OCEAN-CLIMATE INTERACTION OF EASTERN INDIAN OCEAN FOR TUNA FISHERIES & ITS SOCIO-ECONOMY IMPACTS [*)]

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[*)] Submitted to the 16th Indian Ocean Tuna Commission Conference November 2014.

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ABSTRACT

The complexity of the climate - ocean interactions in Indonesia is caused by the Indonesia's geographical position at the crossroads of the Indian and the Pacific Ocean. Periodic phenomena such as ENSO, and non- periodic such as IOD affect Indonesian Monsoon system. A large volume of water masses from the Pacific Ocean that flows into the Indian Ocean passing through the territorial sea of Indonesia (Indonesian Through- flow) helps to provide a balance to the ocean climate in Indonesia as part their migration areas. For Tuna fisheries in Indonesia, Indian Ocean plays an important role for tuna's habitat. This article describes the physical condition of the ecosystem in the East Indian Ocean based on archive data of the climate - sea survey, and also describes sustainable tuna habitat survey data based on tuna catches data. The southern part of Indian Ocean is a high primary productivity area for tuna because there is a periodic Java upwelling system occurred between June and October annually, and the eddy current system encourages nutrients and chlorophyll from the coast towards the open sea. This is an excellent tuna habitat for the sustainable production of tuna fisheries.

INTRODUCTION

Exploration to assess characteristic of the Eastern Indian Ocean has a history of its own, which has been done about 50 years ago. But the linkage with fisheries are rare as done in the Pacific Ocean and the Atlantic Ocean.

The Eastern Indian Ocean, especially in the west off Sumatra and south off Java has a quite complex sea-air interaction, that was allegedly very closely related to the sustainability of fisheries. Particularly in the south of Java, there is a "semi-pe<u>R</u>manent j<u>A</u>va coas<u>T</u>al <u>U</u>pwelling" (RATU), that goes around of July until October in every year, that causes the high productivity in its region (Pranowo, 2014). An existing of Eddies current then pulling out prymary productivity from coastal zone to the open seas where tuna habitats are there (Pranowo et al., 2005), see Figure.1.

This article describes the physical (i.e. Mixed Layer Depth) condition of the ecosystem in the East Indian Ocean based on archive data of the climate - sea survey (WOA 2009), and also describes sustainable tuna habitat survey data based on tuna catches data. Some literatures are used also for disscussion and reviews particularly for its social and ecosystem impacts.
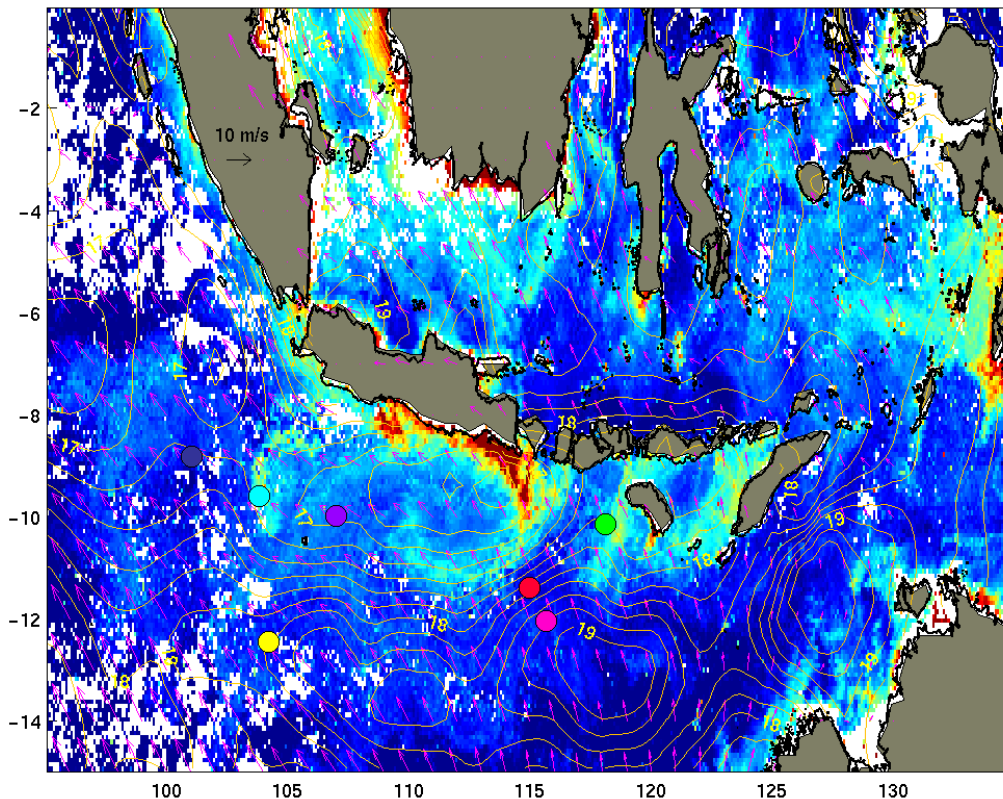
Figure 1. An Eddies currents pulling the primary productivity to the off shelf from coastal area of South Java and Lesser Sunda Islands (Pranowo et al., 2005). This picture is overlayed satellite data of the wind patern (pink arrows), sea surface height (yellow contours), and chlorophyll (shaded colors), while the collor dots represent the argo floats.

