, 30 Des 2020 jam 02.05

Dear Erick Nugraha,

I had a discussion with my fellow editors and my superiors concerning your 3rd manuscript with no Discussion. The conclusion was that any paper must discuss its findings in concordance with previous studies in the field, otherwise cannot be highlighted the novelty of the study. So in order to can publish the paper you should introduce some discussions, citing research in the field. Thank you for understanding!

Looking forward for your kind response!

Kind regards,
Editor AACL Bioflux
Senior Researcher
Miklos Botha, PhD.

Study of tunas (*Thunnus* spp.*)* swimming layer using tuna longliner in the Northern Indian Ocean, Indonesia

Bongbongan Kusmedy, Jerry Hutajulu, Eddy Sugriwa Husen, Heru Santoso, Hari Prayitno, Rahmat Muallim, Maman Hermawan, Tonny Efijanto Kusumo, Erick Nugraha, Aldhy Oktavildy

Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia. Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

Abstract. Research on the depth of the tuna swimming layer was carried out from November 2016 to May 2017 in the Indian Ocean. The present study aims to obtain information about tuna long liner operating techniques, determine the composition of the main catch and determine the depth of the tuna swimming layer in the Indian Ocean. This research is a case study of tuna fishing activities on tuna long liner. The catch obtained in this study consisted of 85 *Thunnus obesus*, 45 *Thunnus alalunga*, 23 *Thunnus albacares* (15%), and 7 (4%) *Thunnus maccoyii*. The *Thunnus obesus* swimming layer was at a depth of 41–327.48 m. The swimming layer of *Thunnus alalunga* was found at a depth of 41–327.48 m. The *Thunnus albacares* swimming layer was found at a depth of 41–327.48 m. The swimming layer of the *Thunnus maccoyii* was found at a depth of 189-310.54 m.
Key Words: ~~Swimming layer depth, tuna, Thunnus spp~~., Thermocline layer, Hook rate, Basket system, South Savu Sea

Introduction. Tuna longline is one of the most effective fishing gears to catch tuna. In addition, this fishing gear is selective to catch tuna (Nugraha & Setyadji 2013). Tuna longline is a combination of several lines with branch line and is equipped with buoys and hook (Subani & Barus 1989). Tuna longline consists of a series of main lines, and on the main line at a certain distance there are several branch lines that are shorter and smaller in diameter. At the end of the branch line is linked a hook with bait (Sjarif & Mulyadi 2004) (Figure 1). This bait includes sardine (*Sardenilla longiceps*), Indian mackerel (*Rastrelliger kanagurta*), scad mackerel (*Decapterus* spp.), bigeye scad (*Selar crumenophthalmus*), squid (*Loligo* spp.) and milkfish (*Chanos chanos*) (Santoso 1995). Milkfish (*Chanos chanos*) ~~life are~~ also used for longline fishing life bait, especially by Taiwanese vessels (Beverly et al 2003).

The distribution and abundance of tuna is strongly influenced by variations in temperature and water depth parameters. Information concerning the distribution of tuna based on temperature and water depth is very important to support the success of tuna fishing operations (Novianto & Bahtiar 2011).

Pelagic fish are fast swimming fish. Tuna is a fast swimmer that differs in epipelagic waters (>500 m) and can swim as far as 55 km every day (Nurjanah et al 2014). Tuna fish live by navigating the world's great oceans with a swimming speed of up to 50 km hour^{-1} (Baskoro & Wahyu 2004).

The interaction between target fish and bycatch is strongly influenced by the swimming layer (Novianto & Nugraha 2014). The depth of the swimming layer of tuna is influenced by temperature and salinity. The depth of the hook can be determined by changing the distance between two adjacent buoys. In addition, there are still other ways, namely by changing the length of the tuna longline such as main lines, branch line and buoy lines (Djatikusumo 1997).

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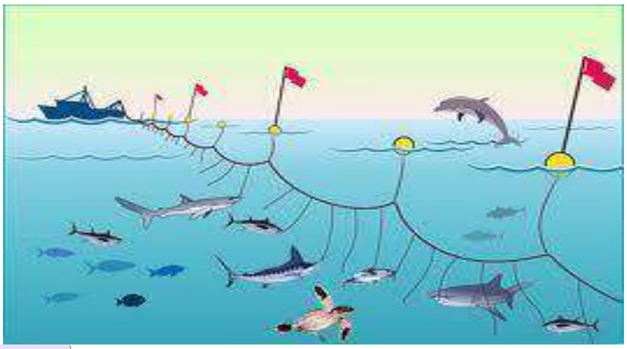

Figure 1. Tuna longline fishing (https://ikantunaku.wordpress.com)

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Fishing ground. The fishing areas in Indonesian waters for tuna are Banda Sea, Maluku Sea, waters of south Java Island continuing to the east, as well as south of Sumatra waters, around Andaman and Nicobar, waters of north Irian Jaya, south of Timor waters and so on (Ayodhyoa 1981).

~~Tunas are special pelagic inhabitants that lies below the thermocline layer during the day, immigrates to the thermocline layer during sunset, spreads between the thermocline layer and the water bed at night, and descends to the deepest layer at sunrise.~~

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Generally, most pelagic fish rise to the surface before sunset. After sunset, these fish spread out on the water column, and sink into deeper layers after sunrise. Demersal fish usually spend the day at the bottom and then rise and spread in the water column at night (Reddy, 1993).

The distribution of tuna is influenced by several factors, two of which are temperature and the swimming layer of tuna (Nakamura, 1969). And Sedana, 2004. said the parameters of the fishing area according to the target catch species as in table 1 below:

Table 1

Fishing area parameters according to the target catch species (Sedana, 2004)

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Species	Depth (m)	Temperature (ºC)
Bigeye tuna (*T. obesus*)	50-600, thermocline layer	10-17
Yellowfin tuna (*T. albacares*)	50-250, top and middle layers	18-28
Albacore (*T. alalunga*)	50-600, thermocline layer	10-17
Blue Marlin (*Makaira nigricans*)	50-150, top and middle layers	18-22

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Fishing season. The fishing season for several types of tuna in Indian Ocean is generally thought to last for six months (Sedana 2004).

Table 2

Season of Indian Ocean tuna fishing (Sedana, 2004)

Species	Season (month)	Range of peaks
Southern bluefin tuna (*T. maccoyii*)	January - April	January
Yellowfin tuna (*T. albacares*)	November - January	December
Bigeye tuna (*T. obesus*)	February - June	June
Albacore (*T. alalunga*)	June - August	June
Other large pelagic species	July - December	October

Swimming layer. The distribution of tuna fish (based on depth of water) is most influenced by swimming layer and temperature (Nugraha et al 2010). Several previous research results also showed differences in the depth of the swimming layer of each type of tuna obtained in the Indian Ocean. *T. obesus* can be found at a depth of 186-285 m, *T. albacares* at 149-185 m, and *T. alalunga* at a depth of 161-220 m (Santoso 1999). *T. obesus* was caught at a depth of 300-399.9 m, *T. albacares* 250-299.9 m and *T. alalunga* at 150-199.9 m (Nugraha & Triharyuni 2009).

The purpose of the present study was to find out the types of tuna caught in Indonesian waters and to know the depth of the swimming layer in the Nothern Indian Ocean.

