Analyses of pole and line fishery: catch composition and use of live bait for catching skipjack tuna *Katsuwonus pelamis* and yellowfin tuna *Thunnus albacares* in Fisheries Management Area 715, Indonesia

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Abstract. The present study provides information about pole and line fishery. The study was carried out from December 2016 to April 2017 using four commercial pole and line fishing vessels in the waters of Fisheries Management Area (FMA) 715 of Republic of Indonesia. The objectives of the study are to know the catch composition and the catch rate per trip, the ratio between catch and live bait fish, length distribution and length-weight relationship of catch. The pole and line catch consisted of skipjack tuna *Katsuwonus pelamis*, yellowfin tuna *Thunnus albacares* and bullet tuna *Auxis rochei* with the composition of 72.7%, 24.5% and 2.8%, respectively. The ratio of catch to live bait in used among the fishing vessels were varied with the highest ratio of 10.7 to 1.0 occurred on vessel 4 and the lowest ratio of 5.8 to 1.0 took place on vessel 2. The average size of *K. pelamis* and *T. albacares* were 44.4 cm and 46.1 cm, respectively. The *K. pelamis* caught during the study was in mature stage and *T. albacares* was in immature stage. The *K. pelamis* and *T. albacares* have a positively allometric growth.

Key Words: catch composition, live bait, pole and line, skipjack, yellow fin tuna.

Introduction. Indonesia is the second largest tuna producer in the world that using a pole and line fishing. The largest producer country is Japan with a total catch of 28%, followed by Indonesia 25%, Maldive 21% and other countries 26% (IPNLF 2016). Species caught using pole and line are skipjacktuna *Katsuwonus pelamis*, yellowfin tuna *Thunnus albacares*, bigeye tuna *Thunnus obesus* and albacore *Thunnus alalunga*. Based on data provided by International Seafood Sustainability Foundation (ISSF 2010), *K. pelamis* is the largest tuna catch in the world, where skipjack has a percentage of 57%, *T. albacares* 27%, *T. obesus* 11% and *T. alalunga* 5%.

In Indonesia, there are various fishing gears to catch *K. pelamis* such as: long line, hand line, pole and line, purse seine and gill net. Pole and line is one type of fishing gear which is very famous among fishermen residing in the central and the eastern part of Indonesia. The main target of pole and line fishing is *K. pelamis*. However, other pelagic fish such as small size *T. albacares* which is relatively equal in size and forming fish schools with *K. pelamis* is also caught. Pole and line fishing uses live bait to catch its target fish. The bait is usually called anchovy, a small fish with the length of 8–10 cm. The live bait is obtained from other vessel using lift net or other fishing gear. Live bait is one of the limiting factors in pole and line fisheries. Achievement in pole and line fishing is largely determined by the availability of adequate live bait.

The objectives of this research are to know: (1) the catch composition and the catch rate per trip (2) relation between catch and live bait fish (3) length distribution and length-weight relationship of catch.

Material and Method. The study was carried out from December 2016 to April 2017. This research was conducted using four commercial pole and line fishing vessels in the Seram and Halmahera Sea (FMA-RI 715). Figure 1 shows the fishing grounds of the pole and liner during the research. Table 1 shows the general specification of the pole and line fishing vessels used in the study.