MATERIAL & METHODS

We used three types of data. We used *Mixed Layer Depth* (MLD) data (ΔT=0.5°C) and temperature data derived from WOA 2009 (Monterey & Levitus, 1997; Locarnini et al., 2010) to describe normal conditions of the physical characteristic. For fisheries dataset we used the Tuna dataset collection which is provided by the Research Institute for Tuna Fisheries (LPPT) Agency for Marine and Fisheries Research and Development Repulic of Indonesia. An ocean current prediction dataset from HYCOM data archieve

(Cummings & Smedstad, 2013) is also used to preliminary investigate the tuna catchment area and its relation to eddy current.

RESULTS AND DISCUSSION

Relationship between Mixed Layer Depth and Tuna Catch

We tested the relationship between MLD and Tuna catches and between temperature and Tuna catches. The results can be seen in Figure 2 and Figure 3. Using a Pearson test, MLD and Tuna catch has a positive relationship. The Pearson correlation coefficient is +0.891. This shows that the depth of the MLD and the catch of tuna has a strong positive linear correlation. This shows that the deeper the MLD, the more the tuna catch, particularly for big eye tuna. For transition season 1, it has the highest temperature at about 28.47 °C but produces the lowest catch at about 12,973 fish. This is presumably due to the dissolved oxygen content in Transition Season 1 in the distribution of tuna has a sufficiently low value, thus resulting in reduced number Tuna.
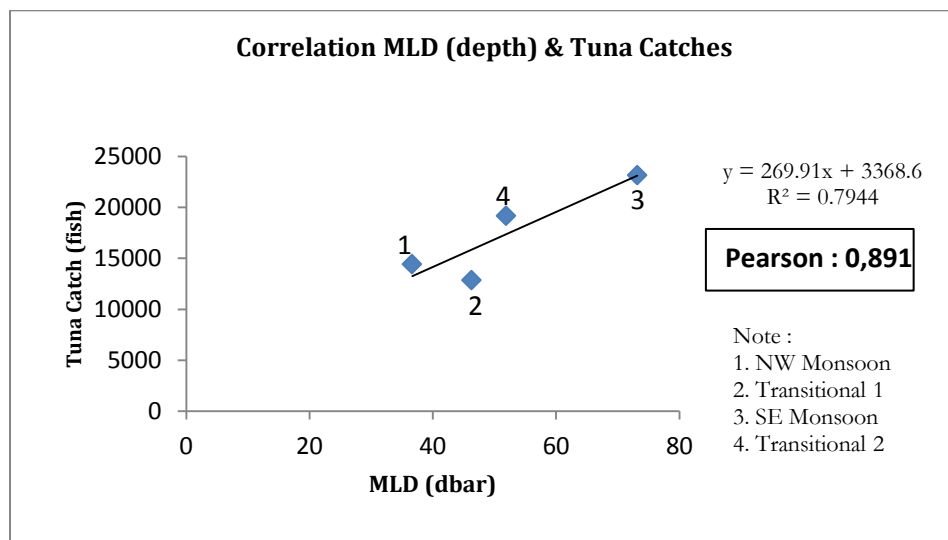
Correlation MLD (depth) & Tuna Catches

$y = 269.91x + 3368.6$
$R^2 = 0.7944$

Pearson : 0,891

Note :
1. NW Monsoon
2. Transitional 1
3. SE Monsoon
4. Transitional 2

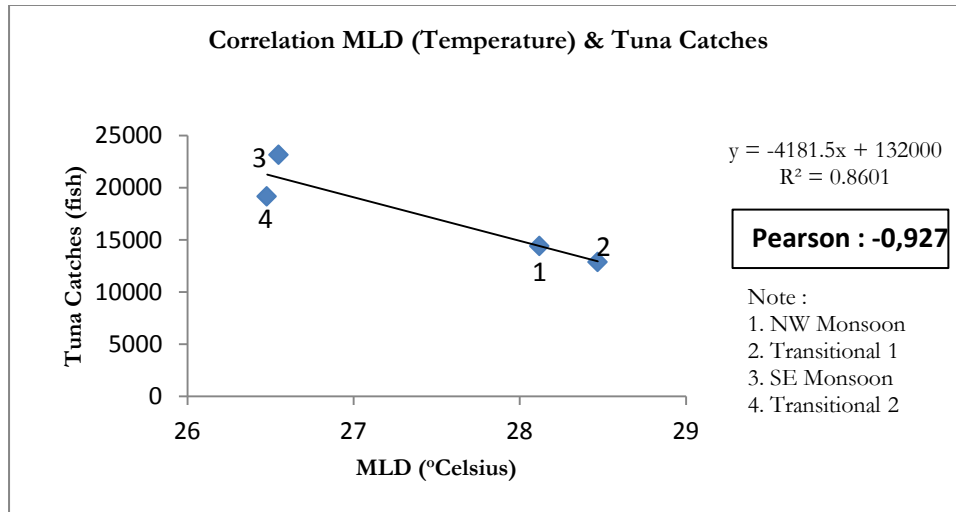**Figure 2.** Corellation between Mixed Layer Depth [dbar] and Tuna Catchment [fish unit].

Figure 3. Corellation between Mixed Layer Depth [°C] and Tuna Catchment [fish unit].

