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INDONESIAN TUNA LONGLINE FISHERY FOR ALBACORE (*Thunnus alalunga*) IN EASTERN INDIAN OCEAN

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ABSTRACT

This study highlighted the occurrence of the Indonesian tuna longline fishery targeting albacore (*Thunnus alalunga*) caught in the Eastern Indian Ocean based in Benoa throught observer program from 2010-2013. This paper also presents the current information on Cacth Per Unit of Effort (CPUE), size distribution, length-weight relationship, swimming layer and feeding periodicity of albacore. Total albacore samples that could be analyzed were 3152 which were taken from scientific observer data from 2010-2013. The study area of albacore was between 0°65'S-33°68'S and 75°79'E-131°47'E. Albacore length (cm FL) distributed from 7-196 cm FL (median=93 cm FL, mode=100 cm FL, mean=92.12 cm FL) and dominated at size 95 cm FL. The higher percentage length of albacore > 90 cm (L50) occured in the area between (30-35°S and 80-95°E) and (10-15°S and 120-125°E). The length weight relationship was determined to be $W=0.0045\ FL^{1.8211}$ (W in kg, FL in cm). The CPUEs (no. Fish/1000 hooks) distribution of ALB showed the uneven distribution. The lowest CPUEs occurred in 2010 (0.688) and then followed by 2011 (0.694), 2012 (1.272) and 2013 (1.953). The swimming layer of albacore based on *minilogge*r data were distributed from at 118 to 341 m depth and mostly cacth at depth of 156 m with temperature degree 18°S. The feeding periodicity of albacore's are start from 7:45 am to 17:59 pm, mostly active at 10 am to 11am.

Key Words : albacore, tuna longline, CPUE, swimming layer and feeding periodicity.

INTRODUCTION

Albacore (ALB) is one of a major important commercial species of Indonesian tuna longline fisheries in Eastern Indian Ocean. The production of albacore (*Thunnus alalunga*) was the third-largest tuna after yellow fin tuna (*Thunnus albacares*) and big eye tuna (*Thunnus obesus*). Groups of tuna production reached up to 1.297.062 tons from 2004-2011. The total cacth production consist of yellow fin tuna 69%, big eye tuna 24%, albacore 6% and southern blue fin tuna 1% (DJPT, 2012).

Albacore (*Thunnus alalunga*) is a temperate tuna species, widely distributed in temperate and tropical waters of all oceans. The main fisheries are in temperate waters. In the Atlantic, their geographic limits are from 45-50° N and 30-40° S, while in the Indian Ocean, their distribution ranges from 5° N to 40° S with adults occurring from 5° N to 25° S. (ISSF, 2014).

In the Indian Ocean, albacore is caught almost exclusively under drifting longline (98%), with remaining cacthes recorded under purse seines and other gears (IOTC, 2007; Nishida & Tanaka, 2008). Cacth of ALB by Indonesian longline fleets operating in Indian Ocean from 2004-2006 was estimated at 9,081 tons by IOTC, while 53.4% of which was landed at Benoa fishing port (Proctor *et al*., 2007).

The information about distribution and environment factor is important to determine CPUE and stock assessment, especially for migratory species (Lehodey, 2001). The aims of this research is to recognize the current information on cacth, size, spatial distribution, swimming layer and feeding periodicity of albacore (*Thunnus alalunga*) in Eastern Indian Ocean based by scientific observer program.

MATERIALS AND METHODS

Data analyzed were obtained from onboard observer program on commercial tuna longline fleets based at Benoa-Bali in period March 2010-

October 2013. Based on 25 fishing trips (2.338 fishing days), cacth and effort data were collected. Data collected using fork length (cm FL) with level of accuracy 1 cm and setting recorded by *global positioning system* (GPS). The fishing effort (f) and CPUEs for ALB could be calculated using the following formula, modified from De Metrio and Megalofonou (1998):

$f = (a'/1000) \times d$

Where a' is the average number of hooks in longline per day (devided by the 1000 hooks longline effort unit), d is the number of fishing days per trip.

CPUE=N/f (N is the number of fish caught)

CPUE=B/f (B is the biomass of fish caught)

Length (L) – weight (W) relationship of ALB was fitted to 269 speciment using fork length (cm FL). The parameter (a,b) of the power equation describing the length-weight relationship;

$W=aL^b$

The cacth data including CPUEs, and size of ALB were georeferenced in 5° grids of latitude and longitude. We used *surfer 9* program to describe spatial distribution of CPUE and size.