Material and Method. The research was carried out from November 2016 to May 2017 using longliners operating in the Indian Ocean (Figure 3). The equipment used in this research were: cameras, stationery, calculators, laptops, meters, and tuna caught as research objects.

Figure. 2 Longliners in Bali, Indonesia.

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At the time of research, the catching system used two basket systems, namely basket with thirteen branch lines and basket with six branch lines.

The methods used in data collection consisted of carrying out activities on longliner fishing vessel and using several methods, namely: observation, interview, and literature study.

Data analysis. The data analysis was performed using descriptive method, namely by reducing the data obtained in the field and comparing it with literature studies. Data and information obtained during the implementation of the study was analyzed by descriptive analysis method and qualitative analysis methods. Formula 1 and formula 2 below were used to calculate the depth of the fishing line using the Yoshihara method (1951).

$$D = fl + bl + {}^{1}/_{2}\, BK \left\{ \sqrt{(1 + Cotg^2\sigma)} - \sqrt{\left(1 - \frac{2j}{n}\right)^2 + Cotg^2\sigma} \right\}$$

Where:
D - depth of hook (m)
Fl - length of the float line
bl - length of branch line
BK - length of play line in 1 basket (m)
j - number of branch line position
n - number of branch lines in 1 basket + 1

K	θ	Cotg²θ
0.47136	79	0.03778
0.48657	78	0.04777
0.51698	77	0.05330

0.60821	69	0.14232
0.54739	75	0.07127
0.51698	77	0.05330
0.63862	66	0.18960
0.77927	54	0.52786
0.60821	69	0.14232
0.56674	73	0.09079

The value of the angle σ was obtained first by finding the curvature coefficient of the main line.

$$K = \frac{Vk\ x\ Ts}{BK\ x \sum b}$$

Where:
K - coefficient of curvature
Vk - ship speed (km h^{-1})
Ts - setting time (hours)
b - number of baskets

Formula 3 below was used to calculate the catch rate in the ratio of the catch to the number of hooks.

$$Hook\ rate = \frac{Number\ of\ fish\ caught/trip}{Number\ of\ hooks\ attached\ /\ trip}\ x\ 100$$

Fishing ground. The area of operation during the voyage was area 1 of the distribution of *Thunnus maccoyii*) fishing areas, which is around the south of the islands of Bali, Lombok and Sumbawa (Figure 2).

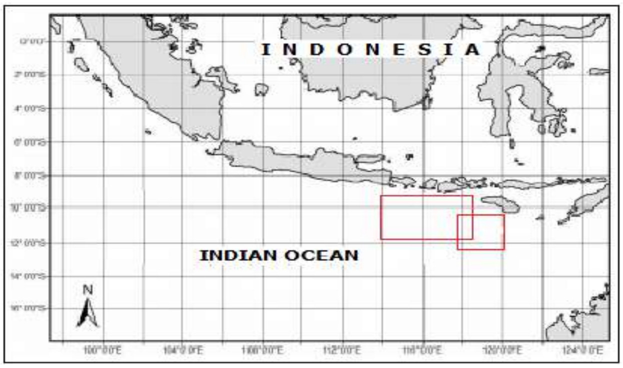

Figure 3. Longliner fishing ground.

Results and Discussion.

Basket with thirteen branch lines. From the 64 settings, there were 48 settings using basket with thirteen branch lines (Figure 4), the setting time started at 06.00 central Indonesia time (WITA) until it finishes average five hours per setting time, setting using basket with thirteen branch lines is done when the moon is in the dark moon (not in a full moon) and when hauling is at 17.00 central Indonesia time (WITA) until the end of the hauling time is 9-12 hours depending on the weather and the main line is disconnected or not, the more main line decisions the longer the hauling process.

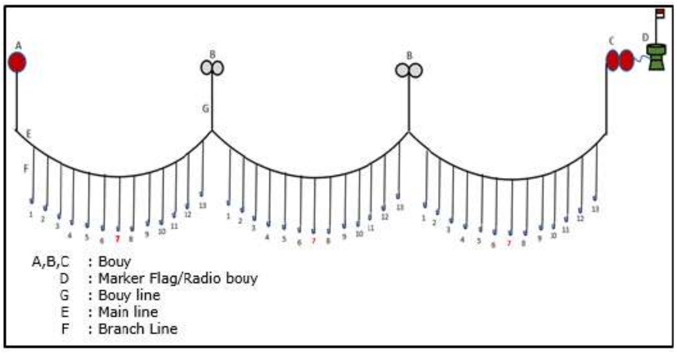

Figure 4. Sketch of basket with 13 branch lines.

The main catch using basket with 13 branch line was 90 fish, 56.25% of the total main catch. The tuna caught were *T. alalunga*, *T. obesus*, *T. albacares* and *T. maccoyii*.

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Basket with six branch lines. From 64 times of the overall settings, for 16 times basket with six branch lines was used (Figure 5). Unlike the thirteen branch line basket, this setting is done at 17.00 central Indonesia time (WITA) until it's finished, the setting takes 6-7 hours because the speed of the main line throwing the speed is slightly reduced when using this basket, because the hooks does not sink too deep due to chasing tuna that swim on the surface of the water, this basket is usually used at full moon, 3 days before full moon and 3 days after full moon.

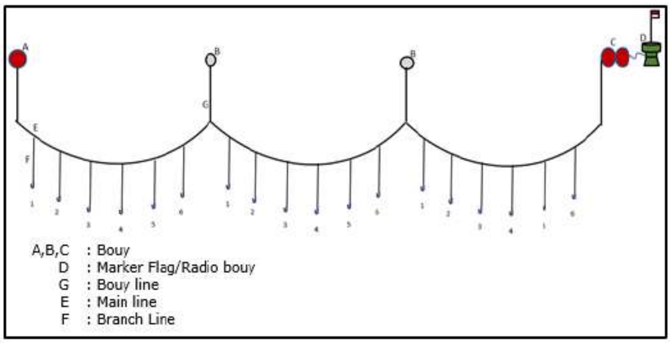

Figure 5. Sketch of basket with 6 branch lines.

The main catch using a basket with six branch lines consisted of 70 fish, 43.75% of the total main catch. From the two types of basket, the highest catches were obtained in basket with 6 branch lines viewed from the catch comparison factor with the number of settings perspective.

Catch composition. The catch obtained was grouped into main catch and bycatch. The main catch was considered to consist of tuna species, while bycatch consisted of any other species.

The total catch obtained during 91 days of fishing operation or 64 settings consisted of 160 fish. The main catch obtained included *T. alalunga*, *T. obesus*, *T. albacares* and *T. maccoyii*. Comparison of the amount of catch can be seen in Figure 6.

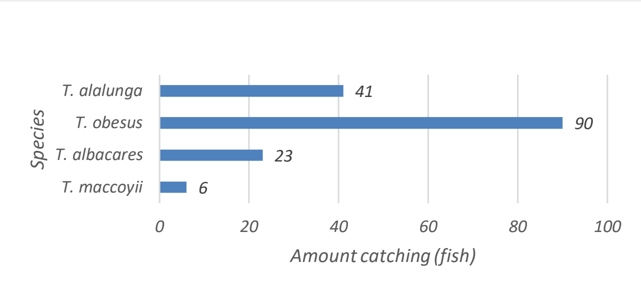

Figure 6. Comparison of the amount of catches.