For each season, we overlaid the MLD with tuna catch distribution. Cath distribution data gathered from observer data from LLPT. Red line denoted the Regional Fisheries Management (RFM) boundary. Java sea belongs to the RFM 573. In Northwest season, the tuna catch distribution is mostly at the MLD of 40 dbar or 40.79 meter with an average temperature around 29 $^{\circ}$C (see Figure 4 and Figure 5). The map shows that there are more tuna catch is outside the RFM or open ocean. On the transision season, tuna are distributed at the MLD of 50-60 dbar or 51-61 meters with average temperatures ranging from 28.5 – 29 $^{\circ}$C (see Figure 4 and Figure 5).
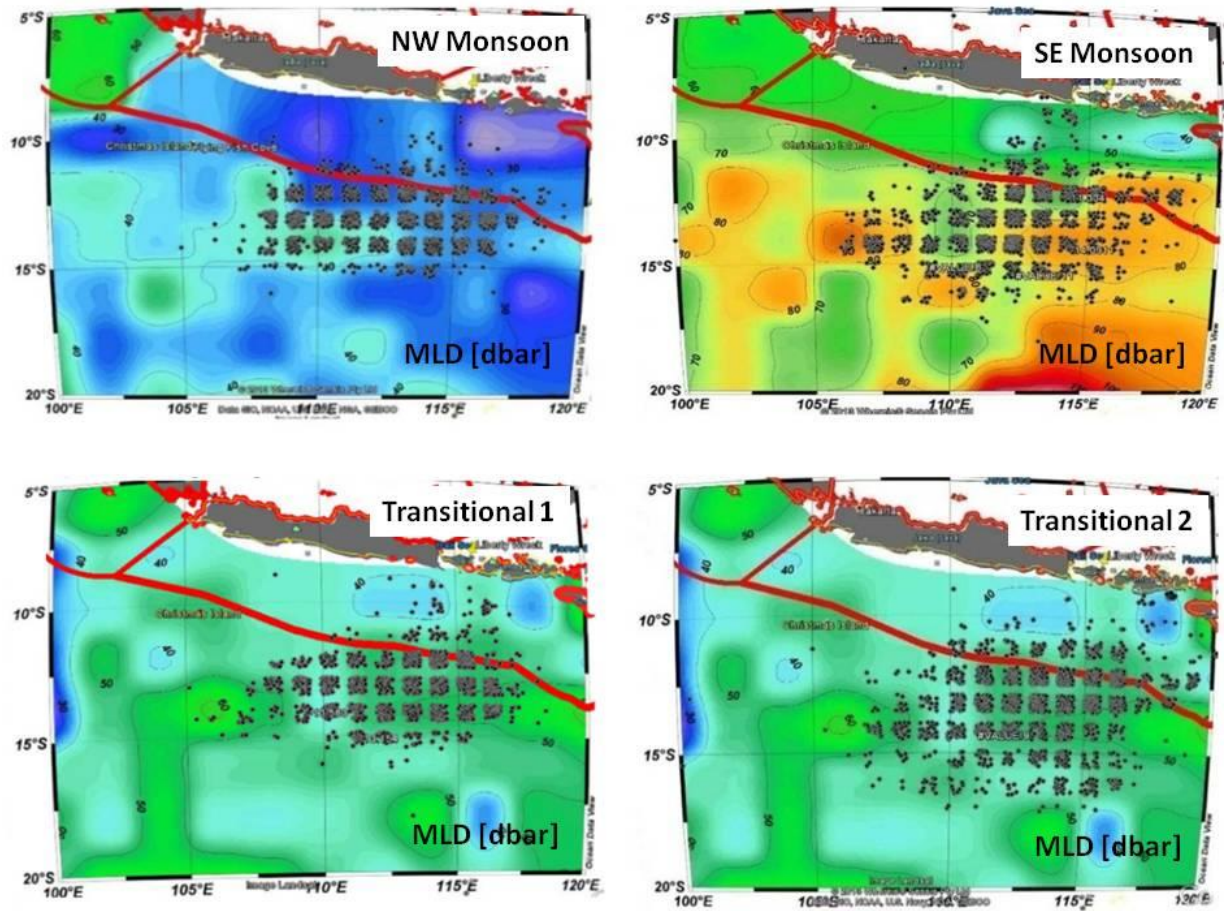
Figure 4. A seasonally climatological Mixed Layer Depth [dbar] (shows in shaded colors) in South Java of the Eastern Indian Ocean overlayed with Tuna vessels distributions. Red lines is An Indonesia Fisheries Management Area's boundaries.