In this study, we used *minilogger* to determine the depth of hook and *hook timers* to recognize the feeding peridicity. The type of hook timer was HT 600 from NKE *Instrumentation*. The *hook timers* were fitted into the one series with branch line and will be linked directly with main line. The type of *minilogger* was SP2T-1200 from *NKE Instrumentation*. *Minilogger* was fitted at the end of branch line and replaced the hook. Figure 1 shows the position of *minilogger* dan *hook timer* on tuna longline gear.

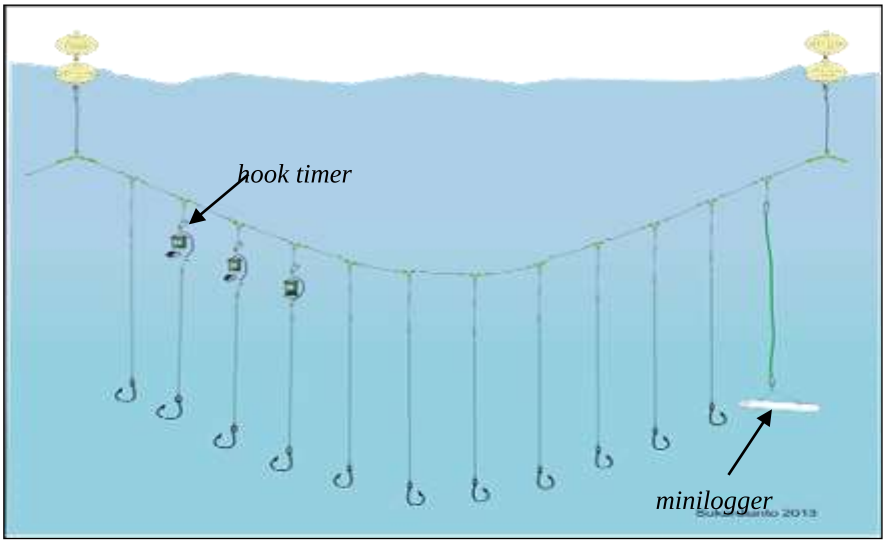


Figure 1. The position of *hook timer* and *minilogger* on tuna longline gear

We used *radio data pencil* to transfer data from minilogger to *WinMemo* program in the computer. The data from *WinMemo* was transferred to microsoft excel program to be analyzed and presented as graphical form. The feeding periodicity data which was obtained from *hook timer* then analyzed using the diagram.

RESULT

Fishing Gear and Method

Fishing boats (longliner) are of wooden which is laminated by fiberglass type ranging from 17 to 33 m in length. The engine power ranges from 350 to 450 hp. The crew number 12 to 15 persons. The fishing gear that used by Indonesian longliners is a tuna longline that is set horizontally. The mainline is made of polyamid (PA) monofilament (4 mm diameter) and length of 50 m/piece. The float line also using PA monofilament (5 mm in diameter). The branch line using PA monofilament (1.8 mm in diameter) and length of 25 m. The hook is a single baited hook (size 4 and 4 cm in length). Frozen sardine (*Sardinella lemuru*) is usually used as the bait.

Each fishing boat often uses from 400 to 2700 hooks . Figure 1 shows a schematic drawing of mainline and branchlines with floats between two flags buoys, in addition to details of brancline (snood) structure.

Study Area

The study area of ALB can be described base on result of *onboard observer program* in 2010-2013. The ALB fishing area caught by tuna longline fisheries was between 0°65'S-33°68'S and 75°79'E-131°47'E. The ALB fishing area mostly conducted outside Indonesian Exclusive Economic Zone (EEZ) Figure 2.

