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The Potential Fishing Ground and Spatial Distribution Pattern of Albacore (Thunnusalalunga) in Eastern Indian Ocean

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ABSTRACT
The current work highlighted the estimation on potential fishing grounds area of Albacore (ALB) (Thunnusalalunga) in the Eastern Indian Ocean. This data used in this study was 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 stakeholders about the spatial distribution and the potential fishing grounds area (PFGA) of ALB in Eastern Indian Ocean. The methods used in this study are the combination of spatial distribution of CPUE and the percentage of mature ALB in Eastern Indian Ocean. The result show that the distribution and fishing grounds of ALB are influenced by the spatial distribution of oceanographic variables i.e. sea surface temperature (SST), salinity, a temperature at a depth of 100 m, chlorophyll concentration and oxygen content at a 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 the 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 the southern 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 the southern hemisphere and far away to mid-Indian Ocean.
KEYWORDS;*-Albacore, fishing grounds, CPUE, spatial distribution and Eastern Indian Ocean*

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I. INTRODUCTION

Albacore (ALB) is one of a major important commercial species of Indonesia tuna longline fisheries in Eastern Indian Ocean. The production of Albacore (T. alalunga) was the third-largest tuna after Yellowfin Tuna (T. albacares) and bigeye tuna (T. obesus). During 2004-2011, groups of tuna production reached up to 1.297.062 tons consisting of 69% Yellowfin Tuna, 24% Bigeye Tuna, 6% Albacore and 1% Southern BluefinTuna [1]. In the Indian Ocean, Albacore is caught almost exclusively under drifting longline (98%), with remaining catches recorded under purse seines and other gears. The average catch of ALB in the Indian Ocean ranged was 37,082 tons year^{-1} in 2008-2012 and the average catch from Indonesia was 12,000 tons year^{-1} and also representing approximately 33% of the total catches of ALB in the Indian Ocean [2].

Albacore (T. 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 Ocean, 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 [3].The distribution and the abundance of ALB greatly influenced by the oceanographic condition [4], [5]. The previous study in the Pacific and the Atlantic Ocean indicated that ALB distribution affected by sea surface temperature (SST) distribution [6], hydrographic front [7], depth of thermocline zone [8], [9],[10] and nutrients [11]. The ALB can move from one to another's areas following the oceanographic conditions which are suitable for its live and behavior.

A main problem encounter in industrial tuna longline fishery is the increasing of operational cost, especially in fuel cost. Fuel cost was reaching up to 42.55% of the total operational cost [12]. Most of the fishing ground area for industrial tuna long liner in Indonesia occurred in outside of Exclusive Economic Zone and far away from coastline [13]. Thus, the determining of ALB fishing ground area will reduce the time and operational cost especially fuel cost and increase the efficiency.The aims of this research are 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 Indonesia tuna long liners.

II. METHODS

1. Data Collection

Data analyzed were obtained from RITF onboard observer program on commercial tuna longline fleets based at Benoa-Bali in a 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 a level of accuracy 1 cm and setting recorded by Global Positioning System (GPS).

The fishing gear that used by Indonesian long liners was a tuna longline that was set up horizontally. The mainline was made of polyamide (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 (S. lemuru) was usually used as a bait. Each fishing boat often uses from 400 to 2700 hooks per set.

2. Data Analysis

Catch data was collected on board during 93 fishing trips (8,339 fishing days). Data collection was 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, [14]:

$f = (a'/1000) \times d$ ……………….. (1)

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

CPUE=N/f (N was the number of fish caught)
CPUE=B/f (B was 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 was 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 [15], [16]. The determination of potential fishing ground area (PFGA) was done by a combination of CPUE and percentages of mature fish distribution. The PFGA is classified into five criteria Figure1.