Figure 5. A seasonally climatological of Mixed Layer Depth [°C] (shows in shaded colors) in South Java of the Eastern Indian Ocean overlayed with Tuna vessels distributions. Red lines is An Indonesia Fisheries Management Area's boundaries.
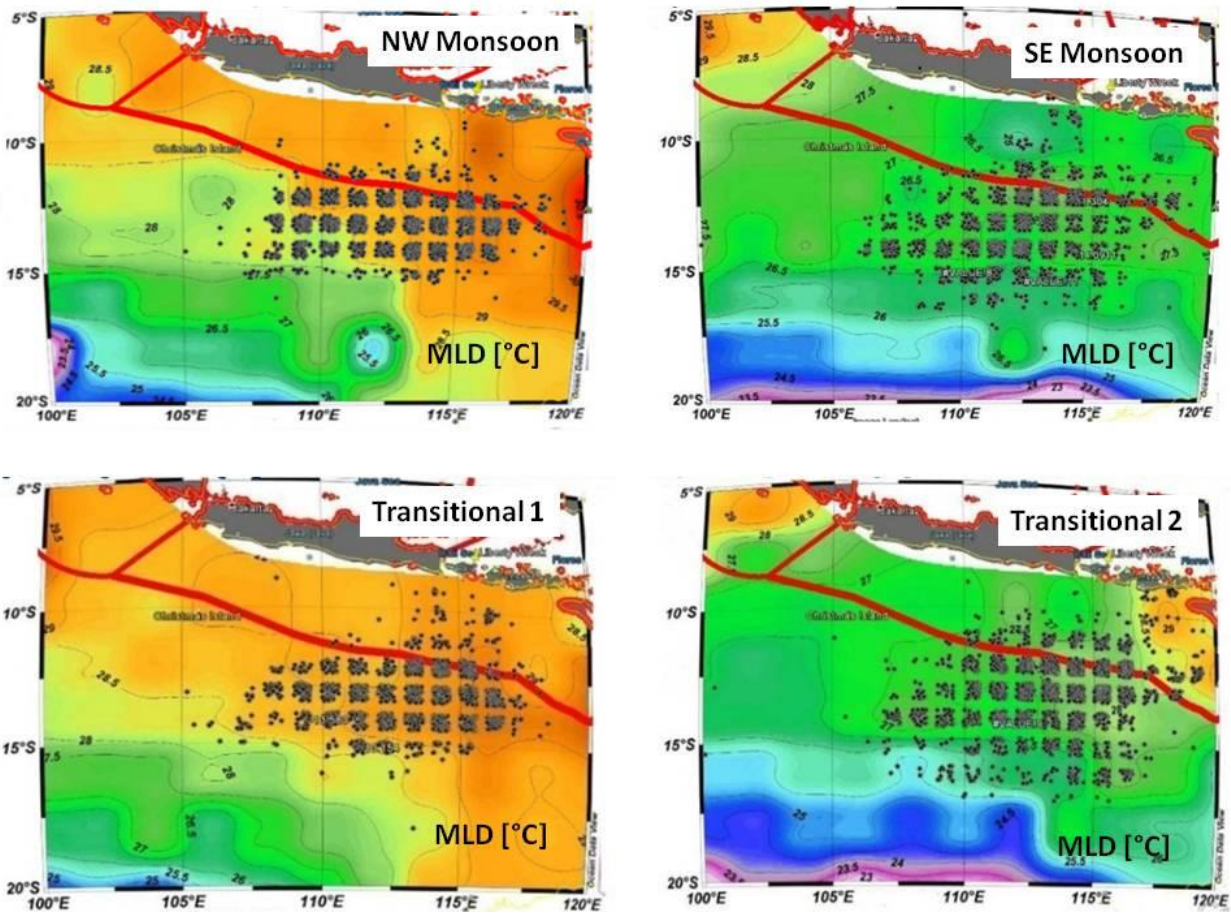
On Southeast season, Tuna are found more at the MLD of 70-90 dbar or 71,39 – 91,79 meters. In this season, the catch distribution is larger than those of the two previos seasons. This shows that the deeper the MLD, the larger the catch distribution. In addition, the temperature range in this season is relatively cooler at about 26.5 – 27 ^{o}C (see Figure 4 and Figure 5). This low MLD temperature could be due to upwelling, the cold layer from carried to the MLD layer. This upwelling is also accompanied by nutrient

flow to the MLD layer.This makes the MLD layer becomes more fertile. This explains the high tuna catch distribution at MLD layer at east season than any other seasons.

At transition season 2, tuna is found more distributed at MLD of 50 – 60 dbar or 51 - 61 meters having temperatures ranging from 26 to 27 ^{o}C (see Figure 4 and Figure 5). The MLD depth of this season is shorter than the east season. This is in accordance with smaller tuna catch distribution.