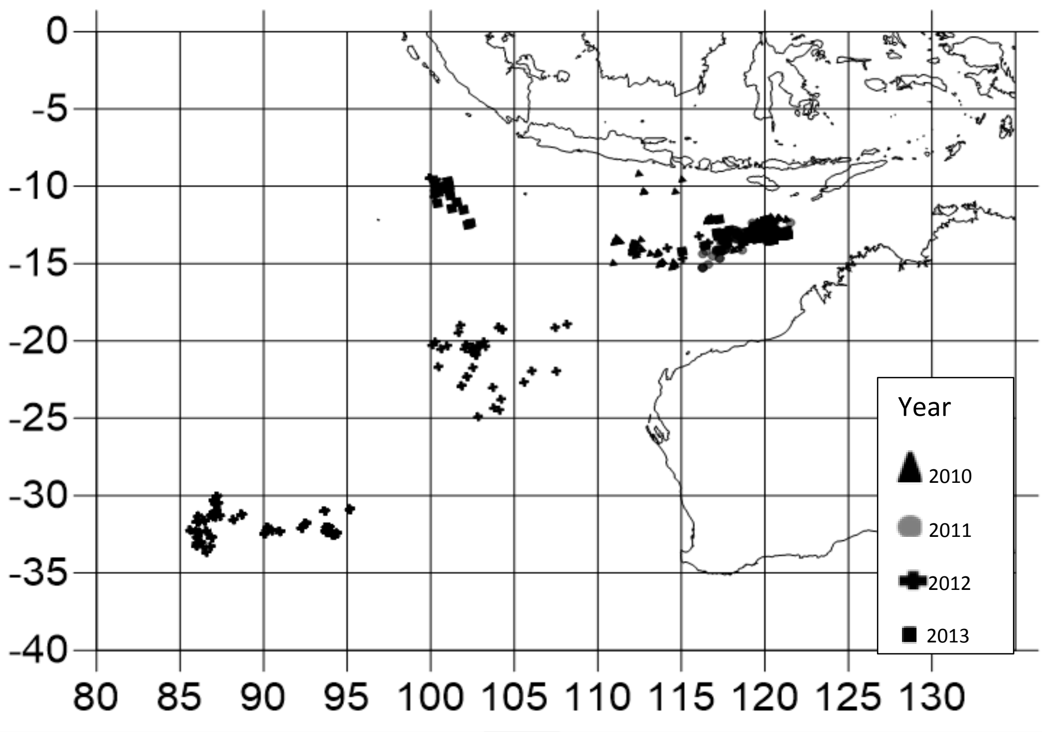


Figure 2. Map of the study area of ALB in Eastern Indian Ocean by Indonesian Tuna Longline fleets sets from 2010-2013.

Size Distribution

Total ALB samples that could be analyzed were 3152 which were taken from scientific observer data from 2010-2013. ALB length (cm FL) distributed from 70-196 cm FL (median=93 cm FL, mode=100 cm FL, mean=92.12 cm FL) and dominated at size 95 cm FL (Fig 3 and 4).

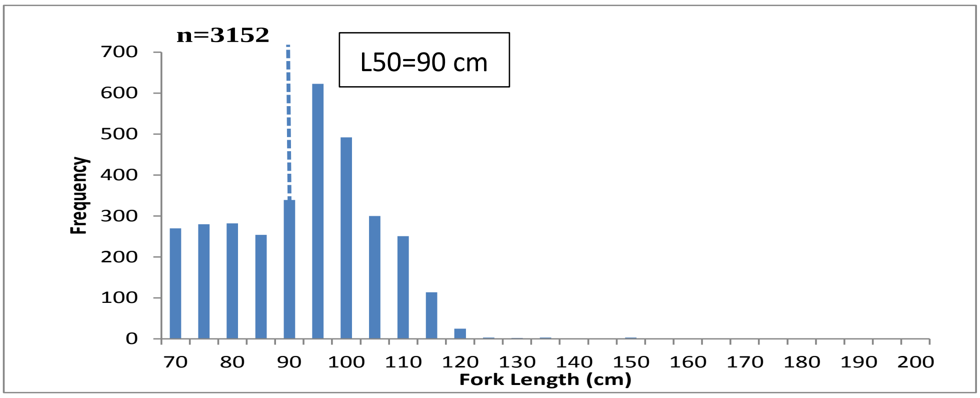


Figure 3. Length frequency distribution for ALB observed taken in Indonesian longline fishery operating in Eastern Indian Ocean in 2010-2013.

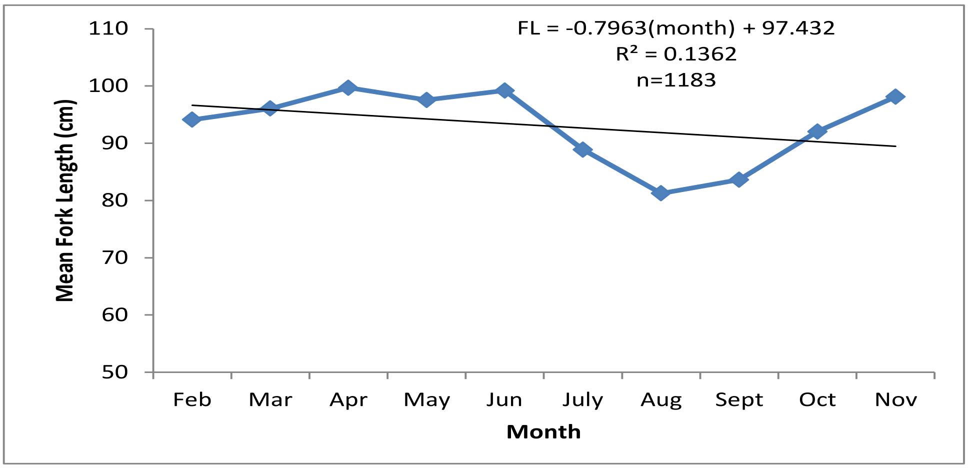


Figure 4. Mean FL distribution by month for ALB observed taken in the Indonesian pelagic longline fishery operating in Eastern Indian Ocean (2010-2013).