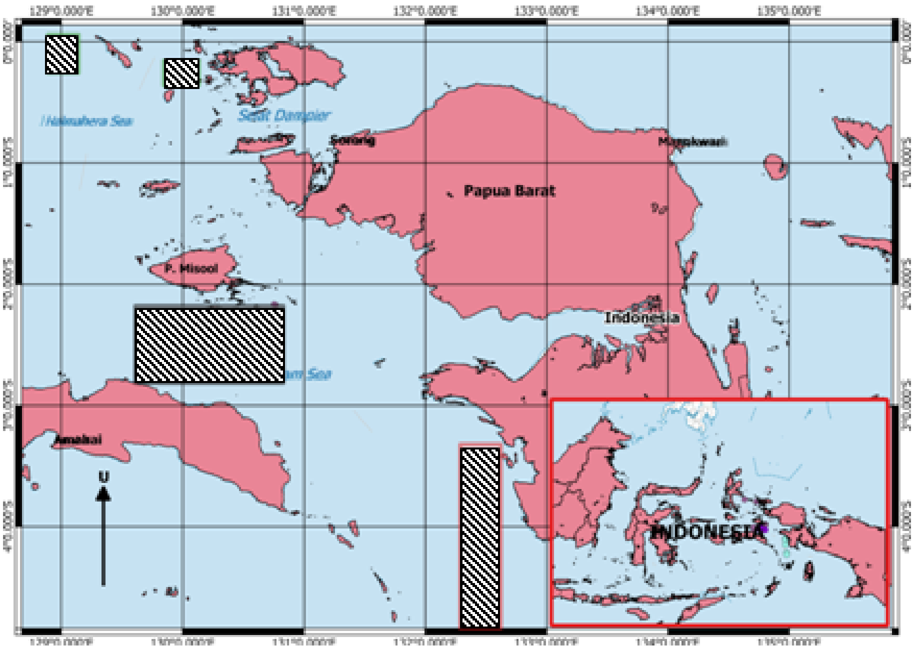

Figure 1. Research location in FMA 715 waters, Indonesia. Shaded areas are the fishing ground during the study.

Table 1

General specification of fishing vessels

Code or alias	*Vessel 1*	*Vessel 2*	*Vessel 3*	*Vessel 4*
Name of vessel	KM. Aspac 11	KM Aspac 16	KM Aspac 03	KM Dioskuri 4a
Place of registration	Sorong	Jakarta	Sorong	Sorong
Built	1996	1996	1994	2004
Flag	Indonesia	Indonesia	Indonesia	Indonesia
Material	Wooden	Wooden	Wooden	FRP
LOA	24.46 m	24.64 m	22.16 m	27.85 m
Breadth	4.38 m	4.58 m	4.38 m	5.00 m
Depth	2.24 m	2.65 m	2.28 m	2.75 m
Gross tonnage	57 GT	49 GT	55 GT	87 GT
Main eng.	280 HP	280 HP	280 HP	200 HP
Aux. eng.	22 HP	22 HP	11 HP	22 HP
No of fishermen	16 persons	21 persons	18 persons	33 persons
Fishing gear	Pole and line	Pole and line	Pole and line	Pole and line

Other equipments used in this research were pole and line (fishing rod, line and hook), gauges, scales, global positioning system (GPS), digital cameras and stationery.

Data collection was carried out by recording activities on board without disturbing the conduct of fishing as commercial fishing vessels. Recorded data consisted of the date the vessels in and out of fishing port, vessels position, amount of live bait in use, species of fish and the number of fish caught by the pole and line operation. Total catch was measured during the fishing vessel unloading fish at the fishing port. Total weight of live bait used in the fishing operation was recorded while bait was bought from bait fisherman. In additions to the catch data, measurements of size and weight of *K. pelamis* and *T. albacares* randomly sampled from the catch were also collected.

Data analyzing. The collected data were analyzed to obtain catch rate per trip, the ratio of live bait and catch, length distributions and length-weight relationship.

Catch rate per trip. According to Waileruny et al 2014, the catch per unit effort (CPUE) is an attempts to determine the abundance and fishery resources utilization level in certain areas. CPUE is usually determined for fishing efforts for a certain period of time such as one year or more. This research was carried out in five month period, so that we calculate catch rate per trip during the period of study as follows:

$$Catch\ rate\ per\ trip = \frac{Catch}{Effort}$$

Notes:

Catch rate per trip	=	catch per effort
Catch	=	total catch
Effort	=	Total effort or trip of fishing

The relation between catch and live bait. According to Anderson et al (2014), the relation between catch and live bait in use is analyzed with regression formula as follows:

The linear regression equation used is: $\hat{y} = a + bx$,

Where:
y = Amount of catch fish (kg)
X1= The use of live bait on fishing with pole and line (kg)

The constant value of a and b are calculated as follows:

$$a = \frac{(\Sigma y)(\Sigma x^2) - (\Sigma x)(\Sigma xy)}{n \Sigma x^2 - (\Sigma x)^2}$$

$$b = \frac{n \Sigma xy - (\Sigma x)(\Sigma y)}{n \Sigma x^2 - (\Sigma x)^2}$$

Where:
Σx = total amount of live bait (kg)
Σy = total amount of catch fish (kg)
Σx^2 = amount of each live feed usage squared (kg)
Σy^2 = amount of each fish that is squared (kg)
Σxy = amount of multiplication results between live bait and catch fish.
n = amount of fishing.

The correlation between live bait and catch. According to Hasan (2004), the correlation coefficient (r) is used to determine the level of closeness of the relationship. The correlation coefficient serves to determine the direction of the relationship numerical variables. Variable relation can be positive or negative. The formula to calculate the correlation coefficient is as follows:

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

Notes :
r = Pearson correlation coefficient
X = independent variable (live bait)
Y = dependent variable (catch)

According to Sudaryono (2014), positive (+) or negative (-) notation of r indicates the direction of the relationship between two variables. The positive notation (+) means the relationship between two positive correlation variables, if one variable is increased, the other one is also increased. The negative notation (-) means that two variables are inversely correlated (negative correlation), which means that the increment of one variable will be followed by the decreasing of the other variable.

Length and weight relationship. The length-weight relationship is analyzed using the allometric linear model (ALM) to calculate the parameters a and b through measurement of weight and length changes. According to De Robertis & William (2008), the bias correction on the mean weight change of the logarithmic unit is used to predict the weight of length parameters according to the following allometric equation:

$$w = a\,L^b$$

Where w is the weight of the fish (g) and L is the total length of the fish (cm), a and b are constant parameters. Parameter b is also known as allometry coefficient. The value of allometry coefficient (b) has and importance biological meaning, indicating the rate of weight gain relative to the growth in length. If b is equal to 3.0, growth is isometric. If the value of b is greater than 3.0, the shape of fish more rotund as length increases. A value of b is less than 3.0, indicating the shape of fish is less rotund as length increases.

Results and Discussion

Catch composition and catch rate per trip. The research activities were conducted using four pole and line commercial fishing vessels. Table 2 shows the total catch and the number of trip of each vessel during the study.

Table 2

Total catch and the number of trip of each vessel

Vessel	*Total catch (kg)*	*Trip (times)*	*Average catch per trip (kg)*
1	50,276	5	10,055
2	27,649	3	9,216
3	27,317	3	9,106
4	97,345	5	19,469
Total	202,587	16	12,662

As can be seen from Table 2 the average catch per trip of vessel 4 is the highest compared to other vessels used in the study and the vessel 3 has the lowest average catch per trip. The total number of trips of all vessels during the research is 16 trips. Fishing trip of each vessel is the duration of the vessel outside the fishing base (fishing port), since the vessel is out of port for catch until the vessel return to the fishing base to unload the catch. The number of days for each fishing trip varied between the fishing vessel, but mostly the time period of fishing trip is about 2-3 weeks long. The activities of the fishing vessel during a fishing trip include the voyage to and from fishing ground, fishing operation in fishing grounds, voyage to and from bait fishermen location to buy live bait. In one fishing trip, the fishing vessel has to buy live bait, from a bait fisherman, a couple of times. Many times, the fishing vessels have to stay in the bait fisherman location for a couple of days, because the live bait is not available and the vessels have to wait for the bait fishermen to catch the live bait.