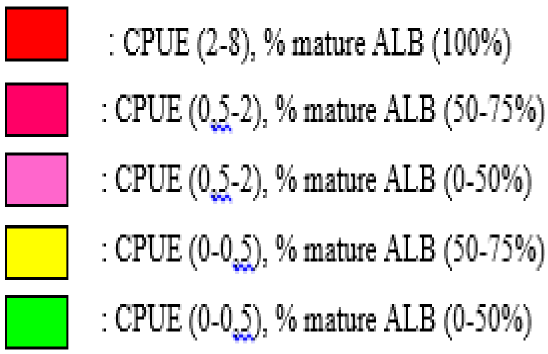


Figure 1. Five (5) criteria of (PFGA) classification in Eastern Indian Ocean

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

3. 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 was located between 0-40 °S and 75-130 °E Figure 2. The ALB fishing area was mostly located outside Indonesian Exclusive Economic Zone (EEZ). Both CPUE and size of ALB were georeferenced in 5° grids of latitude and longitude. The surfer9 program was used to describe the spatial distribution of CPUE and the percentage of mature ALB.

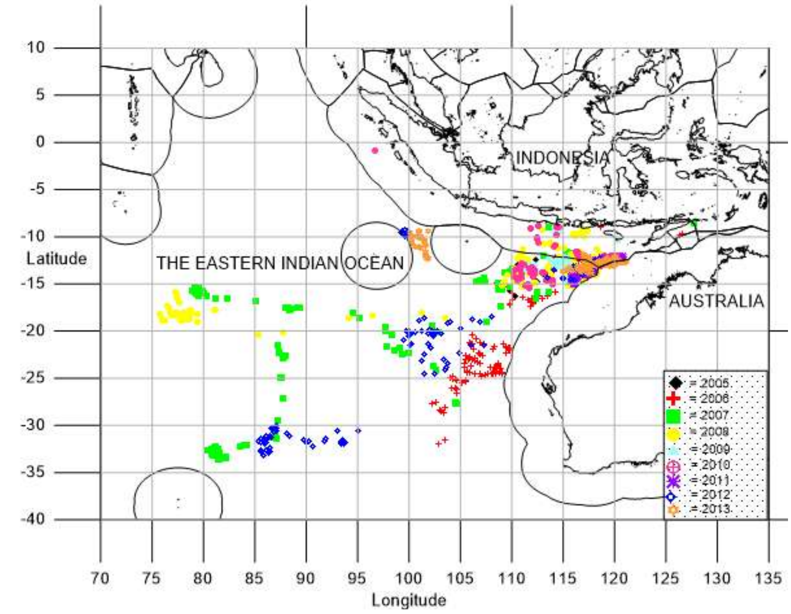


Figure 2. Map of the study area in Eastern Indian Ocean by RITF observer program sets from 2005-2013

III. RESULT VIEW

1. CPUE Spatial Distribution

The overall CPUE indicated that ALB tuna was distributed widely between (5-35 °S and 70-125 °E) in Eastern Indian Ocean. The highest CPUE (> 5.001) occurred in the area between (30-35 °S and 80-95 °E), the intermediate CPUE (1-5) occurred 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 Figure 3.

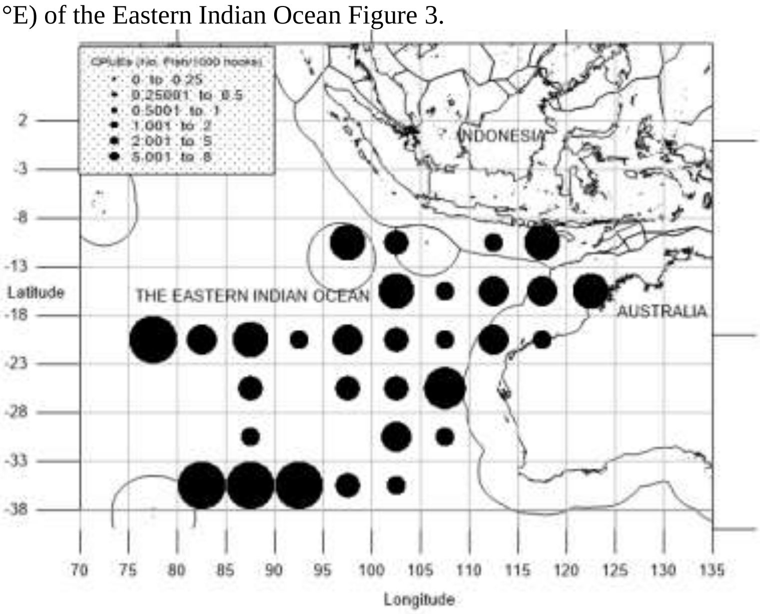


Figure 3. CPUE spatial distribution of Indonesian ALB longline fishery, indexes in Eastern Indian Ocean Based on RITF Observer Program conducted from 2005-2013.