The total catch was dominated by *T. obesus* with a total catch of 90 fish (56%), 41 *T. alalunga* (26.54%), 23 *T. albacares*. (14.20%) while the lowest catch was recorded for *T. maccoyii* amounting 6 fish (4%).

Catch composition of based on size. The tuna species caught had different lengths according to species. The length measurement divided the catch into several categories, namely size 50-100 cm, 100-150 cm, and >150 cm. The distribution of the catch based on length can be seen in Figure 7.

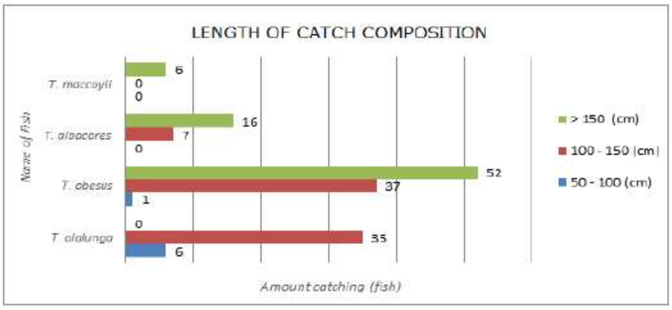

Figure 7. Length of catch composition.

There were 35 *T. alalunga* caught at 100-150 cm size or 44.30%. *T. obesus* was caught mostly at >150 cm in size as many as 52 individuals or about 70.27%. *T. albacares* was mostly caught at a size of >150 cm as many as 16 fish or 21.62%. All individuals of *T. maccoyii* caught were all, over 150 cm amounting 6 fish or 4%.

~~The main catch that is mostly caught is bigeye tuna (*T. obesus*) as many as 90 (56%). Bigeye tuna (*T. obesus*) caught the majority measuring more than 100 cm as much as 58.17%. This shows that more than half of the total catch is catch feasible. Bigeye tuna (*T. obesus*) has a catch size above 100 cm (Pranata 2013).~~

~~Albacore tuna (*T. alalunga*) is the second type of tuna caught mostly as many as 41 (26.54%), and as much as 85.38% are catch worthy. This is because the majority of caught are more than 85 cm in size. At that size, albakora tuna species have experienced gonad maturity (Pranata 2013).~~

~~Yellowfin tuna (*T. albacares*) were caught as many as 23 tails or 14.20%. The average that was caught, had a size of more than 105 cm, which was 91.30%.~~

T. maccoyii is the type of tuna caught the least, as many as 6 (4%). However, all the catch of this type has a size of more than 150 cm which means it is feasible catch. The feasible catch category of it measures over 120 cm. *T. maccoyii* in Northern Indian Ocean are similar with catched in the Northern Hemisphere, only smaller in size (Pranata 2013).

Commented [A28]: The values from this section are in contradictory with the above statement (green highlight):
I green T. obesus 52 individuals, 70.27%. In this section T. obesus 90 individuals, 56% etc
Not clear. Please clarify.

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Commented [A30]: Same situation: here T alalunga 41 individuals (26.54%, in the green section T. alalunga 35 ind (44.30%) Contradictory. Please clarify.

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Ya I will deleted. Thank you.

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Catch results based on fishing position. The first basket uses thirteen branch lines to catch tuna whose fishing area is deeper, usually performed when it is not a full moon. The second basket uses six branch lines to catch tuna swimming to the surface of the water, six branch lines are used when the full moon is around 7 days.

a. Basket with 13 branch lines

The composition of the catch based on the number of hooks can be seen in the Table 3.

Table 3

Catch based on 13 fishing lines positions

Species	Branch lines							Fish (ind.)
	1, 13	2, 12	3, 11	4, 10	5, 9	6, 8	7	
Albacore (*T. alalunga*)	2	1	3	3	7	3	3	22
Bigeye tuna (*T. obesus*)	6	6	6	11	12	8	6	55
Yellowfin tuna (*T. albacares*)	2	0	2	2	2	3	0	11
Southern bluefin tuna (*T. maccoyii*)	0	0	0	0	0	2	0	2
Number (fish)	10	7	11	16	21	16	9	90
Number hook	10,150	10,150	10,150	10,150	10,150	10,150	5,075	
Hook rate (%)	0.0985	0.0690	0.1084	0.1576	0.2069	0.1576	0.1773	

Based on the Table 3, *T. alalunga* and *T. obesus* were mostly caught on branch line 5 and 9. *T. albacares* was almost evenly caught in each branch lines, but was not caught on lure numbers 2, 7 and 12. *T. maccoyii* was caught on hook number 6 and number 8 only.

b. Basket with 6 branch lines

The composition of the catch based on the number of 6 hooks can be seen in Table 4.

Table 4

Catch based on position of 6 branch lines

Species	Branch lines			Fish (ind.)
	1,6	2,5	3,4	
Albacore (*T. alalunga*)	6	6	7	19
Bigeye tuna (*T. obesus*)	10	11	14	35
Yellowfin tuna (*T. albacares*)	4	4	4	12
Southern bluefin tuna (*T. maccoyii*)	1	2	1	4
Fish (individuals)	21	23	26	70
Number hook	7,180	7,180	7,180	
Hook rate (%)	0.292	0.320	0.362	

Based on Table 4, *T. alalunga* was mostly caught on fishing lines 3 and 4, and were caught evenly on all fishing lines. *T. obesus* was caught mostly in branch line number 3 and 4, and was caught almost evenly on all fishing lines. *T. albacares* was captured evenly on all hooks. *T. maccoyii* was mostly caught on line 2 and 5 and evenly caught on the other hooks.

Hook rate. The hook rate is a real calculation in quantity proportional to the number of fish caught at one time, for tuna longline itself it is calculated every 100 ~~points~~ hook. ~~of the line.~~ So this hook rate determines whether the area still has good fishing potential or not, so that future availability can be calculated.

Figure 8 shows the result of tuna hook rate for 64 settings, these results are for all the four tuna species captured *T. obesus*, *T. albacares*, *T. alalunga*, and *T. maccoyii*. The results showed that the average hook rate was 0.18% with the highest hook rate at setting 64, with a hook rate of 0.79%. ~~According to Santoso (1999) the hook rate ranges~~

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~~from 1.17–2.73. The highest hook rate occurred at 9.11 hauling, and 12 was very different from what the researchers found, with a hook rate difference of 0.77%.~~

The percentage of hook rate, we can show on figure 8 below:

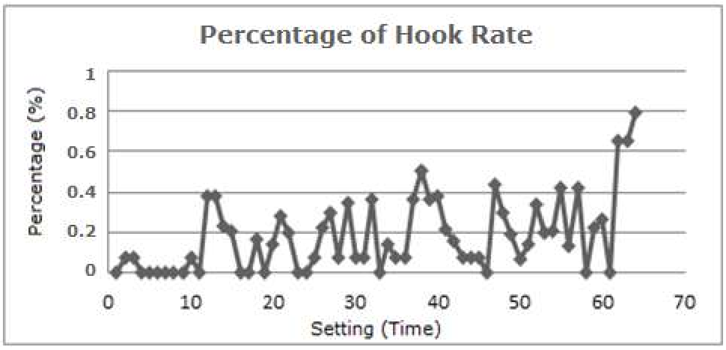

Figure 8. Percentage of hook rate.