The higher percentage length of ALB > 90 cm (L50) occured in the area between (30-35°S and 80-95°E) and (10-15°S and 120-125°E) Figure 5.

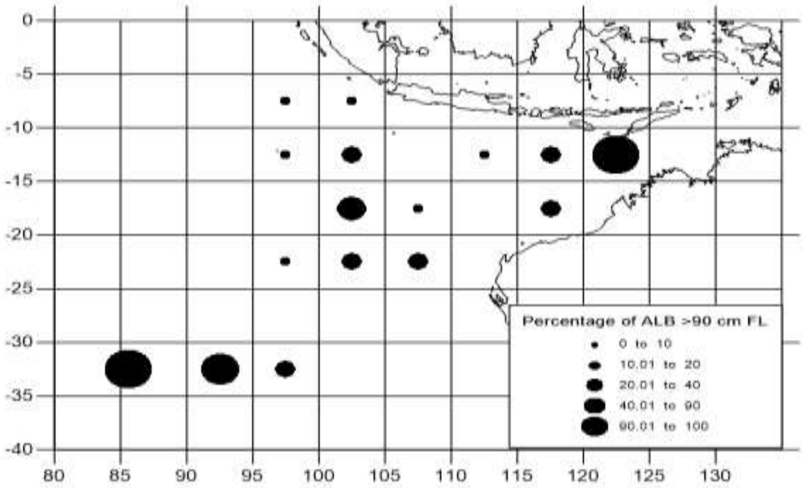


Figure 5. Spatial distribution of percentage of ALB over 90 cm FL recorded by Benoa Observer, aggregated from 2010 to 2013 with 5 x 5 grid.

Length and Weight Relationship

The data was taken from observer program in 2010-2013, involved 269 samples. Result of *t*-test of *b* for ALB was <3, with *b*=1.8211 (Fig. 6). It's assumed that the growth pattern of ALB were negative allometric, where the growth in length is faster than the growth in weight.

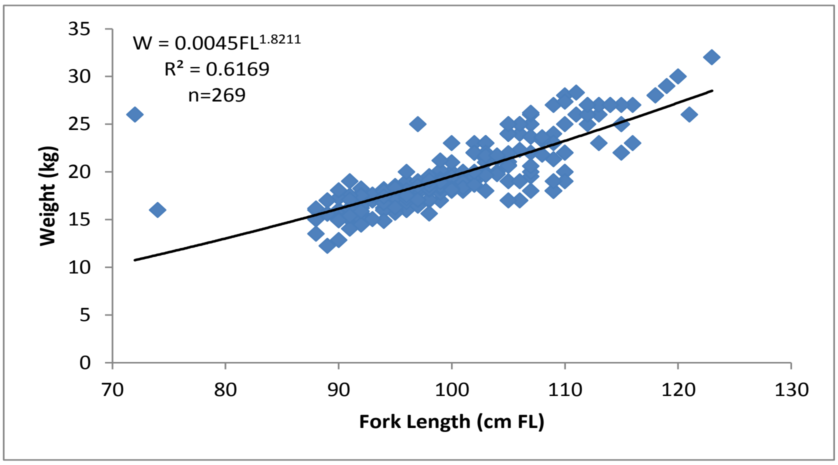


Figure 6. Weight-fork length exsponensial regression of ALB sampled from the Indonesia's Scientific Observer, operating in Eastern Indian Ocean in 2010-2013

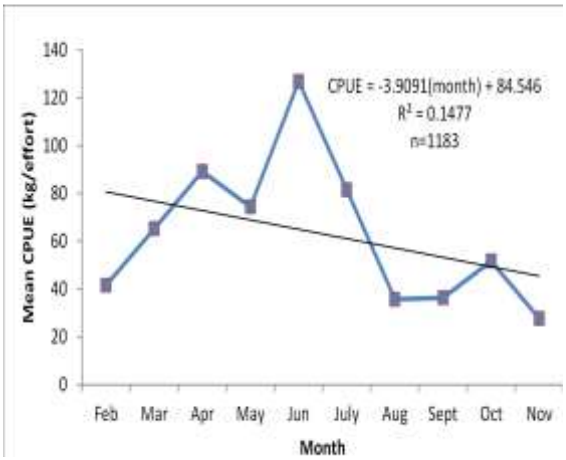
Cacth Rate and Cacth Per Unit of Effort (CPUE)

The data of cacth rate and cacth per unit of effort (CPUEs) of ALB caught by tuna longline fleets tabulated by year in Table 1.