The bimonthly mean of CPUE spatial or temporal distribution (2005-2013) shows in Figure 4. The bimonthly moving average of CPUE showed that in February-March, the CPUE value index was distributed evenly 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 spreaded in a specific area. In April-May, the higher CPUEs index is spread widely in the area between the southern coast of (Java, Bali and Nusa Tenggara) and the 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 the southern coast of West Java and the 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 occurred in mid of Indian Ocean precisely in coordinated (15-30 °S and 75-100 °E) Figure 4.

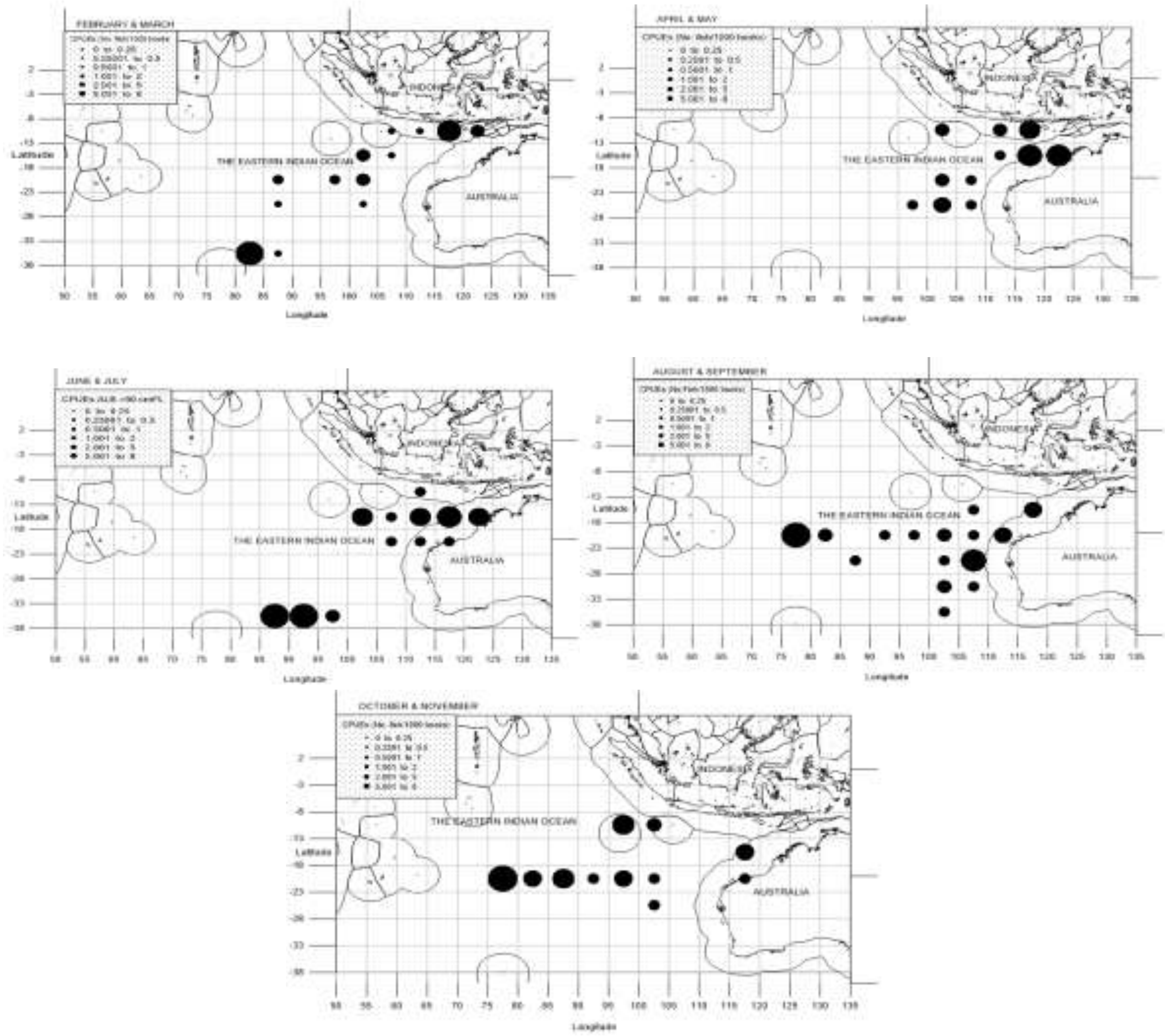


Figure 4. Bimonthly CPUE spatial distribution of ALB in Eastern Indian Ocean Based on RITF scientific observer program summarized from 2005-2013.

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 were found than other areas. The highest CPUE (> 5.001) occurred in the area between 30-35 °S and 80-95 °E, the