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Estimated depth of tuna swimming layer

a. Basket with 13 branch lines

The depth of the fishing line in operation with 13 branch lines has different depths as it is shown in Table 5.

Table 5

Calculation of the depth for each fishing line

Branch line number	Depth (m)		
	Upper Limit	Lower Limit	Average
1, 13	41.29	56.87	44.50
2, 12	80.35	113.10	87.49
3, 11	116.25	168.30	128.25
4, 10	147.65	221.56	165.58
5, 9	172.70	270.82	197.47
6, 8	189.14	310.54	220.47
7	194.10	327.49	229.32

b. Basket with 6 branch lines

The depth of the branch lines in operation with 6 hooks has different depths, as it is shown in Table 6.

Table 6

The results of the calculation of the depth of each fishing line number

Branch line number	Depth (m)		
	Upper Limit	Lower Limit	Average
1, 6	41.76	52.99	44.71
2, 5	75.47	103.72	82.38
3, 4	95.28	145.11	106.19

Swimming layer. The spread of tuna in the sea is determined by two factors, namely internal factors and external factors. Internal factors include genetics, age, size and behavior. Different genetics causes differences in morphology, physiological responses, and adaptability to the environment. External factors are environmental factors, including oceanographic parameters such as temperature, salinity, density, depth of the thermocline layer, currents, water mass circulation, oxygen and food abundance. The swimming depth of tuna varies depending on the species.

In general, tuna is caught at a depth of 0-400 meters. The preferred water salinity ranges from 32 to 35 ppt or in oceanic waters. The water temperature ranges of tunas from 17-31ºC (Pranata 2013).

Tuna catches based on the position of the fishing line (Table 3 and Table 4) and the calculation results of each fishing line number depth value (Table 5 and Table 6) obtained can be used as material for estimating the depth of the swimming layer for each species of tuna.

T. alalunga was caught in all branch lines, the majority was caught on branch line 5 and 9 (Table 3) as much as 31.82%. It is suspected that *T. alalunga* swimming layer is at a depth of 172.70-270.82 m. The distribution of *T. alalunga* is strongly influenced by temperature and this tuna prefers lower temperatures. According to Nugraha & Triharyuni (2009), the distribution of *T. alalunga* is in a temperature range of 14-24ºC with a catching temperature range of 17-24ºC. At juvenile stage, *T. alalunga* prefers habitat in the area around the equator and its swimming layer is near the surface layer. After maturity (>95 cm), begins to move to a deeper layer (Block & Stevens 2001).

T. obesus catches were recorded almost evenly across the hooks. The depth of the swimming layer of this species is estimated to be at a depth of 41.30–327.49 m, the majority being caught at 172.70–270.82 m depth interval (branch line 5 and 8). *T. obesus* are often caught on deeper branch lines (no. 4, 5, and 6), because *T. obesus* prefer deep water with cooler temperatures (Block & Stevens 2001). The swimming area for *T. obesus* is located just below the thermocline layer, so it is advisable to use the deep sea tuna longline type (Santoso 1999).

T. albacares caught ~~on all hooks~~ were 23 (81.81%). The swimming layer of this species is thought to be at a depth of 189.14–310.54 m. *T. albacares* is often found in fishing lines close to the surface. Mainly this species is generally found above 100 m deep layers which have sufficient oxygen content. In the deeper layers where oxygen levels are low, *T. albacares* individuals are rare, while juvenile *T. albacares* can be found clustered with *K. pelamis* and *T. obesus* in the surface layer. When they are mature, they tend to stay in this water layer. The distribution of *T. albacares* is in the temperature range of 18–31°C (Block & Stevens 2001).

T. maccoyii was caught in a quantity of 7 individuals and all of them was caught on branch line 2, 3, and 4 but mostly found on branch line number 2 amounting to 42.85%. Tuna which has a large body size has a spreading area with temperatures between 5-20ºC and can be found at depths of up to 1,000 m. This high adaptation behavior to extreme temperatures is due to the fact that *T. maccoyii* can raise its blood temperature above water temperature using its muscle activity (Block & Stevens 2001). *T. maccoyii* caught in the present study were suspected to be spawning individuals.

Figure 9 is an illustration of the swimming depth layer of tuna from the results of the present study. It can be seen the difference in the depth of the swimming layer between the four species of tuna captured. The difference in the vertical distribution of tuna is caused by several factors, one of which is temperature (Pranata 2013). According to the results of research by Nugraha & Triharyuni (2009), in the Indian Ocean *T. obesus* was caught in the temperature range of 10.0-13.9ºC, *T. albacares* at 16.0-16.9ºC, and *T. alalunga* at 20.0-20.9ºC. In addition, differences in location or geographic location also affect the habitat of tuna.

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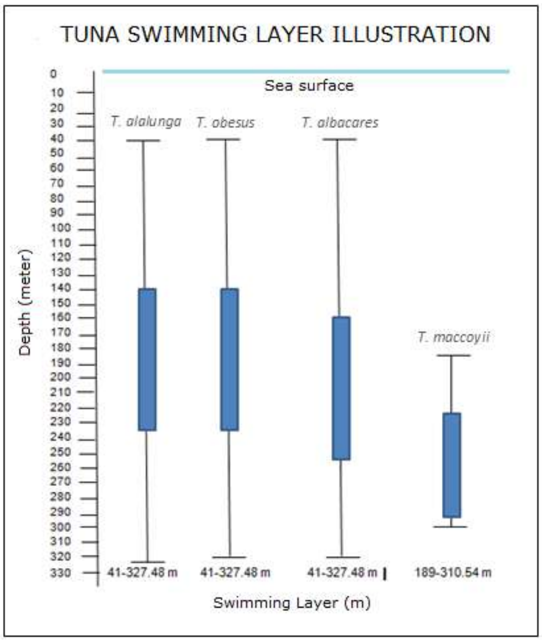

Figure 9. Tuna swimming layer illustration.

Several previous research results also showed differences in the depth of the swimming layer of each type of tuna captured in the Indian Ocean waters. The results of Santoso (1999) research show that *T. obesus* can be found at a depth of 186-285 m, *T. albacares* at 149-185 m, and *T. alalunga* at a depth of 161-220 m. Nugraha & Triharyuni (2009) reported that *T. obesus* was caught at a depth of 300-399.9 m, *T. albacares* at 250.0-299.9 m, and *T. alalunga* at 150.0-199.9 m.

Figure 9 illustrates the overall depth rage of the tuna's swimming layer. *T. alalunga* was caught at a depth range of 41–327.48 m, *T. obesus* was caught at the depth range of 41–327.48 m, *T. albacares* was caught at the depth range of 41–327.48 m and *T. maccoyii* was caught at the depth rage of 189–0 310.54 m.

Conclusions

1. The operation of tuna fishing consists of two processes, namely in setting and hauling. The average setting time was around 5 hours depending on the catch quantity. Hauling was performed from 17.00 until early morning.
2. Overall catches consisted of *T. obesus*, *T. albacares*, *T. alalunga*, and *T. maccoyii*. The average hook rate was 0.18% with the highest hook rate at setting 64, with a hook rate of 0.79%.
3. Concerning the tuna swimming layer, *T. alalunga* was caught at a depth range of 41–327.48 m, *T. obesus* was caught at a depth range of 41–327.48 m, *T. albacares* was caught at a depth range of 41–327.48 m and *T. maccoyii* was caught at a depth range of 189 - 310.54 m.
4. The main catch obtained in the present study consisted of 85 *T. obesus*, 45 *T. alalunga*, 23 *T. albacares* (15%), and 7 (4%) *T. maccoyii*.