There are even more interesting phenomenon about the relationship between the physical aspects of the South of Java Sea as part of Eastern Indian Ocean, that based on tuna vessels coordinates tuna during February - July 2013, generally shows the operation area of tuna catchment are fitted to eddies current location which is also in accordance with MLD area, see Figure 6 and Figure 7.
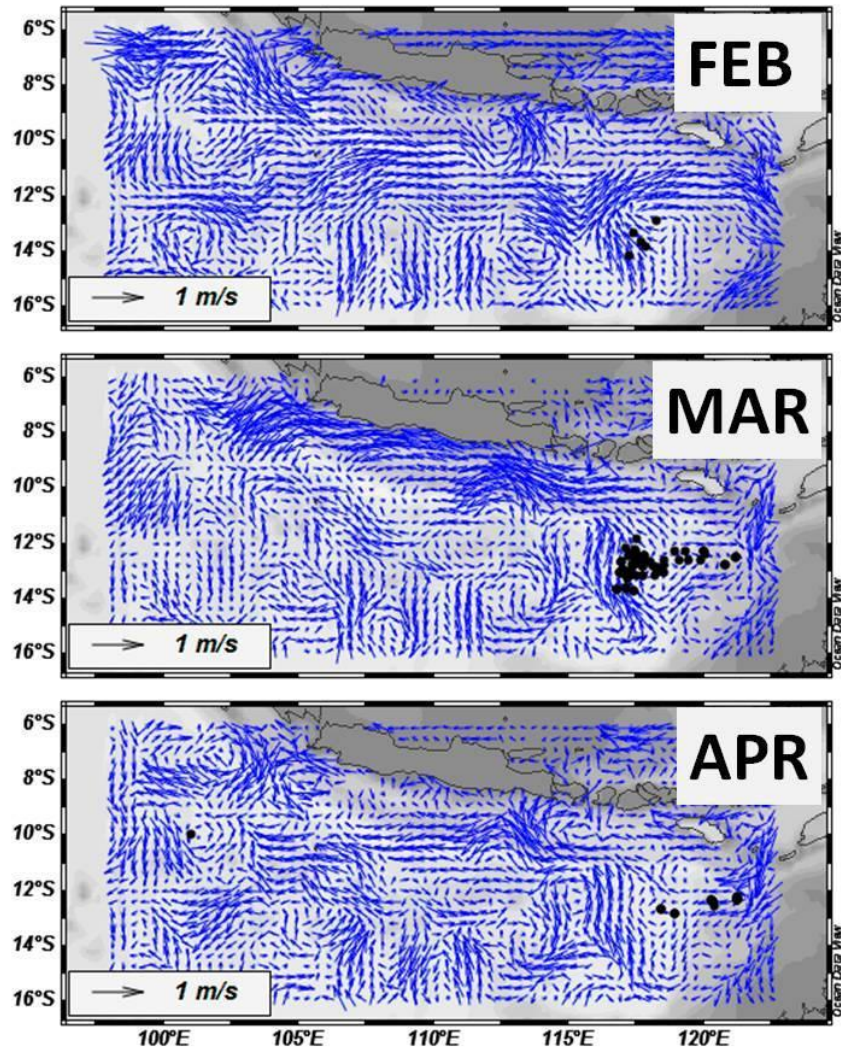
Figure 6. Tuna vessels (black dots) are mostly fishing in the eddies curents zone, during Februari – April 2013. Coordinate tuna vessels collected by LPPT, while ocean current is derived from HYCOM archieve dataset.
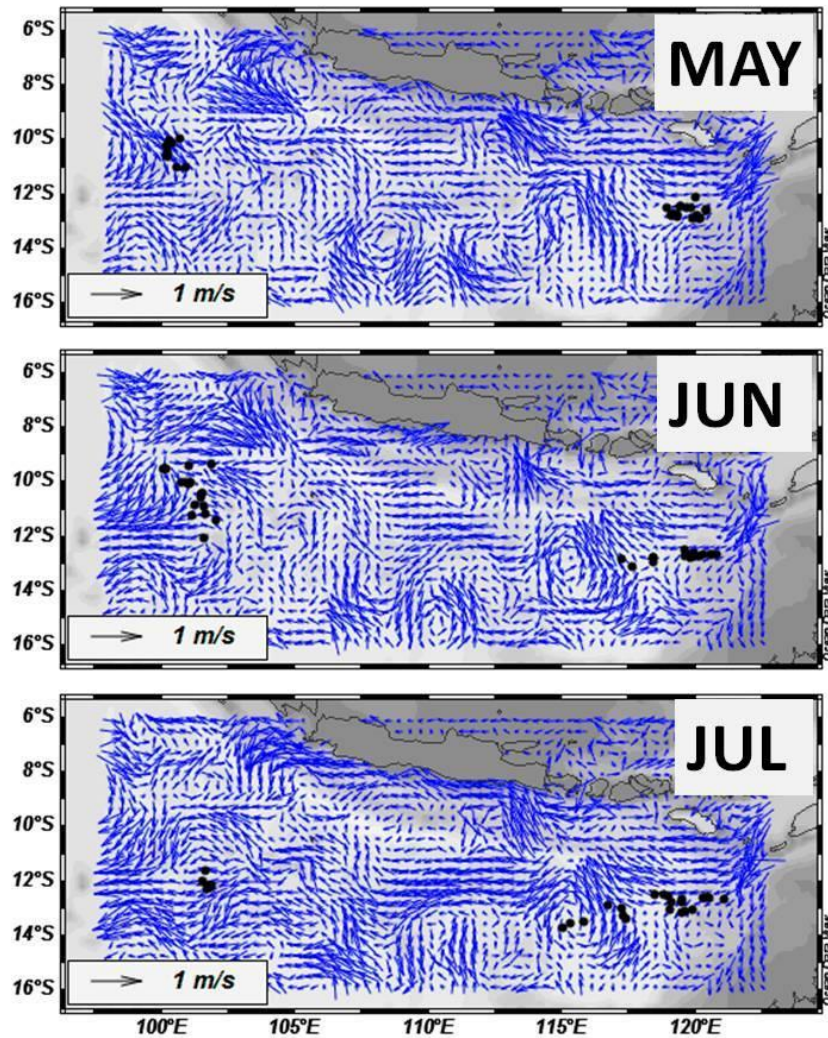
Figure 7. Tuna vessels (black dots) are mostly fishing in the eddies curents zone, during May – July 2013. Coordinate tuna vessels collected by LPPT, while ocean current is derived from HYCOM archieve dataset.

Upwelling Variations for Sustainable Fisheries

Sumatra-Java-Timor upwelling area, as the target location of the near future of Eastern Indian Ocean Upwelling Research Initiative (EIOURI) project (2015-2019/2020), has a strong relation to the Fisheries management Areas (FMA) 572 (Indian Ocean – west

Sumatera) and 573 (South of Java – East Nusa Tenggara), are two fisheries management area among eleven FMAs that located within the Indian Ocean Tuna Commission (IOTC) area of competence (Satria *et al.*, 2011). See Figure 8**.** Long line contribute a bigger proportion (44 %) of tuna catch compare to other gears and the number of active long liners registered and operated on the two FMAs is grown up from 1118 vessels in 2011 become 1227 vessels in 2013 (Satria *et al.*, 2011; Satria *et al.*, 2013).
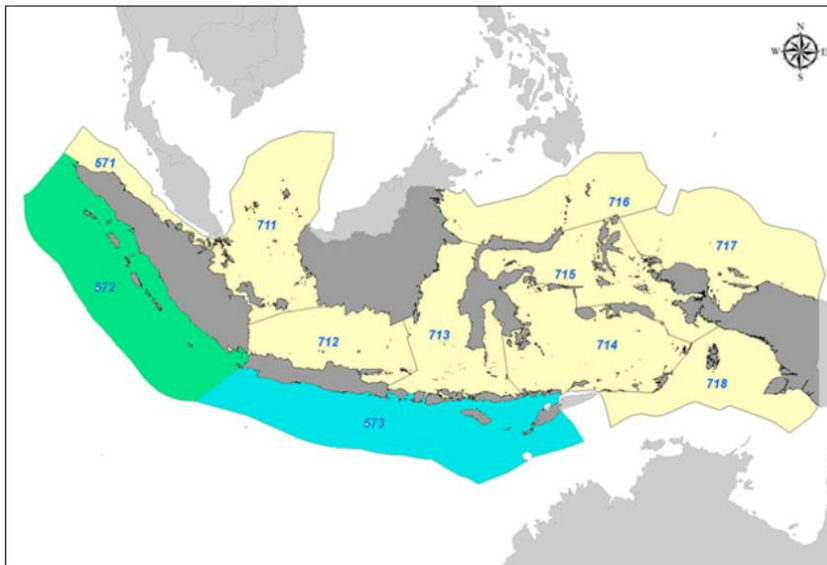

Figure 8. Fisheries Management Area (PERMEN KP. 01/2009). Eastern Indian Ocean is consisting the West of Sumatera (FMA-572), and South of Java – East Nusa Tenggara (FMA-573).

