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THE POTENTIAL FISHING GROUND AND SPATIAL DISTRIBUTION PATTERN OF ALBACORE (*Thunnus alalunga*) IN EASTERN INDIAN OCEAN

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ABSTRACT

The current work highlighted the estimation on potential fishing grounds area of Albacore (ALB) (*Thunnus alalunga*) in the Eastern Indian Ocean. These data used in this study were based on the Research Institute for Tuna Fisheries (RITF) observer program in Benoa from 2005-2013. The aim of this study is to give the information to the longline fisheries stake holder about the spatial distribution and the potential fishing grounds area (PFGA) of ALB in Eastern Indian Ocean. The methods used in this study is the combination of spatial distribution of CPUE and the percentage of mature ALB in Eastern Indian Ocean. Result show that the distribution and fishing grounds of ALB are influenced by spatial distribution of oceanographic variables i.e. sea surface temperature (SST), salinity, temperature at depth of 100 m, chlorophyll concentration and oxygen content at depth of 200 m. In February and March, the PFGA distribution spread out evenly in the Eastern Indian Ocean. In April and May, the PFGA distribution began to move to the area between southern coast of (Java, Bali and Nusa Tenggara) and northern coast of Australia at the coordinates (5-15°S and 110-125°E). In June and July, the PFGA spread widely in the area between south coast of Java, Bali, Nusa Tenggara and Australia with the coordinate (5-25°S and 100-125 °E). In August and September, PFGA moved to the west coast of Australia (10-35°S and 75-120 °E). In October and November, PFGA moved to southern hemisphere and far away to mid Indian Ocean.

KEYWORD: Albacore, fishing grounds, , CPUE, spatial distribution and Eastern Indian Ocean

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*). During 2004-2011, groups of tuna production reached up to 1.297.062 tons consisting of 69% yellow fin tuna, 24% big eye tuna, 6% albacore and 1% southern blue fin tuna (DGCF, 2012).

In Indian Ocean, albacore is caught almost exclusively under drifting longline (98%), with remaining catches recorded under purse seines and other gears (IOTC, 2007; Nishida & Tanaka, 2008). According to IOTC (2013), the average catch of ALB in Indian Ocean ranged was 37,082 tons year^{-1} in 2008-2012. The average catch from Indonesia was 12,000 tons year^{-1} representing approximately 33% of the total catches of ALB in Indian Ocean. About 53.4% of ALB catch coming from Indonesia is landed at Benoa fishing port (Proctor *et al*., 2007).

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).

The distribution and the abundance of ALB greatly influenced by the oceanographic condition (Barata *et al*., 2011). The previous study in Pacific and Atlantic Ocean indicated that ALB distribution affected by sea surface temperature (SST) distribution (Ramos *et al*., 1996), hydrographic front (Kimura *et al*., 1997) and the depth of thermocline zone (Chen *et al*., 2005). The ALB can move from one to anothers areas following the oceanographic conditions which are suitable for it's live and behaviour.

The main problem encounter in industrial tuna longline fishery is the increasing of operational cost, especially in fuel cost. Fuel cost reaching up to 42.55% of the total operational cost (Rochman & Nugraha., 2015). Most of fishing ground area for industrial tuna longliner in Indonesia occured in outside of Exclusive Economical Zone and far away from shoreline. Thus, the determining of exact ALB fishing ground area will be reduce the time and operational cost especially fuel cost and increase the efficiency.

The aims of this research is to estimate ALB potential fishing ground and to recognize ALB spatial distribution in Eastern Indian Ocean. Hopefully, the result of the current work would be used as reference point for stake holder, especially for the Indonesian tuna longliners.

MATERIAL AND METHODS

Data Collection

Data analyzed were obtained from RITF onboard observer program on commercial tuna longline fleets based at Benoa-Bali in period of August 2005 to October 2013. Based on 93 fishing trips (8.339 fishing days), catch 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 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 per setting.

Data Analysis

Catch data were collected on board during 93 fishing trips (8,339 fishing days). Data collected included fork length (cmFL) with level accuracy 1 cm and setting position recorded by *Global Positioning System* (GPS). The fishing effort (f) and CPUE for ALB were calculated using the following a formula, modified from De Metrio & Megalofonou (1998):

$$f = (a'/1000) \times d \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where a' is the number of hooks in longline per day (devided by the 1000 hooks longline effort unit), d' is the number of fishing days per trip. The CPUE is calculated in two ways based on the fish number and weight.