During the research, the vessel no. 1 and vessel no. 4 caught *K. pelamis*, *T. albacares* and bullet tuna (*Auxis rochei*). Vessel no. 2 and vessel no. 3 caught *K. pelamis* and *T. albacares*. Figure 2 shows the catch composition of all vessels during the study. As shown in the figure, catch composition was dominated by *K. pelamis* in all of the vessels during the experiment.

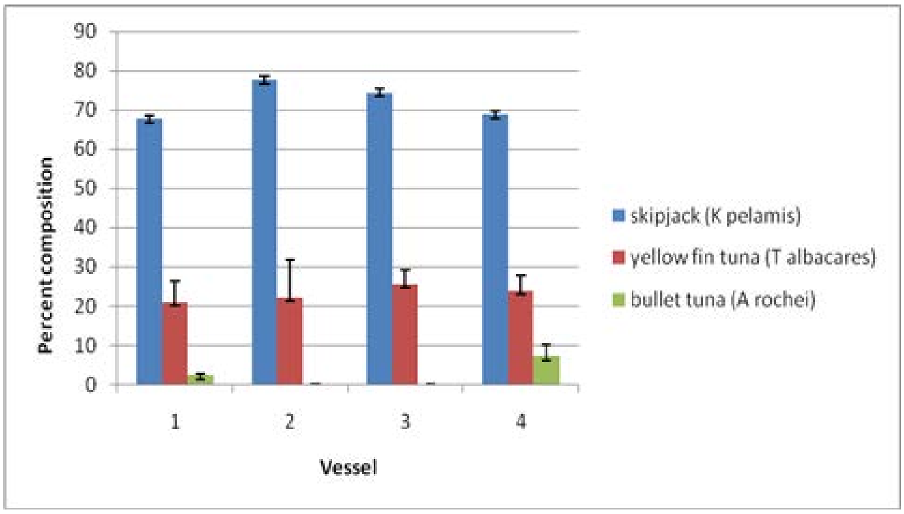

Figure 2. Catch composition (%).

The catch rate illustrates the capture capability of a fishing gear per fishing effort. In this study, capture capability is represented as an average catch per fishing trip. Figure 3 shows the average catch per trip and standard error of each vessel.

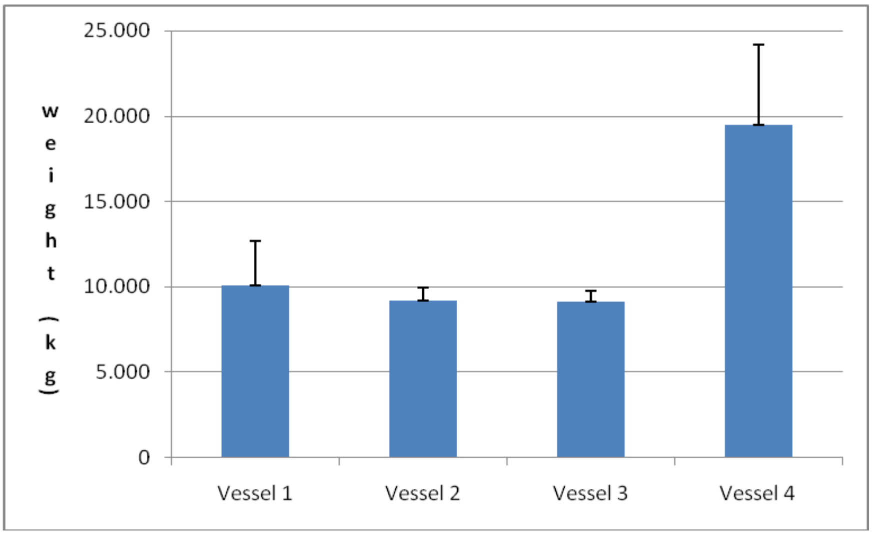

Figure 3. Average catch per trip and standard error of each vessel.