Table 1. Effort, hook rate, cacth and CPUEs of ALB caught by Indonesian tuna longline fleets during year 2010-2013.

No	Year	∑ Effort	Number of Hooks	Cacth Number	Tonnage (kg)	Average Weight (kg)	CPUE (No.fish/1000 hooks	(number/effort)	(kg/effort)
1	2010	664	841,576	579	12,141	20.97	0.688	0.87	18.29
2	2011	504	513,216	356	6,858	19.26	0.694	0.71	13.61
3	2012	792	1,152,852	1466	21,624	14.75	1.272	1.85	27.30
4	2013	378	384,490	751	13,854	18.45	1.953	1.99	36.65

ALB CPUEs ranged between 0.688 – 1.953 fish/1000 hooks. CPUEs for ALB were highest in 2012 and 2013 (1.272 and 1.953 fish/1000 hooks). The overall moving average of CPUE showed that ALB cacthes generally increase from November to (June and July) and decrease in August to November (Fig. 7). ALB had higher cacth rate in area between (30-35°S and 80-100°E), (5-10°S and 95-100°E), and (10-15°S and 120-125°E) Figure 8.



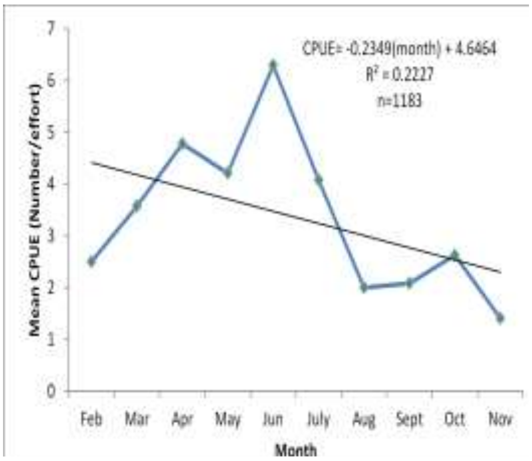


Figure 7. Nominal CPUEs by month for ALB recorded by observer during year 2010-2013

From 25 tuna longline observer trips (2.338 fishing days), all of trips caught ALB with the total number was 3152 fishes and the hook rate between

0.688 – 1.953 per 1000 hooks (Table 2). From the extend study area, the coordinate of the study area devided into 5 x 5 ° grid to recognize hook rate value. The spatial CPUEs distribution of ALB in Eastern Indian Ocean is shown in Figure 8.

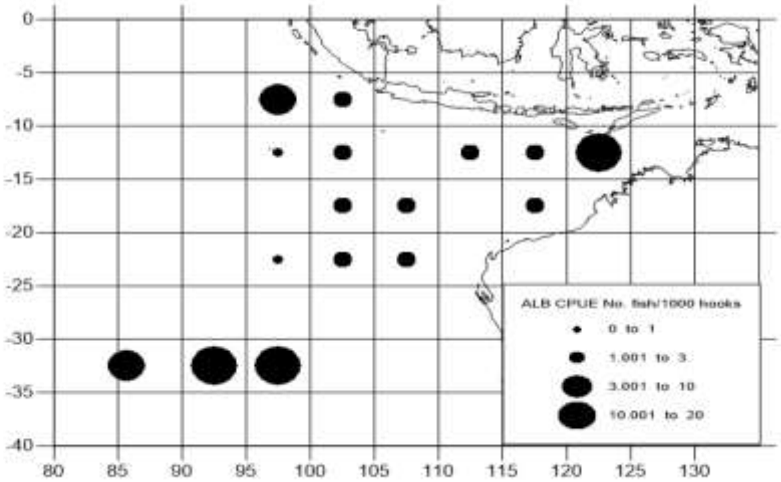


Figure 8. Spatial distribution of nominal CPUEs (no. fish/1000 hooks) for ALB recorded by Benoa Observer, aggregated from 2010 to 2013 with 5 x 5 grid.

Swimming Layer

Majority of Indonesian longline fleet based at Benoa port Bali are using middle longline type with 12 number of hooks and depth between 100-350 m. We used *minilogger* to recognize the depth of hook. We assumed that the depth of hook number 1 as equal as number 12 and the depth of hook number 2 as equal as number 11 and so on. The recorded of *minilogger* data showed that the average of deepest hook type was 341.52 m depth and the average of shallowest hook type was 117.83 m depth (Barata *et al*., 2011). The recorded data from *minilogger* showed that the deepest hook was 340 m and the shallowest hook was 117 m and the majority of ALB were caught at a depth of 156 m with fishing pole position no. 2 and 11 (Figure 9).