intermediate CPUE (1-5) occurred 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 stated that ALB spread throughout the Indian Ocean was between 25 °S and 45 °S [8].

CPUE data is a main source of fish abundance information [17]. The CPUE value was caused by several factors such as fishing technology, the existence of fish stock and the experience of a fishing master. The existence of fish stock was 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 a year [18]. CPUE is also indirectly influenced by the spatial distribution of oceanographic variables i.e. sea surface temperature (SST), salinity, temperature at a depth of 100 m, chlorophyll concentration and oxygen content at a depth of 200 m [8].

2. 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 Figure 5. The highest percentage of mature ALB was found in the area between (15-35 °S and 75-90 °E) and along the south coast of (Java, Bali and Nusa Tenggara).

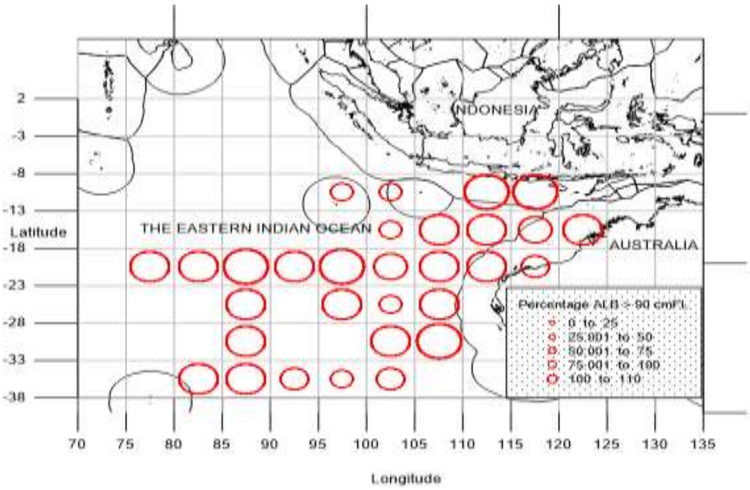
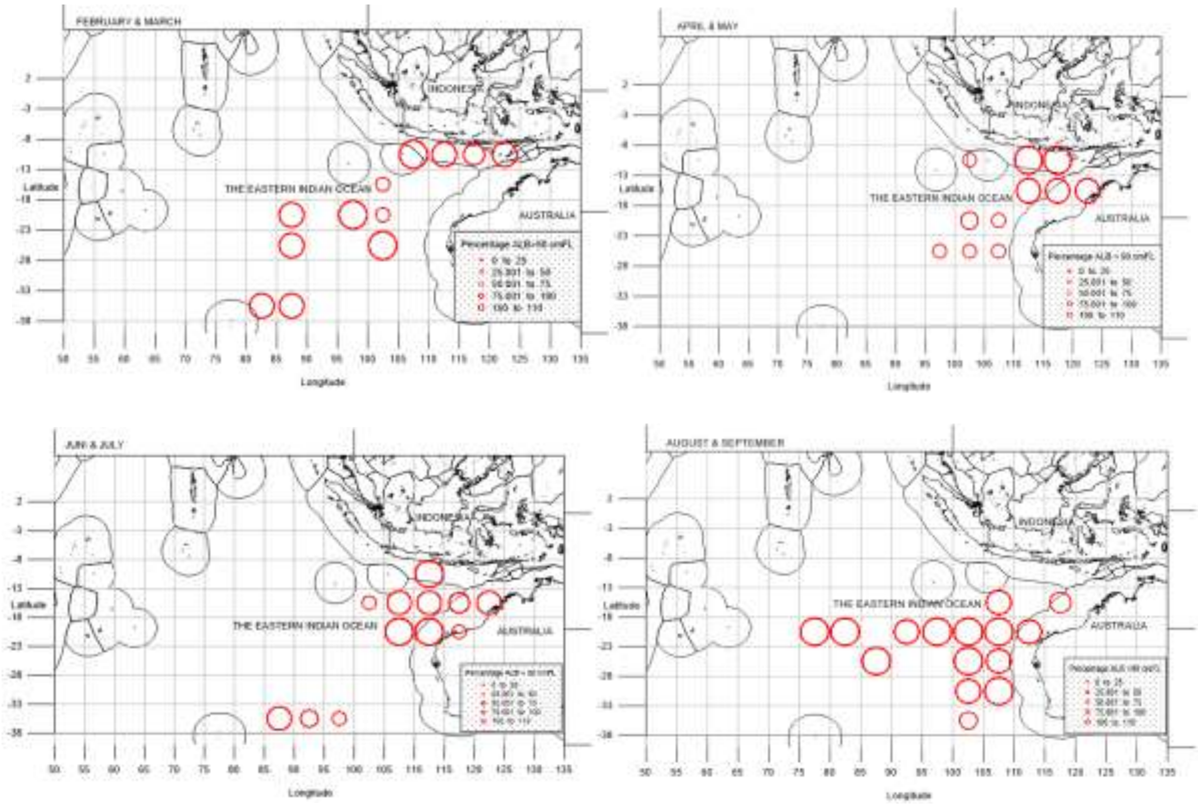