The Indonesian statistic catch of four main tuna species in 2009 is estimated 101,292 ton, and 2012 is estimated 168,626 ton; while the total catch for all species by all gears type tend to increase to just above 600,000 mt in 2010 and 398,540 ton in 2012 (Satria *et al.*, 2011; Satria *et al.*, 2013). The understanding of the climate variability and its relation with biogeochemistry dynamic will be an important basis to enhance the

regulation and policy for the fisheries management to minimazing an ilegal, unreported, and unregulated fishing. Furthermore, It will be minimizing the mean error catchment data linkage with the vessel monitoring system due to improve the fish stock assessment database.
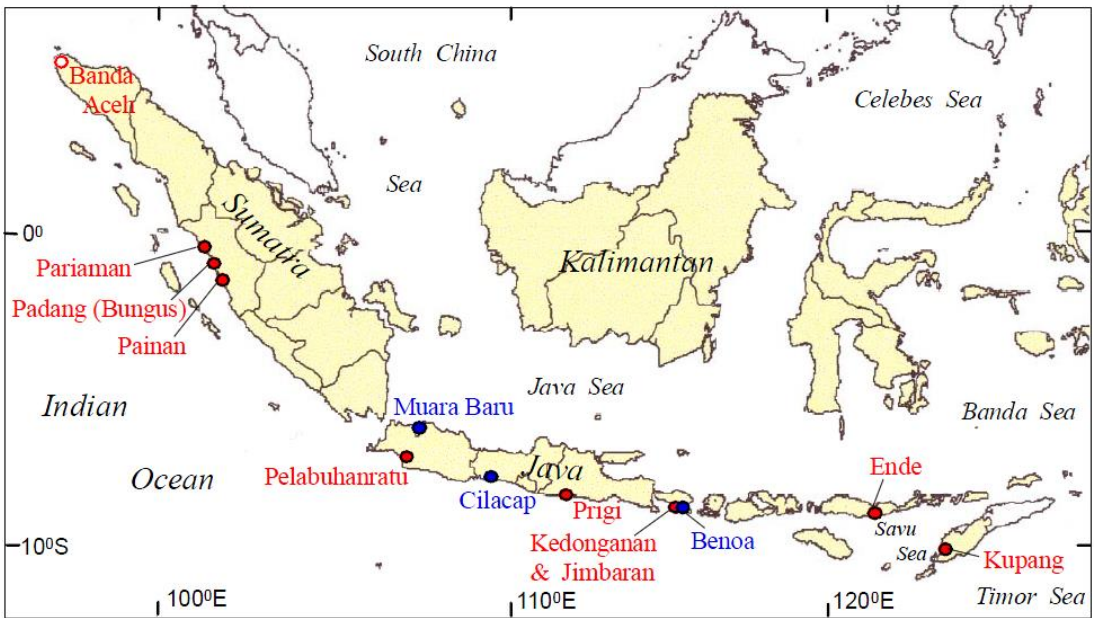

Figure 9. Primary fishing port/landing sites the industrial as blue dots; and artisanal as red dots (Proctor *et al.*, 2003).

There are 3 primary fishing ports/landing sites of Indian Ocean tuna for industrial (i.e. Nizam Zachman Fishing Port at Muara Baru, Jakarta; Cilacap Fishing Port, Central Java; and Benoa Fishing Port, Bali), which are impacted by the ocean-atmosfer interaction. Merely also at least 9 artisanals (i.e. Pariaman, Bungus, Painan at West Coast of Sumatra; Pelabuhanratu & Prigi at South Coast of Java; Kedonganan & Jimbaran in Bali; Ende in Flores; and Kupang in Timor), as the potential growth area of generating small scale fishery, could be affected by intra-seasonal and inter-annual

variability of Indian Ocean, see Figure 9. In facts, July and October the fishing location at off of Cilacap Artisanal Fishing Port, gillnet base on the onboard observation, during 2008-2010 shows closely to coastal compare to April, see Figure 10 (Widodo et al., 2011). According to the upwelling index, July is the upwelling peak, and October is the fish landed peak in Cilacap (Kuswardani, 2013), see Figure 11.
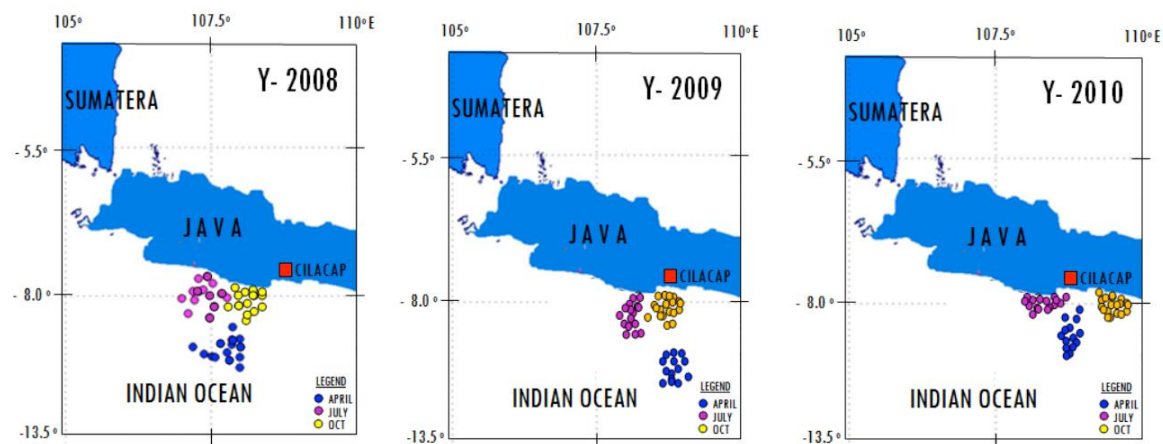