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Authors:
Bongbongan Kusmedy, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: bkhutapea@gmail.com
Jerry Hutajulu, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: jerryhutajulu15@gmail.com
Eddy Sugriwa Husen, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: sugriwastp@gmail.com
Heru Santoso, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: herustppsm15@gmail.com
Hari Prayitno, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: hariprayitno46@gmail.com
Rahmat Muallim, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: rahmatmuallim@gmail.com
Maman Hermawan, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: mhermawan60@gmail.com
Tonny Efijanto Kusumo, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: susilobagaswibisono@gmail.com

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Erick Nugraha, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: nugraha_eriq1@yahoo.co.id
Aldhy Oktavildy, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Jl. AUP Pasar Minggu, South Jakarta, Indonesia, e-mail: Oktavildy@gmail.com

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Miklos Botha <miklosbotha@yahoo.com>
Kepada: erick nugraha

Rab, 30 Des 2020 jam 04.48

Dear Erick Nugraha,

there some minor issues remained unsolved concerning your 4th manuscript. Please see attachment.

Looking forward for your kind response!

Kind regards,

Editor AACL Bioflux
Senior Researcher
Miklos Botha, PhD.

Study of tunas (*Thunnus* spp.*)* swimming layer using tuna longliner in the Northern Indian Ocean, Indonesia

Bongbongan Kusmedy, Jerry Hutajulu, Eddy S. Husen, Heru Santoso, Hari Prayitno, Rahmat Mualim, Maman Hermawan, Tonny E. Kusumo, Erick Nugraha, Aldhy Oktavildy

Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia. Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

Abstract. Research on the depth of the tuna swimming layer was carried out from November 2016 to May 2017 in the Indian Ocean. The present study aims to obtain information about tuna long liner operating techniques, determine the composition of the main catch and determine the depth of the tuna swimming layer in the Indian Ocean. This research is a case study of tuna fishing activities on tuna long liner. The catch obtained in this study consisted of 85 Bigeye tuna (*Thunnus obesus*), 45 Albacore (*Thunnus alalunga*), 23 Yellowfin tuna (*Thunnus albacares*) (15%), and 7 (4%) Southern bluefin tuna (*Thunnus maccoyii*). The swimming layer of *T. obesus*, *T. alalunga* and *T. albacares* was at a depth of 41–327.48 m., whilethe swimming layer of *T.maccoyii* was found at a depth of 189-310.54 m.
Key Words: thermocline layer, hook rate, basket system, South Savu Sea.

Introduction. Tuna longline is one of the most effective fishing gears to catch tuna. In addition, this fishing gear is selective to catch tuna (Nugraha & Setyadji 2013). Tuna longline is a combination of several lines with branch line and is equipped with buoys and hook (Subani & Barus 1989). Tuna longline consists of a series of main lines, and on the main line at a certain distance there are several branch lines that are shorter and smaller in diameter. At the end of the branch line is linked a hook with bait (Sjarif & Mulyadi 2004) (Figure 1). This bait includes sardine (*Sardenilla longiceps*), Indian mackerel (*Rastrelliger kanagurta*), scad mackerel (*Decapterus* spp.), bigeye scad (*Selar crumenophthalmus*), squid (*Loligo* spp.) and milkfish (*Chanos chanos*) (Santoso 1995). *C. chanos* is also used for longline fishing live bait, especially by Taiwanese vessels (Beverly et al 2003).

The distribution and abundance of tuna is strongly influenced by variations in temperature and water depth parameters. Information concerning the distribution of tuna based on temperature and water depth is very important to support the success of tuna fishing operations (Barata et al 2011).

Pelagic fish are fast swimming fish. Tuna is a fast swimmer that differs in epipelagic waters (>500 m) and can swim as far as 55 km every day (Nurjana et al 2014). Tuna fish live by navigating the world's great oceans with a swimming speed of up to 50 km hour^{-1} (Baskoro & Wahyu 2004).

The interaction between target fish and bycatch is strongly influenced by the swimming layer (Novianto & Nugraha 2014). The depth of the swimming layer of tuna is influenced by temperature and salinity. The depth of the hook can be determined by changing the distance between two adjacent buoys. In addition, there are still other ways, namely by changing the length of the tuna longline such as main lines, branch line and buoy lines (Djatikusumo 1997).

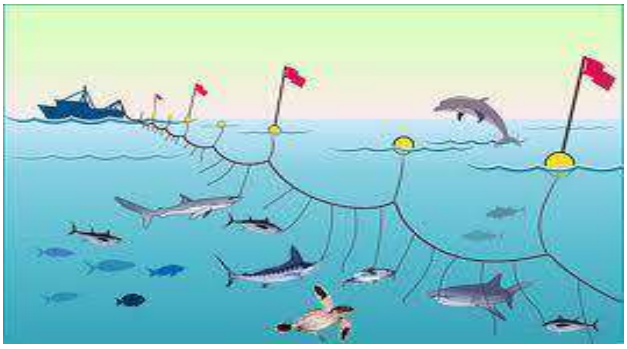

Figure 1. Tuna longline fishing (https://ikantunaku.wordpress.com).

Fishing ground. The fishing areas in Indonesian waters for tuna are Banda Sea, Maluku Sea, waters of south Java Island continuing to the east, as well as south of Sumatra waters, around Andaman and Nicobar, waters of north Irian Jaya, south of Timor waters and so on (Ayodhyoa 1981).

Generally, most pelagic fish rise to the surface before sunset. After sunset, these fish spread out on the water column, and sink into deeper layers after sunrise. Demersal fish usually spend the day at the bottom and then rise and spread in the water column at night (Reddy 1993).

The distribution of tuna's is influenced by several factors, two of which are temperature and the swimming layer of tuna (Nakamura 1969). Sedana (2004) reported parameters of the fishing area according to the target catch species as specified in Table 1.

Table 1

Fishing area parameters according to the target catch species (Sedana 2004)

Species	*Depth (m)*	*Temperature (ºC)*
Bigeye tuna (*T. obesus*)	50-600, thermocline layer	10-17
Yellowfin tuna (*T. albacares*)	50-250, top and middle layers	18-28
Albacore (*T. alalunga*)	50-600, thermocline layer	10-17
Blue Marlin (*Makaira nigricans*)	50-150, top and middle layers	18-22

Fishing season. The fishing season for several types of tuna in Indian Ocean is generally thought to last for six months (Sedana 2004).

Table 2

Season of Indian Ocean tuna fishing (Sedana 2004)

Species	*Season (month)*	*Peak*
Southern bluefin tuna (*T. maccoyii*)	January - April	January
Yellowfin tuna (*T. albacares*)	November - January	December
Bigeye tuna (*T. obesus*)	February - June	June
Albacore (*T. alalunga*)	June - August	June
Other large pelagic species	July - December	October

Swimming layer. The distribution of tuna fish (based on depth of water) is most influenced by swimming layer and temperature (Nugraha et al 2010). Several previous research results also showed differences in the depth of the swimming layer of each type of tuna obtained in the Indian Ocean. *T. obesus* can be found at a depth of 186-285 m, *T. albacares* at 149-185 m, and *T. alalunga* at a depth of 161-220 m (Santoso 1999). *T.*

obesus was caught at a depth of 300-399.9 m, *T. albacares* 250-299.9 m and *T. alalunga* at 150-199.9 m (Nugraha & Triharyuni 2009).