Figure 5. The percentage of mature ALB (> 90 cmFL)spatial distribution of Indonesian ALBlongline fishery, indexes in the Eastern Indian Ocean using 5° grids. The data was from RITF observer program ranged from 2005-2013.

The bimonthly mean of L50 spatial or temporal distribution (2005-2013) shows in Figure 6. 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 the western coast of Australia (20-35 °S and 80-105 °E). In April and May, the higher mature ALB index moved on and is concentrated 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 spread widely in the area between the south coast of (Java, Bali, Nusa Tenggara) and a 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 a 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).



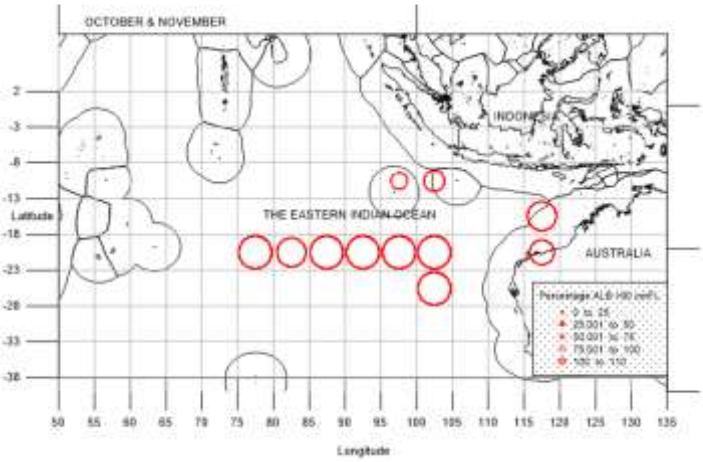


Figure 6. Bimonthly of the percentage of mature ALB index distribution based on RITF scientific observer program summarized from 2005-2013.

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 was distributed widely in Eastern Indian Ocean with the coordinate area (5-35 °S and 75-125 °E) and immature ALB was distributed in the area over 35 °S. The mature ALB (> 90 cmFL) or larger than 14 kg congregated in Central Indian Ocean (10-30 °S) and ALB smaller than 14 kg in South of 30 °S [8]. The distribution of availability and vulnerability of ALB are strongly influenced by Oceanographic condition [5]. The matures ALB (spawning and non-spawning) depend on environmental variables such as sea surface temperature (SST), a temperature at a depth of 100 m (Temp_100), a salinity at a depth of 0 m (Sal_0) and the dissolved Oxygen at 200 m depth (OXY_200). SST was significant for immature, spawning and non-spawning stage of ALB [8]. The Central Indian Ocean has an optimal environmental variable 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 gr. L-1) and OXY_200 (ranged from 5.75-5.09 mg. L-1) [8]. 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 gr. L-1).