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

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

All data were combined by month and year to determine monthly distribution pattern. We also calculated mean of CPUE and the percentage of mature ALB indices for all years in all grids. It is done in order to describe the spatial distribution of ALB (CPUE spatial distribution and the percentage of mature ALB spatial distribution).The determining of mature fish was done according to (Uenayagi, 1969 ; Wu &Kuo, 1993). The determination of potential fishing ground area **(PFGA)** is done by combination between CPUE and percentages of mature fish distribution. The PFGA is classified into five (5) criteria :

: CPUE (2-8), % mature ALB (100%)

: CPUE (0,5-2), % mature ALB (50-75%)

: CPUE (0,5-2), % mature ALB (0-50%)

: CPUE (0-0,5), % mature ALB (50-75%)

: CPUE (0-0,5), % mature ALB (0-50%)

The maps describing the average of CPUE, the percentage of mature ALB and PFGA distribution were made by using *Surfer9* program. Monthly distribution maps were produced to explore temporal patterns. The PFGA is defined as region where the CPUE and the percentage of mature ALB are in highly cumulative value.

Study Area

The study area of ALB is mapped based on the result of *onboard observer program* conducted by Research Institute For Tuna Fisheries (RITF) from August 2005 to October 2013. The area is located between 0-40°S and 75-130°E (Fig. 1). The ALB fishing area is mostly located outside Indonesian Exclusive Economic Zone (EEZ). Both CPUE and size of ALB were georeferenced in 5° grids of latitude and longitude. The *surfer 9* program was used to describe the spatial distribution of CPUE and the percentage of mature ALB.

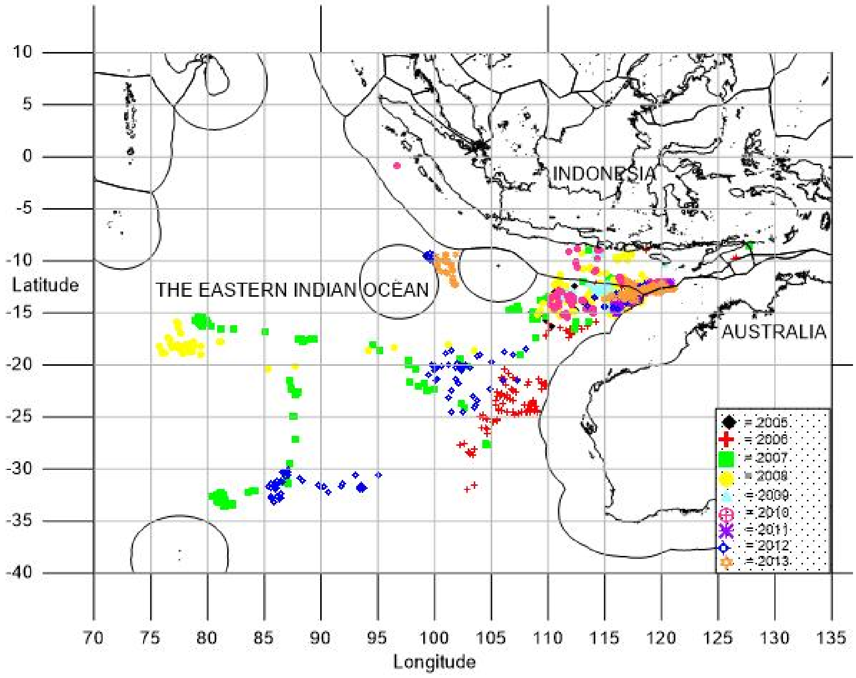


Fig. 1. Map of the study area of ALB in Eastern Indian Ocean by RITF observer program sets from 2005-2013.

RESULTS AND DISCUSSION

Result

CPUE Spatial Distribution

The overall CPUE indicated that ALB tuna were widely distributed between (5-35°S and 70-125°E) in Eastern Indian Ocean. The highest CPUE (> 5.001) occured in the area between (30-35°S and 80-95°E), the intermediate CPUE (1-5) occured in the area south of (Java, Bali, Nusa Tenggara) and West of Australia with the coordinate between (5-25°S and 105-125°E) and the lowest CPUE evenly distributed in the area between (5-35°S and 70-125°E) of the Eastern Indian Ocean (Fig. 2).