The purpose of the present study was to find out the types of tuna caught in Indonesian waters and to know the depth of the swimming layer in the Nothern Indian Ocean.

Material and Method. The research was carried out from November 2016 to May 2017 using longliners operating in the Indian Ocean (Figure 2). The equipments used in this research were: cameras, stationery, calculators, laptops, meters, and tuna caught as research objects.

Picture. 2 Longliners in Bali, Indonesia.

At the time of research, the catching system used two basket systems, namely basket with thirteen branch lines and basket with six branch lines.

The methods used in data collection consisted of carrying out activities on longliner fishing vessel and using several methods, namely: observation, interview, and literature study.

Data analysis. The data analysis was performed using descriptive method, namely by reducing the data obtained in the field and comparing it with literature studies. Data and information obtained during the implementation of the study was analyzed by descriptive analysis method and qualitative analysis methods. Formula 1 and formula 2 below were used to calculate the depth of the fishing line using the Yoshihara method (1951).

$$D = fl + bl + {}^{1}\!/_{2}\,BK\ \left\{\sqrt{(1 + Cotg^2\sigma)} - \sqrt{\left(1 - \frac{2j}{n}\right)^2 + Cotg^2\sigma}\right\}$$

Where:
D - depth of hook (m)
Fl - length of the float line
bl - length of branch line
BK - length of play line in 1 basket (m)
j - number of branch line position
n - number of branch lines in 1 basket + 1

K	θ	Cotg²θ
0.47136	79	0.03778
0.48657	78	0.04777
0.51698	77	0.05330
0.60821	69	0.14232
0.54739	75	0.07127
0.51698	77	0.05330
0.63862	66	0.18960
0.77927	54	0.52786
0.60821	69	0.14232
0.56674	73	0.09079

The value of the angle σ was obtained first by finding the curvature coefficient of the main line.

$$K = \frac{Vk\ x\ Ts}{BK\ x \sum b}$$

Where:
K - coefficient of curvature
Vk - ship speed (km h^{-1})
Ts - setting time (hours)
b - number of baskets

Formula 3 below was used to calculate the catch rate in the ratio of the catch to the number of hooks.

$$\textit{Hook rate} = \frac{\textit{Number of fish caught/trip}}{\textit{Number of hooks attached / trip}}\ x\ 100$$

Fishing ground. The area of operation during the voyage was area 1 of the distribution of *T. maccoyii* fishing areas, which is around the south of the islands of Bali, Lombok and Sumbawa (Figure 3).

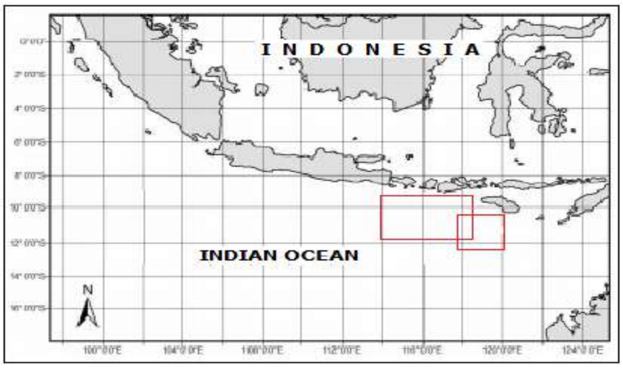

Figure 3. Longliner fishing ground.

Results and Discussion

Basket with thirteen branch lines. From the 64 settings, there were 48 settings using basket with thirteen branch lines (Figure 4), the setting time started at 06.00 central Indonesia time (WITA) until it finishes average five hours per setting time, setting using basket with thirteen branch lines is done when the moon is in the dark moon (not in a full moon) and when hauling is at 17.00 central Indonesia time (WITA) until the end of the hauling time is 9-12 hours depending on the weather and the main line is disconnected or not, the more main line decisions the longer the hauling process.

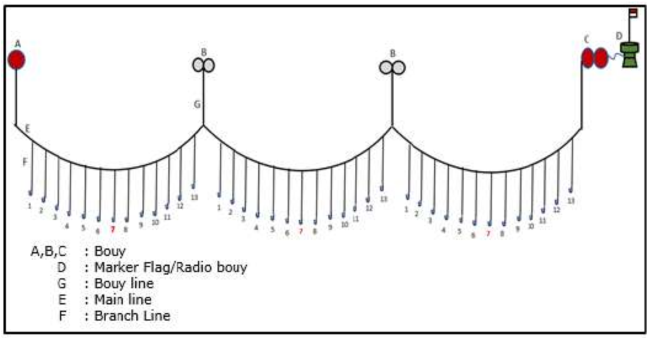

Figure 4. Sketch of basket with 13 branch lines.

The main catch using basket with 13 branch lines was 90 fish, 56.25% of the total main catch. The tuna caught were *T. alalunga*, *T. obesus*, *T. albacares* and *T. maccoyii*.

Basket with six branch lines. From 64 times of the overall settings, for 16 times basket with six branch lines was used (Figure 5). Unlike the thirteen branch line basket, this setting is done at 17.00 central Indonesia time (WITA) until it's finished, the setting takes 6-7 hours because the speed of the main line throwing the speed is slightly reduced when using this basket, because the hooks does not sink too deep due to chasing tuna that swim on the surface of the water, this basket is usually used at full moon, 3 days before full moon and 3 days after full moon.

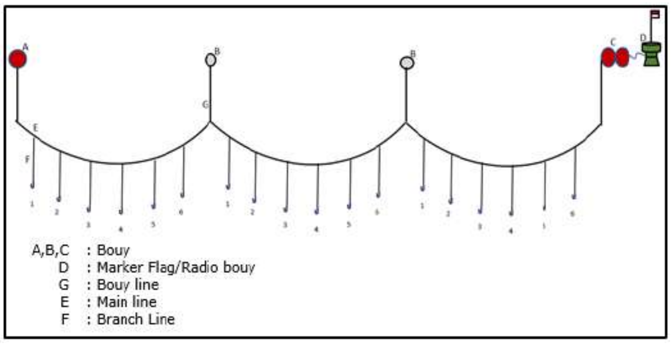

Figure 5. Sketch of basket with 6 branch lines.

The main catch using a basket with six branch lines consisted of 70 fish, 43.75% of the total main catch. From the two types of basket, the highest catches were obtained in basket with 6 branch lines viewed from the catch comparison factor with the number of settings perspective.

Catch composition. The catch obtained was grouped into main catch and bycatch. The main catch was considered to consist of tuna species, while bycatch consisted of any other species.

The total catch obtained during 91 days of fishing operation or 64 settings consisted of 160 fish. The main catch obtained included *T. alalunga*, *T. obesus*, *T. albacares* and *T. maccoyii*. Comparison of the amount of catch can be seen in Figure 6.