3. The Potential Fishing Ground Area (PFGA)

PFGA is the combination of CPUE and the percentage of mature ALB in the area Figure 7. This study also explored some information 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 spatial distribution on the percentage of mature ALB (>90 cmFL) Figure 8.

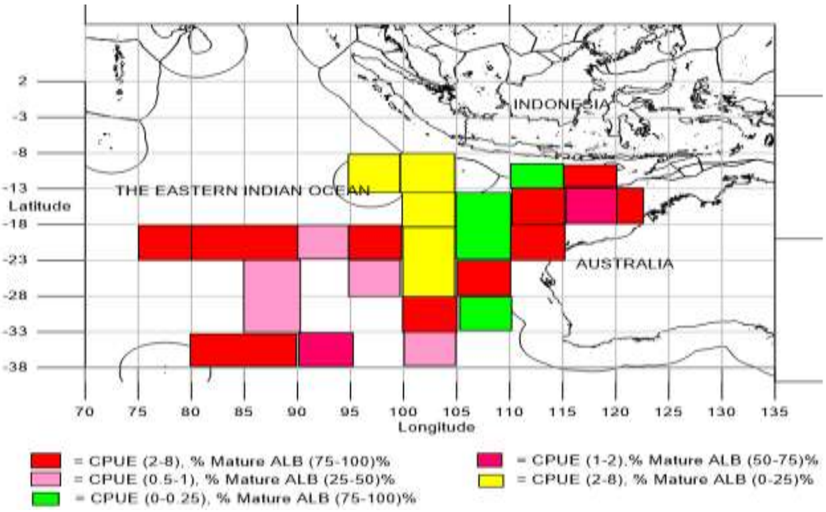


Figure 7. PFGA according to CPUE and the percentage of mature ALB (> 90 cmFL) indexes based on RITF scientific observer program data from 2005-2013