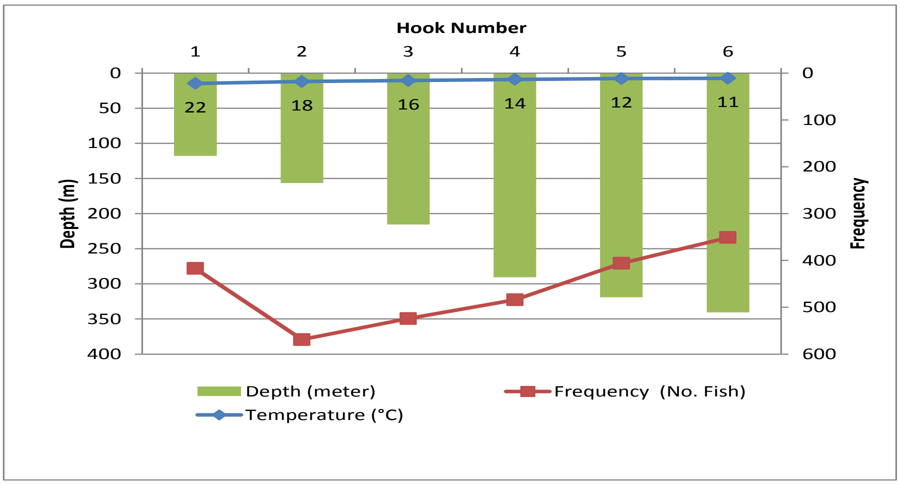


Figure 9. The relationship between the number of hooks, depth, temperature and frequency of ALB caught by Indonesian longline fleets in Eastern Indian Ocean

The data showed that ALB were caught at temperature range from 14-22°C and caught more at 18°C and a depth of 156 m.

Feeding Periodicity

The intencity of the feeding habit of ALB conducted between 07.45 am-17.59 pm with the highest frequency at 10.00-11.00 am. The average of feeding periodicity at 11.44 am (Figure 10).

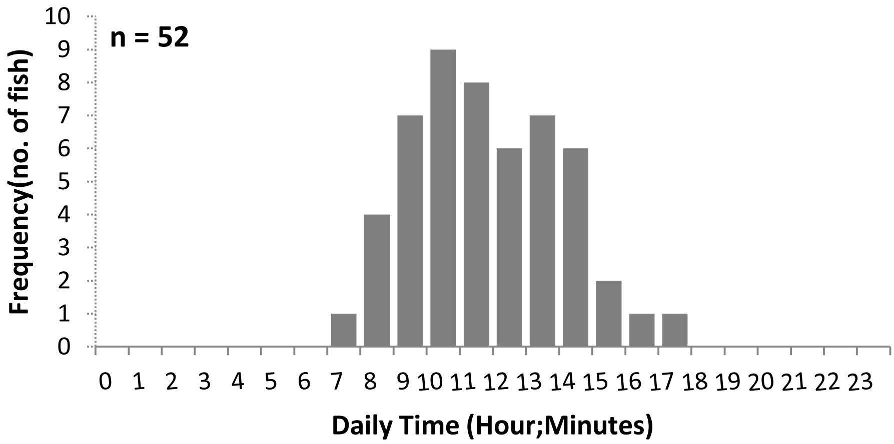


Figure 10. The feeding periodicity of ALB based on data obtained from *hook timer*

DISCUSSION

Size Distribution

The total samples obtained from observer program periods 2010-2013 were 3152 fish. Fish ranged from 70-196 cm FL, and dominated at size 95 cm FL. It was similar to that of Eastern Indian Ocean reported by (Setyadji *et al.*, 2012) (fish ranged from 36-126 cm FL and dominated at size 93-112 cm FL) and South West Pacific Ocean (fish ranged from 43-115 cm FL and dominated at size 90-95 cm FL) reported by (Farley *et al*., 2012). According to (Uenayagi, 1969) and (Wu & Kuo, 1993), the length at the first maturity of Indian Ocean Albacore was 90 cm FL.

Seasonal mean-length distribution were significantly different among month (ANOVA test, F= 115.965 and F_{crit} = 1.883). According to the *scheffe post hock* test, the largest difference occurred in June (mean=97.96 cm FL) and August (mean=79.74 cm FL) (scheffe test, F_{value}=25.510, $F_{critical\ zone}$=16.946). The highest mean-length distribution occurred in June and the lowest occurred in August. It’s might be due to seasonal movement caused by *sea surface temperature* (SST) that influenced reproductive behavior (Chen *et al*., 2005).