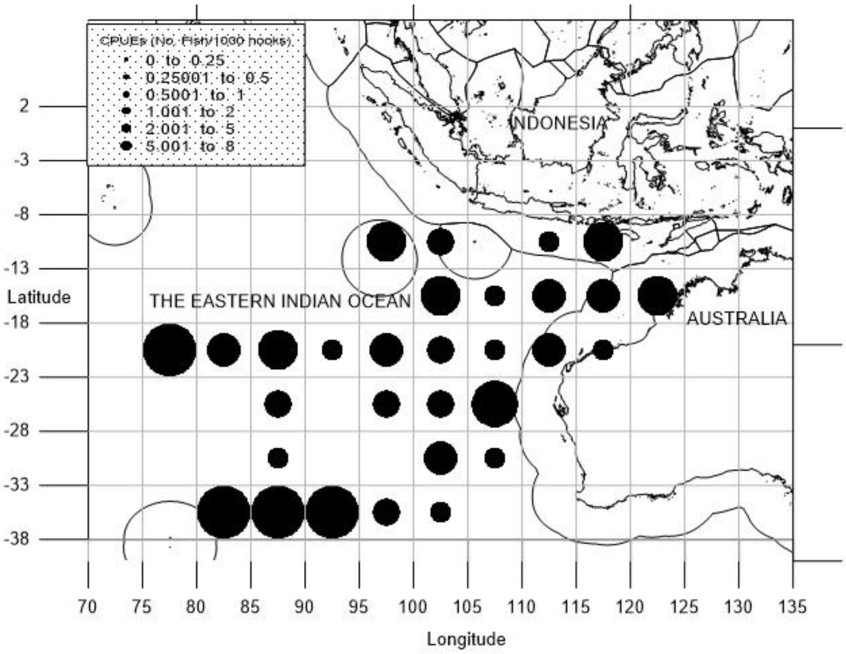
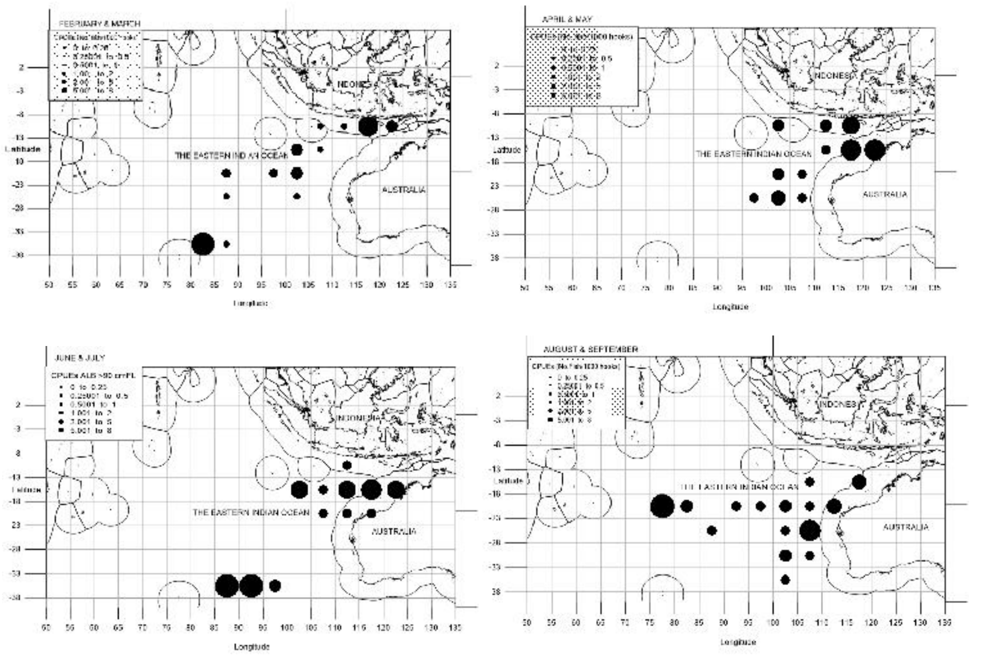


Fig. 2. CPUE spatial distribution of Indonesian ALB longline fishery, indexes in the Eastern Indian Ocean using 5° grids. The data was from RITF observer program conducted from 2005-2013.

Bimonthly mean of CPUE spatial or temporal distribution (2005-2013) shows in Fig.3.



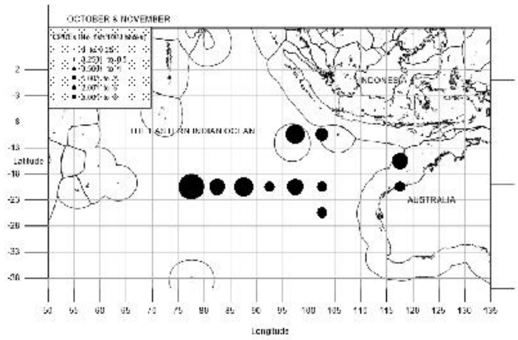


Fig. 3. Bimonthly CPUE spatial distribution of ALB in Eastern Indian Ocean Based on RITF scientific observer program summarized from 2005-2013.

The bimonthly moving average of CPUE showed that in February-March, the CPUE value index is evenly distributed in all areas but there were some specific areas where it is found higher in CPUEs i.e in coordinate (10-15°S and 115-125°E) and (30-35°S and 80-85°E). The higher CPUEs occurred only in narrow area and are spread in a specific area. In April-May, the higher CPUEs index is spread widely in the area between southern coast of (Java, Bali and Nusa Tenggara) and northern coast of Australia (5-15°S and 115-125°E). In June-July, the higher CPUEs index was wider than in April-May and reached out to southern coast of West Java and western coast of Australia. In August-September, the higher CPUEs index began to move into the West Coast Australia. Finally, in October-November the higher CPUEs index began to move away from the coast of Indonesia and Australia. In October-November, the higher CPUEs index spreadly occured in mid of Indian Ocean precisely in coordinated (15-30°S and 75-100°E) (Fig. 3).