As shown in Figure 3 vessel no. 4 has the highest catch rate of 19,469 kg with the standard error of 4.74 kg. Vessel no. 3 has the lowest catch rate of 9,105 kg with the standard error 0.67 kg. The fluctuations of catch rate of each vessel were influenced by weather conditions, experience of the crews, the difference in fishing ground and abundance of the fish in the fishing ground. According to Mustasim (2016), other than the resultant of weather factor, catch and fishing effort depend on the amount and efficiency of the equipment, duration of operation, availability of fish and water condition. The abundance of *K. pelamis* is highly dependent on the oceanography conditions; especially the waters temperature should be suitable for the *K. pelamis* as well as the waters should be rich of food.

The success of fishing by pole and line is highly dependent on the availability of live bait. When the ship sails to the fishing ground, usually it has carried live bait in the live bait tank and the vessel is ready to catch fish. However there are times that the vessel departs from fishing base without carrying any live bait. The vessel has to pick up and buy live bait from a fishermen catching live bait that exist around the fishing ground. To maintain the stability of the availability of live bait, the pole and line fisherman or the company should have a network with live bait fishermen either around the fishing base or around the fishing grounds, so that the pole and line fishing activities can be carried out smoothly.

The kind of live bait used in the study was anchovy (*Stolephorus* sp.). In pole and line fishing *Stolephorus* sp. and *Decapterus macarellus* are commonly used as live bait (Susanto et al 2012). During the research, vessel no. 1 used live bait as much as 6,843 kg, the vessel no. 2 used as much as 4,818 kg, the vessel no. 3 used as much as 3.504 kg and the vessel no. 4 used as much as 8.844 kg. The total catch of each vessel is shown in Table 2. Base on the data of catch and the use of live bait in each vessel, the ratio between catch and live bait of each vessel was calculated as shown in Figure 4.

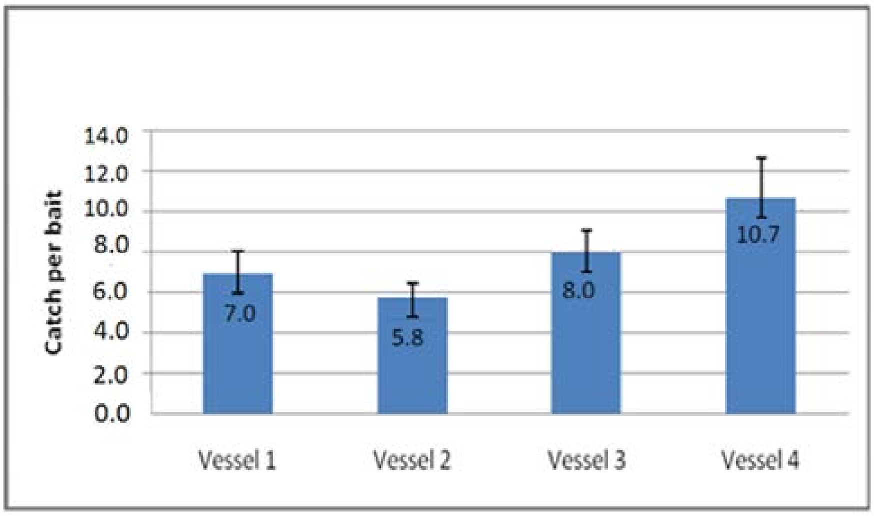

Figure 4. Catch per bait and standard error.