Figure 10. The fishing location at off of Cilacap Artisanal Fishing Port, gillnet base on the onboard observation on the April, July and October 2008, 2009 and 2010 (Widodo et al., 2011).

Figure 13 shows that South of Java, Indonesia and off northwest Australia is a spawning area and a nursery ground of the Southern Bluefin Tuna (SBT), which have two spawning peaks, i.e. during October-November and January-February (Tsuji, 1998). According Tsuji (1998), juveniles migrate seasonally southwards along the west coast of Australia and stay in the coastal waters southwest, south, and southeast of Australia; and also in the central part of Indian Ocean. Furthermore Tsuji (1998) said that, as the fish grow, they extend their distribution to cover the circumpolar area throughout the Indian, Pacific and Atlantic Oceans. The spawning ground of Southern Bluefin Tuna is

considered to be in a very limited area between Australia and Indonesia (Shinguu, 1981; Nishikawa *et al.*, 1985; Matsuura et al., 1997). It is very important to understand the variability of the resource in order to manage it better (Matsuura, et al., 1997).

Polacheck (2006), in his article, assume that is not only environmental factors influence tuna catch. Any fishing activity will potentially have ecosystem effects. By harvesting fish, humans assume the functional role of a top predator in the system. The magnitude of the ecosystem effects will depend both on the functional role of the fish being harvested and the magnitude of the removals from the system. Polacheck (2006) is also emphasized, in the case of tuna fisheries and pelagic ecosystems, there is a lack of data and understanding of the effects on the functioning of the ecosystem as the result of changed abundances in the tuna component. However, the magnitude of the removals can provide some indications of when any potential effects, if they occurred, would most likely have manifested themselves. The major significant impacts of tuna catches to ecosystem function would have been expected to have begun in the mid 1980s. The increasing of the total catch from tuna fisheries, in the Indian Ocean, will be high linearly followed by decreasing the catchrate, see Figure 12. Current total removals for the Indian Ocean are estimated more than 600,000 mt (Polacheck, 2006; Satria, *et al.*, 2013). A kind of research extension to enhance analysis on the Indian Ocean carrying capacity including its fisheries stock assessment is proposed for further development on cachment quota regulation (OPRT, 2008).
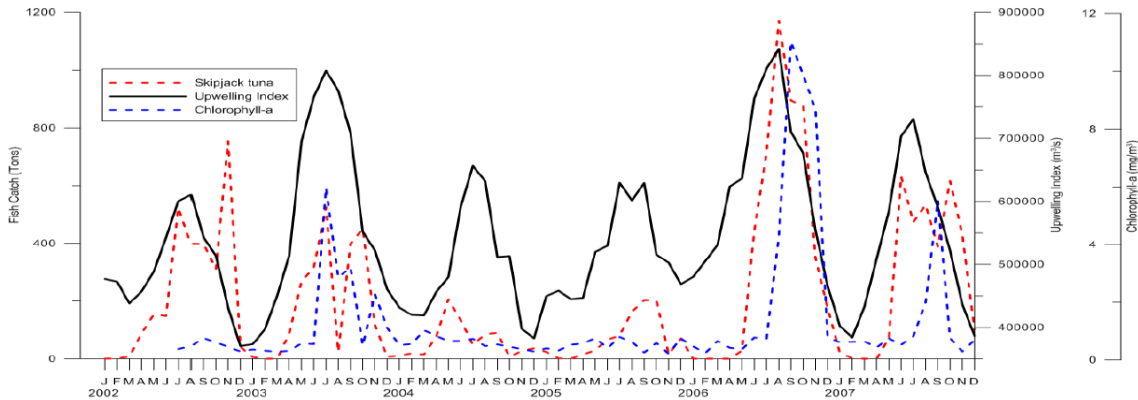
Figure 11. Relationship among tuna catch, chlorophyll-a, & upwelling index in Cilacap Fishing Port, Central Java (Kuswardani, 2013).
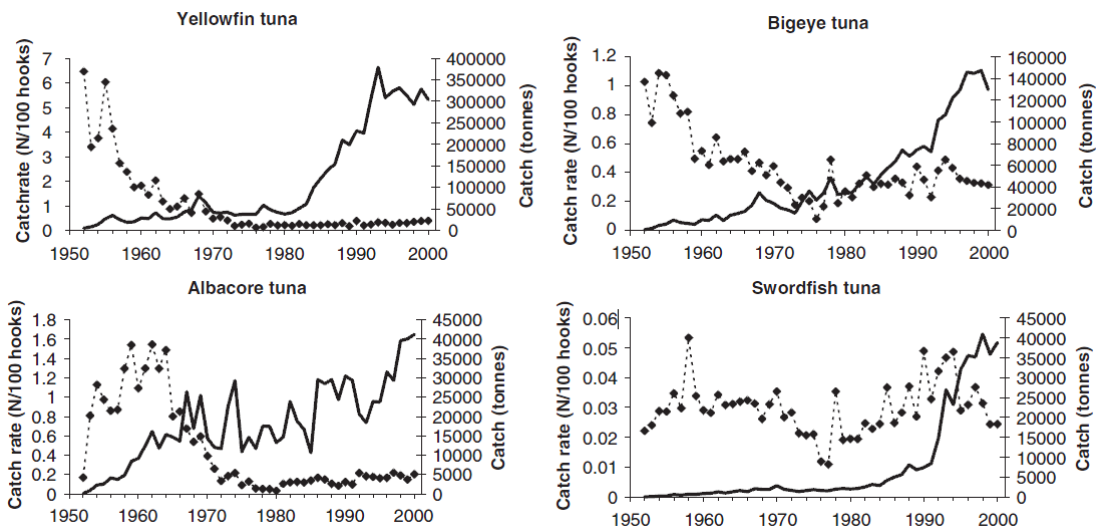