The Percentage of Mature ALB Spatial Distribution

The overall distribution shows that mature ALB with length > 90 cmFL widely distributed in all area of Eastern Indian Ocean (Fig. 4). The highest percentage of mature ALB is found in area between (15-35°S and 75-90 °E) and along the south coast of (Java, Bali and Nusa Tenggara).

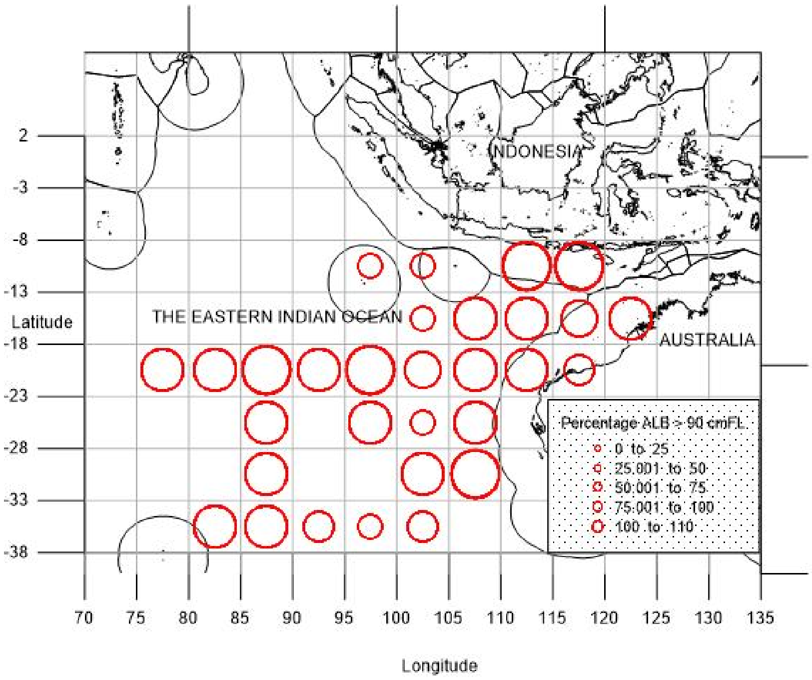
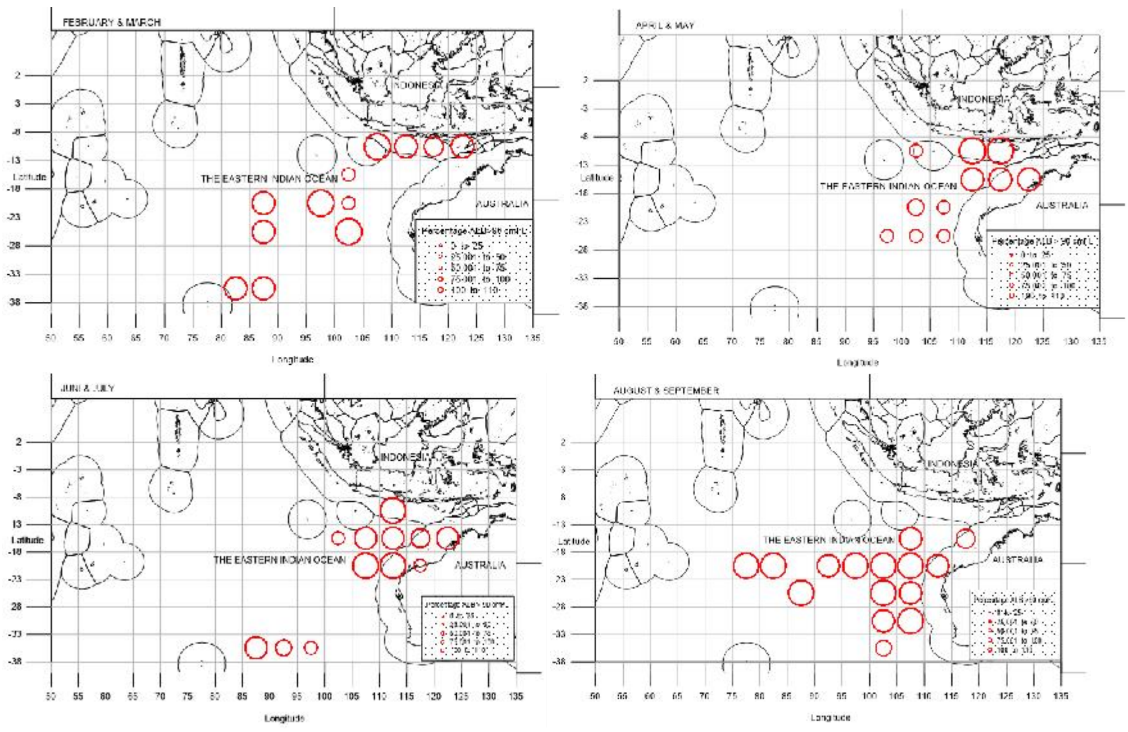


Fig. 4. The percentage of mature ALB (> 90 cmFL)spatial distribution of Indonesian ALB longline fishery, indexes in the Eastern Indian Ocean using 5° grids. The data was from RITF observer program ranged from 2005-2013.