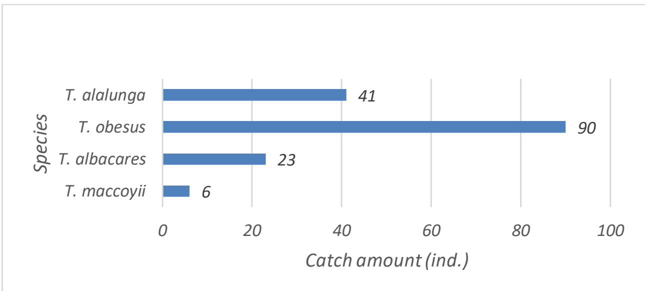

Figure 6. Comparison of the amount of catches.

The total catch was dominated by *T. obesus* with a total catch of 90 fish (56%), 41 *T. alalunga* (26.54%), 23 *T. albacares*. (14.20%) while the lowest catch was recorded for *T. maccoyii* amounting 6 fish (4%).

Catch composition of based on size. The tuna species caught had different lengths according to species. The length measurement divided the catch into several categories, namely size 50-100 cm, 100-150 cm, and >150 cm. The distribution of the catch based on length can be seen in Figure 7.

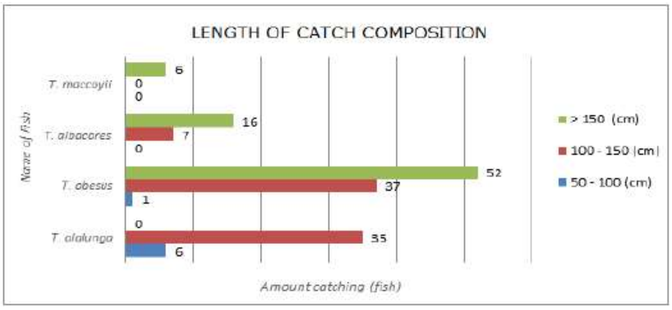

Figure 7. Length of catch composition.

There were 35 *T. alalunga* caught at 100-150 cm size or 44.30%. *T. obesus* was caught mostly at >150 cm in size as many as 52 individuals or about 70.27%. *T. albacares* was mostly caught at a size of >150 cm as many as 16 fish or 21.62%. All individuals of *T. maccoyii* caught were all, over 150 cm amounting 6 fish or 4%.

However, all the catch has a size of more than 150 cm which means it was in the feasible catch category. The feasible catch category implies individuals over 120 cm (Pranata 2013). *T. maccoyii* in Northern Indian Ocean was similar with those captured in the Northern Hemisphere, only smaller in size (Pranata 2013).

Catch results based on fishing position. The first basket uses thirteen branch lines to catch tuna whose fishing area is deeper, usually performed when it is not a full moon. The second basket uses six branch lines to catch tuna swimming to the surface of the water, six branch lines are used when the full moon is around 7 days.

a. Basket with 13 branch lines

The composition of the catch based on the number of hooks can be seen in the Table 3.

Table 3

Catch based on 13 fishing lines positions

Species	Branch lines							Fish (ind.)
	1, 13	2, 12	3, 11	4, 10	5, 9	6, 8	7	
Albacore (*T. alalunga*)	2	1	3	3	7	3	3	22
Bigeye tuna (*T. obesus*)	6	6	6	11	12	8	6	55
Yellowfin tuna (*T. albacares*)	2	0	2	2	2	3	0	11
Southern bluefin tuna (*T. maccoyii*)	0	0	0	0	0	2	0	2
Number (fish)	10	7	11	16	21	16	9	90
Number hook	10,150	10,150	10,150	10,150	10,150	10,150	5,075	
Hook rate (%)	0.0985	0.0690	0.1084	0.1576	0.2069	0.1576	0.1773	

Based on the Table 3, *T. alalunga* and *T. obesus* were mostly caught on branch line 5 and 9. *T. albacares* was almost evenly caught in each branch lines, but was not caught on lure numbers 2, 7 and 12. *T. maccoyii* was caught on hook number 6 and number 8 only.

b. Basket with 6 branch lines

The composition of the catch based on the number of 6 hooks can be seen in Table 4.

Table 4

Catch based on position of 6 branch lines

Species	Branch lines			Fish (ind.)
	1,6	2,5	3,4	
Albacore (*T. alalunga*)	6	6	7	19
Bigeye tuna (*T. obesus*)	10	11	14	35
Yellowfin tuna (*T. albacares*)	4	4	4	12
Southern bluefin tuna (*T. maccoyii*)	1	2	1	4
Fish (individuals)	21	23	26	70
Number hook	7,180	7,180	7,180	
Hook rate (%)	0.292	0.320	0.362	

Based on Table 4, *T. alalunga* was mostly caught on fishing lines 3 and 4, and were caught evenly on all fishing lines. *T. obesus* was caught mostly in branch line number 3 and 4, and was caught almost evenly on all fishing lines. *T. albacares* was captured evenly on all hooks. *T. maccoyii* was mostly caught on line 2 and 5 and evenly caught on the other hooks.

Hook rate. The hook rate is a real calculation in quantity proportional to the number of fish caught at one time, for tuna longline itself calculated for 100 hooks. So this hook rate determines whether the area still has good fishing potential or not, so that future availability can be calculated.

Figure 8 shows the result of tuna hook rate for 64 settings, these results are for all the four tuna species captured *T. obesus*, *T. albacares*, *T. alalunga*, and *T. maccoyii*. The results showed that the average hook rate was 0.18% with the highest hook rate at setting 64, with a hook rate of 0.79%.

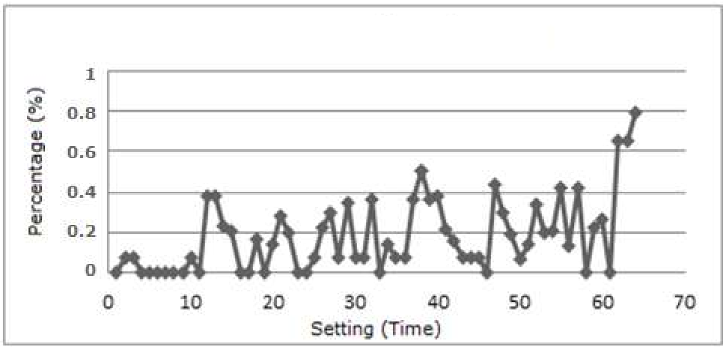

Figure 8. Percentage of hook rate.

Estimated depth of tuna swimming layer

a. Basket with 13 branch lines

The depth of the fishing line in operation with 13 branch lines has different depths as it is shown in Table 5.

Table 5

Calculation of the depth for each fishing line

Branch line number	Depth (m)		
	Upper limit	Lower limit	Average
1, 13	41.29	56.87	44.50
2, 12	80.35	113.10	87.49
3, 11	116.25	168.30	128.25
4, 10	147.65	221.56	165.58
5, 9	172.70	270.82	197.47
6, 8	189.14	310.54	220.47
7	194.10	327.49	229.32

b. Basket with 6 branch lines

The depth of the branch lines in operation with 6 hooks has different depths, as it is shown in Table 6.