Mature ALB (L50>90 cm FL) were mainly distributed in Eastern Indian Ocean south of 10-35°S and 80-135°E and showed widely distributed pattern. The highest consentration of mature ALB conducted at (30-35°S and 80-95°E) and (10-15°S and 120-125°E) (Fig.5). Chen *at al*., 2005 reported that mature albacore concentrated in the Indian Ocean south of 10°S but showed a widely distributed pattern. In north of 10°S, mature albacore (about 22 kg) occurred all year . In the region between 10°S and 30°S, the albacore were mostly mature. The significant difference ($P < 0.001$) in weight composition occurred between the spawning and non-spawning periods. More immature albacore occured in region between 10°S and 30°S during the non-spawning season. Many albacore in region south of 30°S, are immature, with a mean weight of nearly 13 kg throughout the year.

Length and Weight Relationship

Length-weight relationship of ALB in this study were negative allometric, where the growth in length is faster than the growth in weight. Test of *b* (slope) value was 1.8211. According to (Carlander, 1969 in Zhu *et al.*, 2008), the value of the parameter *b* were well within the normal range of 2.5 to 3.5. The value of *b*<2.5 or >3.5 are often derived from sample with narrow size range. So narrow size range (72-123 cm FL) and limited samples (269) may be contributed to the reason why b value = 1.8211 (<2.5) was low for ALB in Eastern Indian Ocean. The comparison of length-weight of ALB in another ocean is shown in Table 2 .

Table 2. Length and weight relationship of ALB in Indian Ocean (compile from several authors)

No	Author	Area	FL Range (cm)	n	Intercept (a)	Slope (b)	R^2
1	Rochman *et al.* (2014)	Eastern Indian Ocean	72-123	269	0.00450	1.8211	0.6169
2	Setyadji *et al*. (2012)	Eastern Indian Ocean	83-106	497	0.00008	2.7271	0.6365
3	Zhu *et al*. (2008)	Indian Ocean	93-119	88	0.00043	2.3428	0.7644
4	Hsu (1999)	Indian Ocean	46-112	2499	0.05691	2.7514	0.9190
5	Zhu *et al*. (2008)	Atlantic	99.1-125	94	0.0438	2.8250	0.7628
6	Zhu *et al*. (2008)	Eastern Pacific	70.01-118	147	0.0542	2.7600	0.8256

Length-weight relationship is an important input to the regional stock assessment as it is used to convert cacthes in weight into cacth in number (Farley *et al.*, 2012). It can also provide information on relative condition of fish (Le chen, 1951 in Farley *et al.*, 2012).

The current study indicated that ALB caught in this study area are in relatively poor condition (compare to the previous study). ALB samples in the current study were heavier on average for length compare to the previous study (slope *b*=1.8211). In addition, morphometrics may not be the best indicator of fish condition and measuring fat content may be better proxy in future studies (Willis and Hobday, 2008 in Farley *et al*., 2012).

Cacth Rate and Cacth Per Unit of Effort (CPUE)

The CPUEs (no. Fish/1000 hooks) distribution of ALB showed the uneven distribution. The lowest CPUE occurred in 2010 (0.688) and then followed by 2011 (0.694), 2012 (1.272) and 2013 (1.953) (Table 1). The different of CPUE caused by the different of fishing area (study area). In 2010 and 2011 fishing activities carried out in the near shore of Indonesia territory (10-15°S and 110-125°E). In 2012, fishing activities carried out in the west of Australian territory (15-35°S and 85-110°E) and in 2013 fishing activities carried out in the south of Sumatera and west of Java (10-15°S and 100-105°E). According to Levesque (2010), the CPUE value caused by several factors such as reproductive behavior and feeding behavior. In the open-ocean environment, the availability of food is often limited to specific areas of oceanic convergence (currents, and sea mounts or ridge), which creates productive fishing conditions at certain times of year.

The average weight of ALB from 2010-2013 ranged between 14.75-20.97 kg. Chen *et al.*,2005 predicted that the weight at first maturity of 90 cm in length was estimated as 13.462 and14.622 kg, respectively. This result is based on the length at first maturity of Indian Ocean albacore (90 cm; Ueyanagi, 1969; Wu and Kuo, 1993) which was substituted into the Von Bertalanffy growth equation by Huang *et al*. (1990):

$$L_t=128.127[1-e^{-0.162(t+0.897)}] \text{ and } W_t=36.831[1-e^{-0.162(t+0.897)}]^{2.857}$$

and by Lee and Liu (1992):

L_t=163.71[1-$e^{-0.1019(t+2.0668)}$] and W_t=81.7[1-$e^{-0.1019(t+2.0668)}$]$^{2.858}$

Therefore, it can be concluded that the ALB caught by Indonesian longline fleets in Eastern Indian Ocean periods 2010-2013 majority was in mature condition.