Bimonthly mean of L_{50} spatial or temporal distribution (2005-2013) shows in Fig.5.



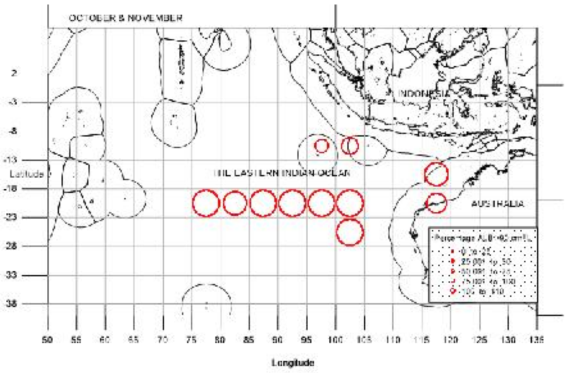


Fig. 5. Bimonthly of the percentage of mature ALB index distribution based on RITF scientific observer program summarized from 2005-2013.

The bimonthly moving average of mature ALB indicated that in February-March, the higher mature ALB index is spread evenly in Eastern Indian Ocean i. e. southern coast of (Java, Bali, and Nusa Tenggara) (5-15°S and 105-125 °E) and western coast of Australia (20-35°S and 80-105 °E). In April and May, the higher mature ALB index moved on and is consentrated in the area of southern coast of (Java, Bali, and Nusa Tenggara) (5-15°S and 110-125 °E). In June and July, the higher mature ALB index spreaded widely in the area between south coast of (Java, Bali, Nusa Tenggara) and west coast of Australia with the coordinate (5-25°S and 100-125 °E). In August and September, the higher mature ALB index moved to the wide open ocean in west of Australia (10-35°S and 75-120 °E). Finally, in October-November the higher mature index of ALB moved to the mid of Indian Ocean precisely at coordinate (10-25°S and 70-110 °E).

The Potential Fishing Ground Area (PFGA)

PFGA is the combination between CPUE and the percentage of mature ALB in the area. There were some areas that showed high CPUE value and high of the percentage of mature ALB. In the others side, there were some areas where the high values of CPUE are found and low in the percentage of mature ALB (Fig.6)

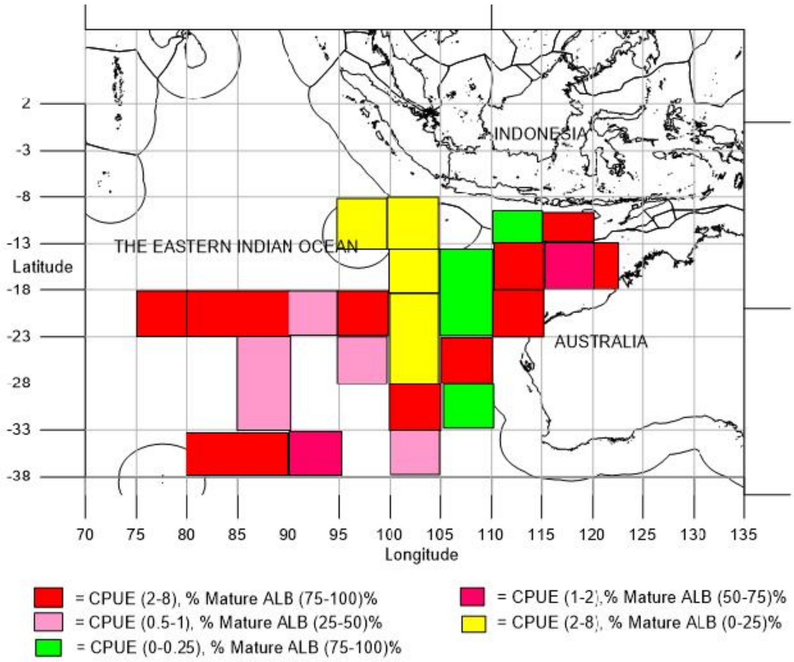
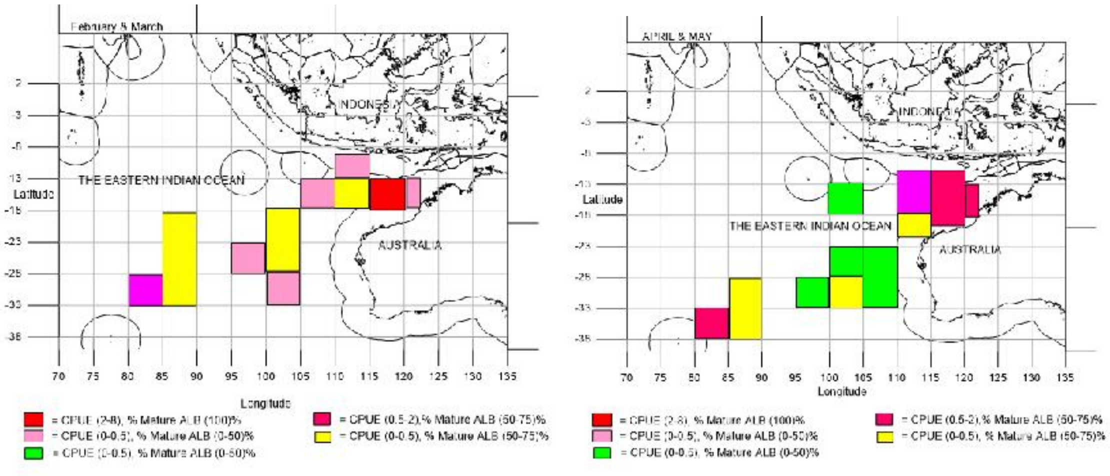