Table 6

The results of the calculation of the depth of each fishing line number

Branch line number	Depth (m)		
	Upper limit	Lower limit	Average
1, 6	41.76	52.99	44.71
2, 5	75.47	103.72	82.38
3, 4	95.28	145.11	106.19

Swimming layer. The spread of tuna in the sea is determined by two factors, namely internal factors and external factors. Internal factors include genetics, age, size and behavior. Different genetics causes differences in morphology, physiological responses, and adaptability to the environment. External factors are environmental factors, including oceanographic parameters such as temperature, salinity, density, depth of the thermocline layer, currents, water mass circulation, oxygen and food abundance. The swimming depth of tuna varies depending on the species.

In general, tuna is caught at a depth of 0-400 meters. The preferred water salinity ranges from 32 to 35 ppt or in oceanic waters and water temperature ranges of 17-31ºC (Pranata 2013).

Tuna catches based on the position of the fishing line (Table 3 and Table 4) and the calculation results of each fishing line number depth value (Table 5 and Table 6) obtained can be used as material for estimating the depth of the swimming layer for each species of tuna.

T. alalunga was caught in all branch lines, the majority was caught on branch line 5 and 9 (Table 3) as much as 31.82%. It is suspected that *T. alalunga* swimming layer is at a depth of 172.70-270.82 m. The distribution of *T. alalunga* is strongly influenced by temperature and this tuna prefers lower temperatures. According to Nugraha & Triharyuni (2009), the distribution of *T. alalunga* is in a temperature range of 14-24ºC with a catching temperature range of 17-24ºC. At juvenile stage, *T. alalunga* prefers habitat in the area around the equator and its swimming layer is near the surface layer. After maturity (>95 cm), begins to move to a deeper layer (Block & Stevens 2001).

T. obesus catches were recorded almost evenly across the hooks. The depth of the swimming layer of this species is estimated to be at a depth of 41.30–327.49 m, the majority being caught at 172.70–270.82 m depth interval (branch line 5 and 8). *T. obesus* are often caught on deeper branch lines (no. 4, 5, and 6), because *T. obesus* prefer deep water with cooler temperatures (Block & Stevens 2001). The swimming area for *T. obesus* is located just below the thermocline layer, so it is advisable to use the deep sea tuna longline type (Santoso 1999).

T. albacares caught on all hooks consisted of 23 individuals (81.81%). The swimming layer of this species is thought to be at a depth of 189.14–310.54 m. *T.*

albacares is often found in fishing lines close to the surface. Mainly this species is generally found above 100 m deep layers which have sufficient oxygen content. In the deeper layers where oxygen levels are low, *T. albacares* individuals are rare, while juvenile *T. albacares* can be found clustered with *K. pelamis* and *T. obesus* in the surface layer. When they are mature, they tend to stay in this water layer. The distribution of *T. albacares* is in the temperature range of 18–31°C (Block & Stevens 2001).

T. maccoyii was caught in a quantity of 7 individuals and all of them was caught on branch line 2, 3, and 4 but mostly found on branch line number 2 amounting to 42.85%. Tuna which has a large body size has a spreading area with temperatures between 5-20ºC and can be found at depths of up to 1,000 m. This high adaptation behavior to extreme temperatures is due to the fact that *T. maccoyii* can raise its blood temperature above water temperature using its muscle activity (Block & Stevens 2001). *T. maccoyii* caught in the present study were suspected to be spawning individuals.

Figure 9 is an illustration of the swimming depth layer of tuna from the results of the present study. It can be seen the difference in the depth of the swimming layer between the four species of tuna captured. The difference in the vertical distribution of tuna is caused by several factors, one of which is temperature (Pranata 2013). According to the results of research by Nugraha & Triharyuni (2009), in the Indian Ocean *T. obesus* was caught in the temperature range of 10.0-13.9ºC, *T. albacares* at 16.0-16.9ºC, and *T. alalunga* at 20.0-20.9ºC. In addition, differences in location or geographic location also affect the habitat of tuna.

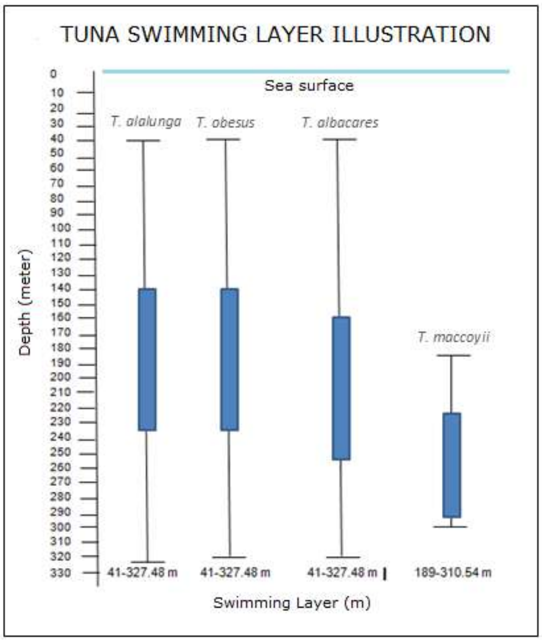

Figure 9. Tuna swimming layer illustration.

Several previous research results also showed differences in the depth of the swimming layer of each type of tuna captured in the Indian Ocean waters. The results of Santoso (1999) research show that *T. obesus* can be found at a depth of 186-285 m, *T. albacares* at 149-185 m, and *T. alalunga* at a depth of 161-220 m. Nugraha & Triharyuni (2009) reported that *T. obesus* was caught at a depth of 300-399.9 m, *T. albacares* at 250.0-299.9 m, and *T. alalunga* at 150.0-199.9 m.

Figure 9 illustrates the overall depth rage of the tuna's swimming layer. *T. alalunga* was caught at a depth range of 41–327.48 m, *T. obesus* was caught at the depth range of 41–327.48 m, *T. albacares* was caught at the depth range of 41–327.48 m and *T. maccoyii* was caught at the depth rage of 189–0 310.54 m.

Conclusions

1. The operation of tuna fishing consists of two processes, namely in setting and hauling. The average setting time was around 5 hours depending on the catch quantity. Hauling was performed from 17.00 until early morning.
2. Overall catches consisted of *T. obesus*, *T. albacares*, *T. alalunga*, and *T. maccoyii*. The average hook rate was 0.18% with the highest hook rate at setting 64, with a hook rate of 0.79%.
3. Concerning the tuna swimming layer, *T. alalunga* was caught at a depth range of 41–327.48 m, *T. obesus* was caught at a depth range of 41–327.48 m, *T. albacares* was caught at a depth range of 41–327.48 m and *T. maccoyii* was caught at a depth range of 189 - 310.54 m.
4. The main catch obtained in the present study consisted of 85 *T. obesus*, 45 *T. alalunga*, 23 *T. albacares* (15%), and 7 (4%) *T. maccoyii*.

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Authors:
Bongbongan Kusmedy, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: bkhutapea@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
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
Hari Prayitno, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: hariprayitno46@gmail.com
Rahmat Mualim, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: rahmatmuallim@gmail.com
Maman Hermawan, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: mhermawan60@gmail.com
Tonny Efijanto Kusumo, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: susilobagaswibisono@gmail.com
Erick Nugraha, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: nugraha_eriq1@yahoo.co.id
Aldhy Oktavildy, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Indonesia, South Jakarta, Jl. AUP Pasar Minggu, e-mail: oktavildy@gmail.com

Miklos Botha <miklosbotha@yahoo.com>
Kepada: erick nugraha

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