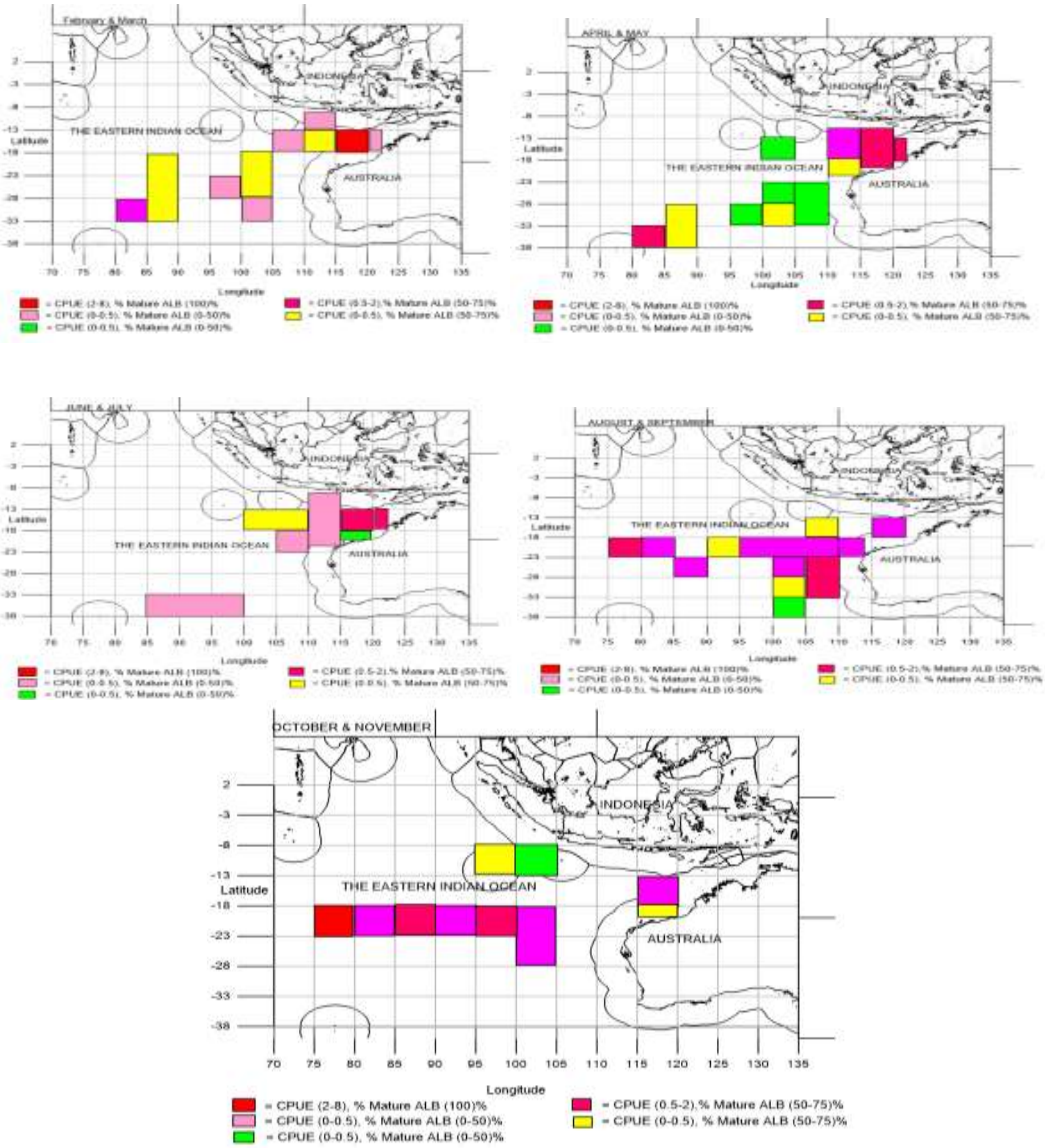


Figure 8. The temporal trend of PFGA according to CPUE distribution and the percentage of Mature ALB based on RITF scientific observer program data from 2005-2013.

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 a southern coast of (Java, Bali and Nusa Tenggara) and a northern coast of Australia. In June and July, the PFGAs were spread widely in the area between a 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 were moved to the west coast of Australia (10-35 °S and 75-120 °E). In October and November, the PFGAs have moved to the southern hemisphere and far away to mid-Indian Ocean.

In February and March, PFGAs are spread out evenly in the Eastern Indian Ocean. It’s accordance with a stable distribution of SST of Indian Ocean from west to the east Indian Ocean with the average temperature 28.26 °C Figure 9a. ALB is started to move from southern to northern hemisphere where the fishes are developing their body and gonadal.

In April and May, the PFGAs seem to move to the area between the southern coast of (Java, Bali and Nusa Tenggara) and the 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 Figure 9b.That was indicated that mature ALB would move to the Eastern Tropical Indian Ocean in the area between the southern coast of (Java, Bali and Nusa Tenggara) and the 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 the 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 and 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 was probably started in between July and September in northern hemisphere [19], [20].

In August and September, the PFGAs were 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) for spawning activity of ALB Figure 10a [8]. The spawning area of ALB in the Indian Ocean was found at the coordinate between 10-25 °S [21].

In October and November, the PFGAs have moved to the southern hemisphere and far away to mid-Indian Ocean. It's in accordance by some previous work [19], [20]. The encouragement of warm SST (29-31 °C) from northern Indian Ocean Figure 10b lead the group of spawning ALB tends to move away to the mid-Indian Ocean.

IV. CONCLUSION

Albacore (ALB) (Thunnusalalunga) is a temperate tuna species, widely distributed in temperate and tropical waters in the Indian Ocean. The distribution of ALB is based on the environmental variables. ALB tend to live in preferred water which suitable for itslifecycle.One of which is SST sea surface temperature. In February and March, the PFGA tends to spread out evenly in the Eastern Indian Ocean. In April and May, the PFGA distribution tends to move to the area between the southern coast of (Java, Bali and Nusa Tenggara) and the 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 the 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 the southern hemisphere and far away to mid-Indian Ocean.

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