The vessel no. 1 has the ratio of 7.0 to 1, with the standard error of 1.0. The vessel no. 2 has a ratio of 5.8 to 1 with the standard error of 0.7. The vessel no. 3 has a ratio of 8.0 to 1 with the standard error 1.1. The vessel no. 4 has a ratio of 10.7 to 1 with the standard error 2.0. The fluctuations of the ratio of catch and live bait of each vessel were influenced by many factors such as oceanic factors such as physical, chemical and biological conditions, sea surface temperature or horizontal and vertical temperature distribution, salinity, chlorophyll-a concentration and front and upwelling phenomenon (Mustasim 2016). The fluctuations of the catch-live bait ratio were also allegedly caused by the differences of crew skills, captain know-how and experience to find fish schooling and the efficient and effectiveness in using of live bait during fishing operation. In pole and line operation, the schooling of the target fish should be kept around and close enough to the vessel, so the vessel's crews can reach and catch the fish using fishing rods. To keep the fish schooling close to the vessel, live bait should be thrown into the sea around the vessel cleverly and effectively. *K. pelamis* is famous as a voracious fish against live bait. According to Surur (2007), *K. pelamis* is a fast swimmer fish and likes to fight for food such as live bait. These fish often invades crowd of small fish on the surface of the water, in a very fast movement. With the properties like this, *K. pelamis* is rather to gather around and close to the vessel and it is possible to catch the fish by using fishing rods of the pole and line.

Figure 5 shows the linier regression analysis model for estimating the relationship of the live bait in use and the catch of the pole and line. In the regression model, the total amount of live bait for every fishing trip is used as an independent variable and the total amount of catch for every fishing trip is used as a dependent variable.

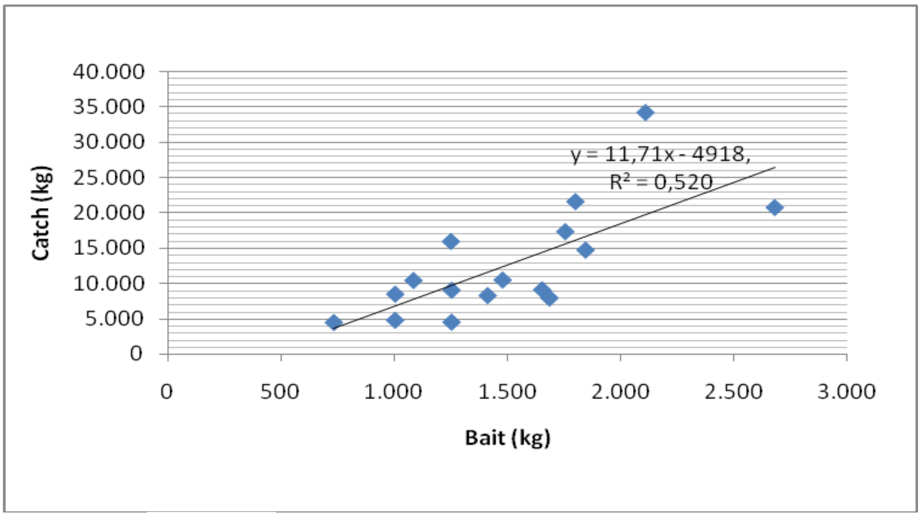

Figure 5. Relation between live bait and catch.

The regression model analysis shows that:

- The regression coefficient of x (live bait) is 11.71, which means that an increase of 1 kg of live bait will increase the catch by 11 kg or 0.117% in ceteris paribus.
- The value of coefficient of determination (r square) is 0.520. This means that 52% of the catch changes are caused by bait variable alterations. The remaining 48% is due to other variables not included in the model.

Table 3 shows the result of hypothesis testing by using t-student test. As shown in the table that the live bait variable is significantly different at 99% confidence level.

Table 3

Regression coefficient value (b_i), T_{count} and R^2

Variable	*Regression coefficient (b_i)*	*T_{count} (db=15)*
Live bait	11.71	3.899*

R^2 = 0,521; $T_{table(0,01)}$ = 2.62;
* real at a confidence level of 99%.

Length distribution and length-weight relationship. To determine the length distribution of the fish caught during the study, 742 *K. pelamis* and 455 *T. albacares* randomly sampled from the catch were measured (total length) and weighted. Table 4 shows the summary of the measurement of sampled fish. Figure 6 shows the length distribution and length-weight scatter diagram of *K. pelamis*, Figure 7 shows the length distribution and length-weight scatter diagram of *T. albacares*.