Fig. 6. PFGA according to CPUE and the percentage of mature ALB (> 90 cmFL) indexes based on RITF scientific observer program data from 2005-2013.

This study also explored some informations about temporal trend PFGA spot in the Eastern Indian Ocean. The temporal distribution of PFGA area based on the comparison of the bimonthly spatial distribution of CPUE and the bimonthly spatial distibution on the percentage of mature ALB (>90 cmFL) (Fig. 7).



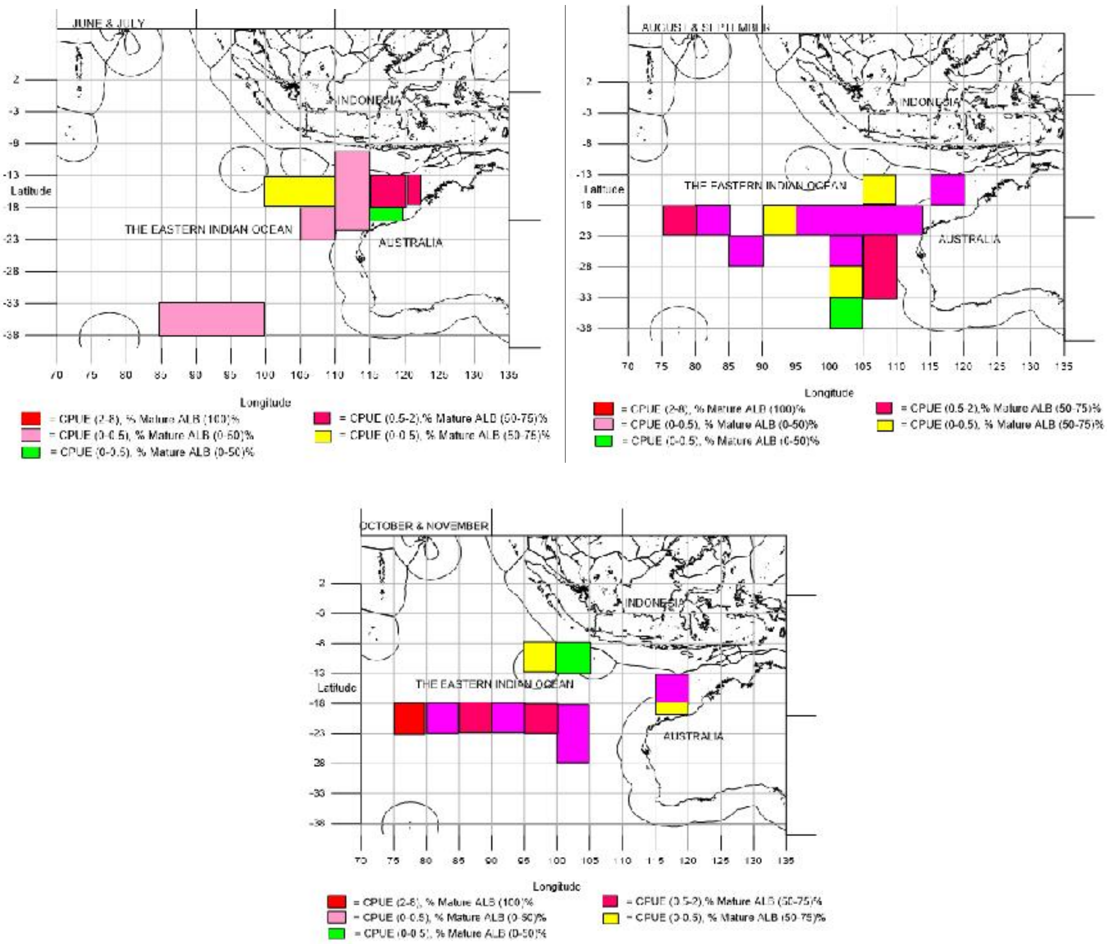


Fig. 7. The temporal trend of PFGA according to CPUE distribution and the percentage of Mature ALB based on RITF scientific observer program data from 2005-2013.