The overall moving average of CPUEs (kg/effort or number/effort) showed that ALB cacthes increased from November to (June and July) and decreased in August to November (Figure 7). It is in accordance with Lee *et al*., 1999 which was stated that monthly CPUEs distribution of ALB during October-November are lower than the others month. This is also consistent with research conducted by Research Institute for Tuna Fisheries about Indexs of Fishing Season (IFS) of ALB with the case study in Cilacap fishing port, Cilacap, Central Java. The study, mentioned that the tuna fishing season expected to be about 4 months (April-Juli) with the peak season in May (RITF,2013).

Swimming Layer

Swimming layer is one of the important factor to get maximum cacthes, especially on tuna longline effort. The research showed that ALB majority were taken at a depth of 156 m with fishing no.2 and 11 (Figure 9). Nugraha and Triharyuni (2009) mentioned that ALB in Indian Ocean were caught in depth of 150-199.9 m. Chavance (2005) showed that ALB on the West Coast of New Caledonia were caught at a depth of 100-410 m. The depth of hook determined by the length of bouy line, branch line, main line, number of hooks and curvature coefficient among branch. This condition caused the difference of depth measurement (swimming layer) of ALB.

The swimming layer of ALB mostly located in the surface layer to mid layer, but there were some of ALB spreaded into deep layer. The big fish of ALB were in deep layer with a fewer in number, while the smaller ALB were in surface layer with a large number of fish. Barata *et al*., (2011a) reported that ALB dominated 64% with size >100 cmFL at depth from 85 to 124.74 m. Chen *et al*., (2005) showed that the distribution of immature ALB were caught at surface layer, while mature ALB were caught at mid layer. Tuna longline which were operated based in Benoa, devided into 3 types. There were surface longline, mid longline and deep longline (Barata *et al*., 2011a). According to Irianto *et al*., (2013) the surface longline type consist of 5 hooks among buoy which was operated at depth of 100 to 175 m, the mid longline type consist of 12 hooks among buoy which was operated at depth of 125 to 350 m, and the deep longline type consist of 18 hooks among buoy which was operated at depth of 150 to 450 m. According to various study above, we can concluded that the assimilation of surface longline type and mid longline type was the suitable way to cacth ALB in their habitat.

Feeding Periodicity

The feeding periodicity depends on the distribution of food and the environmental condition. The water pollution can caused the change of feeding periodicity (Effendie, 2002). The intensity of ALB to search of food was in the morning until evening and 1 time periodically in 24 hours. This indicated that ALB was included in diurnal fish.

Based on the onboard observation using *hook timer*, the intencity of the feeding habit of ALB conducted between 07.45 am -17.59 pm with the highest frequency at 10.00-11.00 am. The average of feeding periodicity at 11.44 am (Figure 10). The activity of diurnal fish have fast movement, active, and migrate within a large area (Effendi, 2002). Gunarso (1998), stated that ALB was searching for food during the day while at night quite active to hunt preys.

Musyl *et al.* (2003), stated that the amount of colour pigment in ALB vision will be influenced to feed habit. The limitation of colour pigment caused that the feeding habit only consentrated in clear water. The ability of sunlight to penetrate the water layer also influenced the ability of fish vision to search of food. In the musky water or in the lower intensity of sunlight, the ability of fish vision to the object in water could be reduced.

Generally, all types of tuna can adjust both the ability of the senses of sight during the day and evening, depending on the setting of cone and rod cells function contained in the fish retina (Masuma *et al.,* 2001). The type of fish which were actived during the day, generally have *cone* that arranged in a rectangular shape. This kind of fish used their visión intensively and active to hunt preys. Tuna fish were not selectived to search for preferred food (Barata *et al.*, 2011b).

CONCLUSION

The study area of Indonesian tuna longline fisheries periods 2010-2013 was between 0-35°S and 75-131°E. The fishing gears was using combination between surface longline and mid longline type with a depth from 117-340 m. The majority of ALB was mature (mean weight=92 cm FL and mode=95 cm FL). The highest distribution of mature ALB conducted at(30-35°S and 80-95°E) and (10-15°S and 120-125°E). The length-weight relationship of ALB were negative allometric, where the growth in length is faster than the growth in weight. The

CPUEs of ALB ranged between 0.688-1.953 fish/1000 hooks with the highest CPUEs in 2012 and 2013 (1.272 and 1.953 fish/1000 hooks). The CPUEs increase from November to (June and July) and decrease in August to November. The majority of ALB were caught at depth of 156 m with average temperature 156 °C. The intensity of the feeding habit ALB conducted between 07.45 am – 17.59 pm with the highest frequency at 10.00-11.00 am.

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