Table 4

Summary of of the measurement of the sampled *Katsuwonus pelamis* and *Thunnus albacares*

Parameters	*K. pelamis (n=742)*	*T. albacares (n=455)*
Total Length (cm)	21–72	23–66
Average	44.4	46.1
Standard Error	0.44	0.32
Weight (gram)	100–7.152	200-5.741
Average	1,738	1,932
Standard Error	65.6	43.6
Coefficient of determination index (r^2)	0.95	0.82
Correlation coefficient index (r)	0.97	0.92
Constant a	0.001	0.007
Allometry coefficient (b)	3.68	3.24

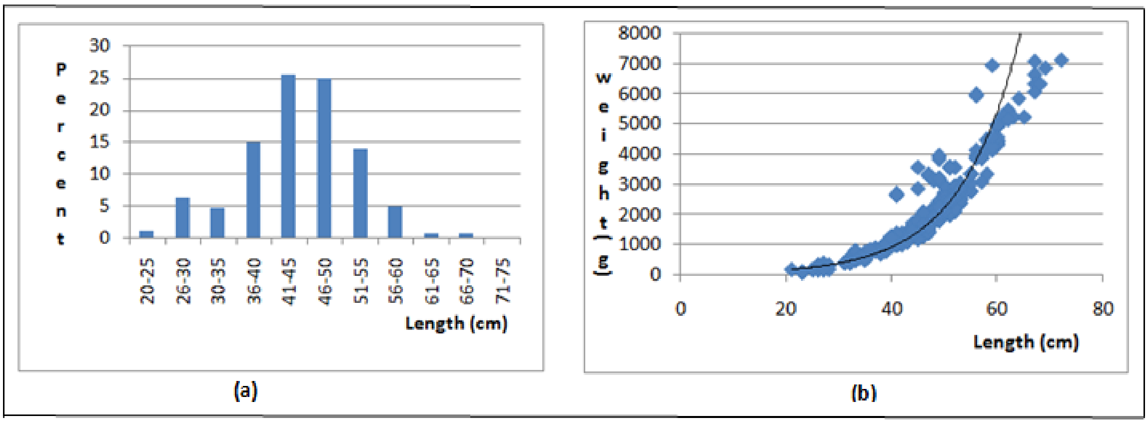

Figure 6. (a) Length distribution of *Katsuwonus pelamis*, (b) Scatter diagram of the length-weight of *K. pelamis*.

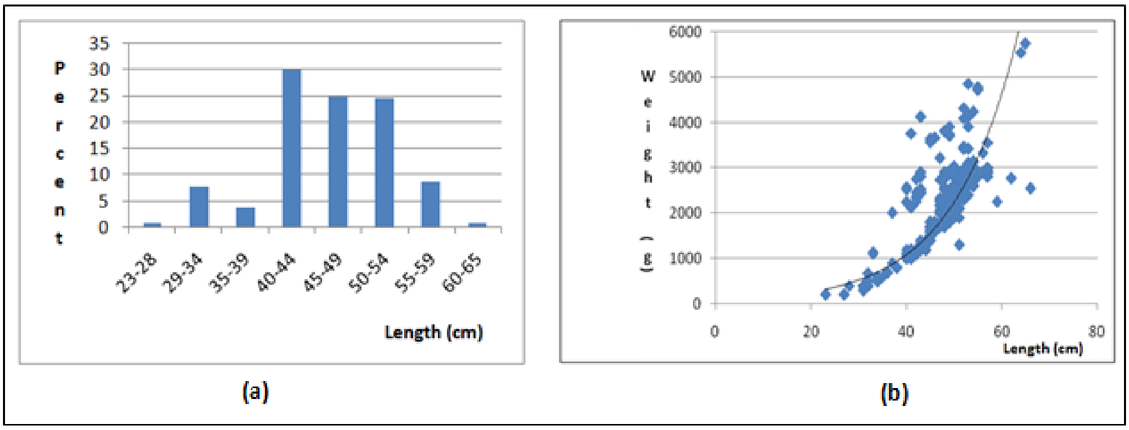

Figure 7. (a) Length distribution of *Thunnus albacares*, (b) Scatter diagram of the length-weight of *T. albacares*.