In February and March, PFGAs are spread out evenly in the Eastern Indian Ocean. In April and May, the PFGAs seem to move to the area between southern coast of (Java, Bali and Nusa Tenggara) and northern coast of Australia. In June and July, the PFGAs are spread widely in the area between south coast of Java, Bali, Nusa Tenggara and Australia with the coordinate (5-25°S and 100-125 °E). In August and September, the PFGAs are moved to the west coast of Australia (10-35°S and 75-120 °E). In October and November, the PFGAs are moved to southern hemisphere and far away to mid Indian Ocean.

Discussion

CPUEs of ALB in Eastern Indian Ocean are spread evenly in this study area (5-35°S and 70-125°E) but there were some areas where the higher CPUE value are found than other areas. The highest CPUE (> 5.001) occured in the area between 30-35°S and 80-95°E, the intermediate CPUE (1-5) occured in the area South of Java, Nusa Tenggara and West of Australia with the coordinate between 5-25°S and 105-125°E. This result is in agree with Chen *et al*., (2005) which stated that ALB spread throughout the Indian Ocean between 25°S and 45°S.

According to Levesque (2010), the CPUE value is caused by several factors such as fishing technology, the existence of fish stock and the experience of fishing master. The existence of fish stock is influenced by fish reproductive behavior and feeding behavior. Associated with 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. According to Chen *et al*., (2005), CPUE is also indirect influenced by spatial distribution of oceanographic variables i.e. sea surface temperature (SST), salinity, temperature at depth of 100 m, chlorophyll concentration and oxygen content at depth of 200 m.

Similarly with CPUE spatial distribution, the mature ALB spatial distribution has the same pattern with CPUE spatial distribution. This study showed that the mature ALB were widely distributed in Eastern Indian Ocean with the coordinate area 5-35 °S and 75-125 °E and immature ALB were distributed in the area over 35°S. According to Chen *et al*., (2005), the mature ALB (> 90 cmFL) or larger than 14 kg congregated in Central Indian Ocean (10-30°S) and ALB smaller than 14 kg congregated in South of

30°S. The distribution of availability and vulnerability of ALB are strongly influence by Oceanographic condition (IOTC, 2014). The matures ALB (spawning and non-spawning) depend on environmental variables such as sea surface temperature (**SST**), temperature at depth of 100 m (Temp_100), salinity at depth of 0 m (Sal_0) and dissolved Oxygen at 200 m depth (OXY_200). SST was significant for immature, spawning and non-spawning stage of ALB (Chen *et al.*, 2005). Based on (Chen *et al.*, 2005), Central Indian Ocean has an optimal environmental variables and has a suitable for mature ALB live stage such as SST (ranged from 19-26°C), Tempt_100 (ranged from 21.3-21.1°C), Sal_0 (ranged from 34.86-35.01 psu) and OXY_200 (ranged from 5.75-5.09 ppm). Non-spawning ALB tends to live in the area with SST 19-22°C, meanwhile spawning ALB are living in the area where SST are > 25°C. The area over 35°S is suitable for immature ALB with SST (ranged from 18.9-24.1°C) and Sal_0 (ranged from 35.32-34.89 psu)

In February and March, PFGAs are spread out evenly in the Eastern Indian Ocean. It's accordance with stable distribution of SST of Indian Ocean from west to east Indian Ocean with the average temperature 28.26 °C (Fig. 10a). ALB is started to move from southern to northern hemisphere where the fishes are developing their body and gonadal.

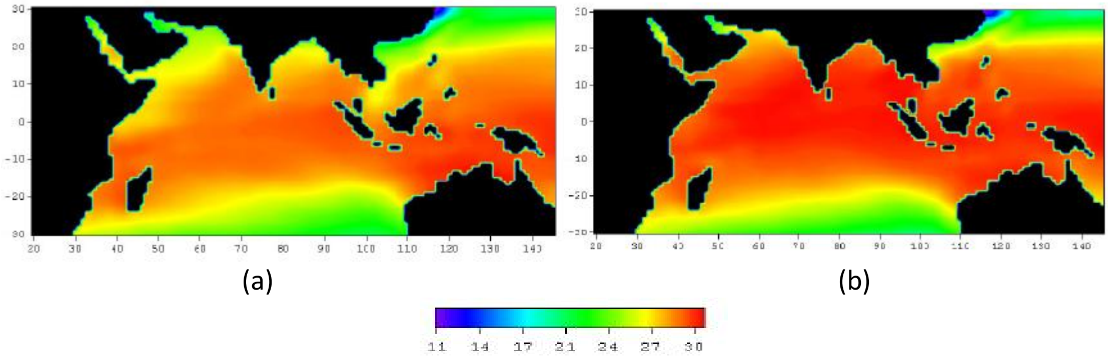
In April and May, the PFGA seem to move to the area between southern coast of (Java, Bali and Nusa Tenggara) and northern coast of Australia. The SST distribution pattern in Eastern Indian Ocean is getting warmer with the average temperature 29.63°C and the Eastern Tropical Indian Ocean relatively warmer than Western Tropical Indian Ocean (Fig. 10b).That's indicated that mature ALB would move to the Eastern Tropical

Indian Ocean in the area between southern coast of (Java, Bali and Nusa Tenggara) and northern coast of Australia, precisely in coordinate (5-15°S and 110-125°E).

In June and July,the PFGAs are spread widely in the area between south coast of Java, Bali, Nusa Tenggara and Australia with the coordinate (5-25°S and 100-125 °E). In June and July, Indian Ocean water is colder than in the previous month where SST of west tropical Indian Ocean colder than the east tropical India Ocean so that the movement of higher CPUE dan the percentage of mature ALB was still in east tropical Indian Ocean with widened area due to the movement ALB from west to east tropical Indian Ocean.The ALB spawning is probably started in between July and September in northern hemisphere (Collette & Nauen, 1983; Santiago & Arrizabalaga, 2005)

In August and September, the PFGAs are moved to the west coast of Australia (10-35°S and 75-120 °E). This movement is related to the condition of SST that is still in optimal requirement (25-28°C) ilustrated in Figure 2 for spawning activity of ALB (Fig. 11a) (Chen *et al*., 2005). The spawning area of ALB in Indian Ocean is found at the coordinate between 10-25°S (Nishida & Tanaka, 2008).

In October and November, the PFGAs are moved to southern hemisphere and far away to mid Indian Ocean. It’s in accordance with some previous work (Collette & Nauen, 1983; Santiago & Arrizabalaga, 2005). The encouragement of warm SST (29-31°C) from northern Indian Ocean (Fig. 11 b) lead the group of spawning ALB tends to move away to the mid Indian Ocean.

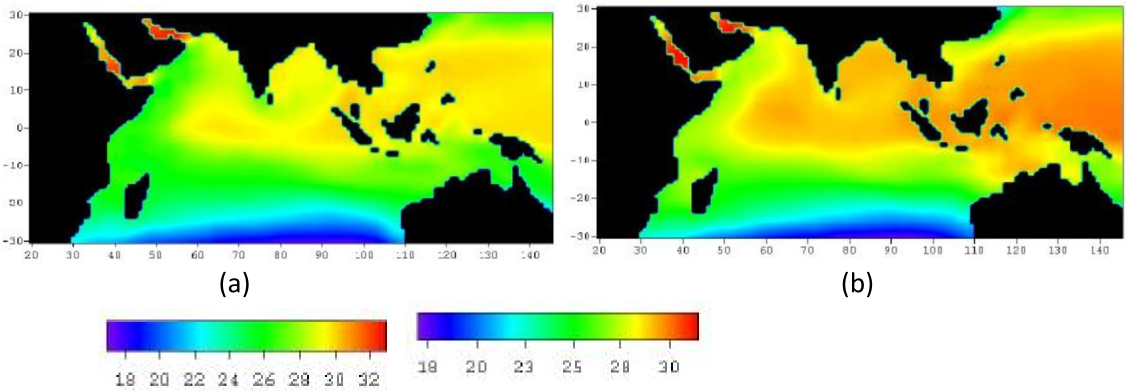


Sea Surface Temperature (SST) (°C)

Figure 10 (a).The distribution of SST at west monsoon (December – Februari) in Eastern Indian Ocean in 2007.

(b).The distribution of SST at the first transitional monsoon (March-May) in Eastern Indian Ocean in 2007.

Source :Martono *et al*., (2008)



Sea Surface Temperature (SST) (°C)

Figure 11(a).The distribution of SST at east monsoon (June August) in Eastern Indian Ocean in 2007.

(b).The distribution of SST at the second transitional monsoon (September-November) in Eastern Indian Ocean in 2007.

Source :Martono *et al*.,(2008)

CONCLUSION

Albacore (ALB) (*Thunnus alalunga*) is a temperate tuna species, widely distributed in temperate and tropical waters in Indian Ocean. The distribution of ALB is depend on the environmental variables. ALB tend to live in preffered wáter which is suitable for it's live cycle. One of which is SST *sea surface temperature*. Based on SST, in February and March, the PFGA tend to spread out evenly in the Eastern Indian Ocean. In April and May, the PFGA distribution tend to move to the area between southern coast of (Java, Bali and Nusa Tenggara) and northern coast of Australia at the coordinate (5-15°S and 110-125°E). In June and July, the PFGA distribution prone to spread widely in the area between south coast of Java, Bali, Nusa Tenggara and Australia with the coordinate (5-25°S and 100-125 °E). In August and September, the PFGA liable to move to the west coast of Australia (10-35°S and 75-120 °E). In October and November, the PFGA tend to move to southern hemisphere and far away to mid Indian Ocean.

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