K. pelamis and *T. albacares* are a schooling pelagic fish. When *T. albacares* is in juvenile stage and its length is relatively equal in size with *K. pelamis*, both fish usually tends to live together to form a fish school. As shown in Table 4 *K. pelamis* has an average length of 44.41 cm and weight of 1.738 g. *T. albacares* has an average length of 46.1 cm and weight of 1,932 g. The length and weight of both fishes are rather similar to each other, so they live together. Manik (2007) stated that in the waters of Philippines, the length of female *K. pelamis* of the first stage of gonad maturity was 34 cm, but mostly at the 40 cm in length. The length of mature *K. pelamis* of 40 cm was found in Cuba and the Philippines, while the length of 45 cm was found in Papua New Guinea (Collette & Nauen 1983). *T. albacares* with the weight of less than 3.2 kg is regarded as a juvenile and this is in accordance with the recommendation issued by the International Commission for the Conservation of Atlantic Tuna (Mayer & Andrade 2008). The length of *T. albacares* with the gonad maturity stage is about 100-110 cm (Goujon & Majkowski 2010). Referring to the size of the catch during the study, the *K. pelamis* was in mature stage and the *T. albacares* was in the stage of juvenile or immature.

The length-weight relationship of fish is intended to give a systematic statement of the relation between length and weight of the fish that can be converted from length to weight or vice versa. Usually functional relationships between length and weight of fish are not linear. Figure 6a and 7a show the scatter diagrams of the observed *K. pelamis* and *T. albacares*, respectively. In the Table 4 can be seen the value allometry coefficient (b) of the observed *K. pelamis* and *T. albacares*. The value of allometry coefficient for both species is greater than 3.0, meaning the shape of fish become more round as length of the fish is increases. Figure 6b and Figure 7b also shows that the correlation coefficient value (r) of length-weight relationships of both species, *K. pelamis* and *T. albacares* are

0.97 and 0.92 respectively, indicating strong correlation between the length and the weight of the fish.

In general, the value of allometry coefficient depends on physiological and environmental conditions such as temperature, pH, salinity, geographical location and sampling techniques (Jennings et al 2001) as well as biological conditions such as gonad development and food availability (Froese 2006). According to Shukor et al (2008), fish that live in the waters of the mainstream generally have a lower value of allometry coefficient and vice versa living in calm waters will result a higher value of allometry coefficient. The value of allometry coefficient is also influenced by the behavior of fish. The more active the fish (pelagic fish) the lower the value of allometry coefficient and vice versa the less active the fish (demersal fish) the higher the value of allometry coefficient. Possibly, this is related to the allocation of energy spent on movement and growth (Muchlisin 2010).

Conclusions. This study provides the information on pole and line fishery in the Fisheries Management Area of 715 of Indonesia, using four commercial pole and line fishing vessels, as follows:

- The catch composition was dominated by *K. pelamis* 147.263 kg (72.7%) followed by *T. albacares* 49.659 kg (24.5%) and *A. rochei* 5,665 kg (2.8%).
- The catch rate per fishing trip was different among the four vessels. The highest catch rate was on the vessel no. 4 with the rate of 19.469 tons per fishing trip and the lowest was on the vessel no. 3 with the rate of 9.105 tons per fishing trip.
- The ratio of catch to live bait fluctuated among the fishing vessels. The highest ratio of 10.7 to 1.0 occurred on vessel no. 4 and the lowest ratio of 5.8 to 1.0 took place on vessel no. 2. From the regression model of live bait and catch, increasing the bait 1 kg will increase the catch by 11.71 kg.
- The *K. pelamis* caught during the study was regarded in mature stage and *T. albacares* was in juvenile stage (immature).
- The *K. pelamis* and *T. albacares* have a positive allometric growth.

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