Figure 12. Comparison of the annual nominal catch rates by Japanese longliners (dotted line) and estimates of total catch from all fisheries (solid line) for tuna (Yellowfin, Bigeye, Albacore, Swordfish) caught by longliners in the Indian Ocean (Polacheck, 2006).
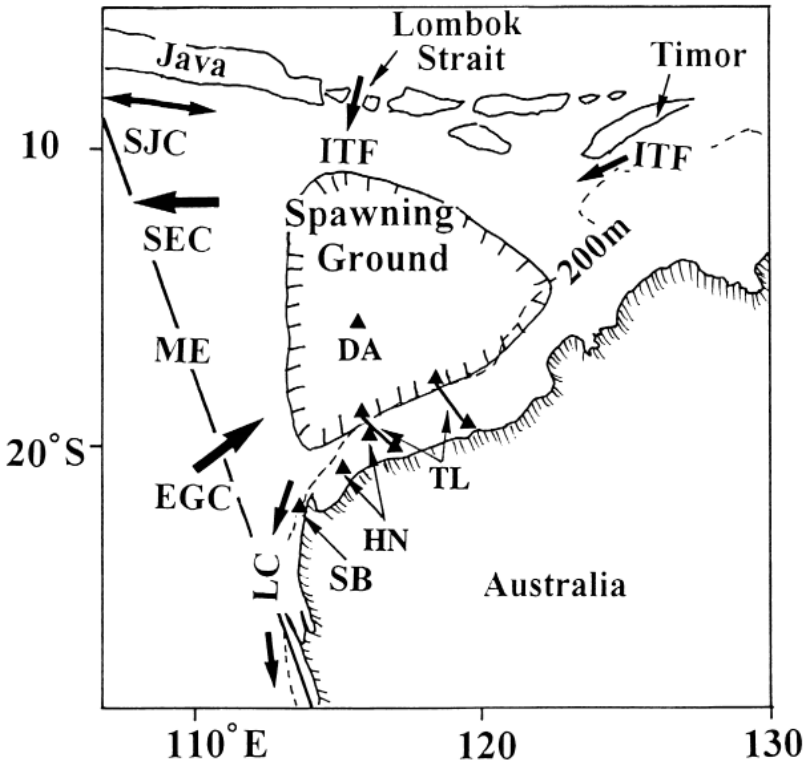
Figure 13. A location of the Southern Bluefin Tuna (SBT) spawning ground southern of Java-Nusa Tenggara (Matsuura et al., 1997). Thick arrows indicate major surface currents. Solid triangles and lines indicate positions of observations of past research. ITF (Indonesia Through-Flow), SJC (South Java Current), SEC (South Equatorial Current), EGC (Eastern Gyral Current), SB (Mooring), LE (Leeuwin Current), HN (Current Meter), DA (Surface Drifter), TL (CTD & Water Quality), ME (XBT).

Physical-Biogeochemistry Dynamics and The Development on Marine Protected Management

In order to complimentary to the Fisheries Management Area, Government of Indonesia publish the Indonesia Marine Ecoregion Map which purpose to be a reference in the development of the plan for management of marine protected area. The marine ecoregion map is mainly generated by the geographical condition, seawater properties characteristic, and the biodiversity/ ecosystems (Rosalina et al., 2013).

We have an experiences that the data and information, which is resulted from the Indonesia-China research project on "Monsoon Onset Monitoring and Its Social and Ecosystem Impacts" (MOMSEI) during 2011-2012 Indian Ocean West Sumatra cruises, used as one of the reference for the development of Indonesia Marine Ecoregion Map to support the national action plan for climate change adaptation (Pranowo et al., 2013).

Figure 14. Indonesia Marine Ecoregion map (Rosalina *et al.*, 2013). The target location for EIOURI study is laying in the Indian Ocean West Sumatra (EL-1), Indian Ocean South Java (EL-2), and Indian Ocean South Bali - Nusa Tenggara- Savu & Timor Sea (EL-9).

Ecoregion map can also serve as a reference point for the control and management plan for environment, see Figure 14. The South Java sea is a nursery ground for sothern bluefin tuna. However, the tuna migrates to Tasmania and Australia when they reach adulthood. Hence, its management lies both in Indonesia and Tasmania seas. One possible multinational management for the southern bluefin tuna is agreement

among these three countries to manage the fishery from the nursery until their adulthood. This can be done by benefit transfer from the country that harveste the tuna to the country that keeps the nursing ground healthy.

Sumatra-Java-Timor high biodiversity influenced by a regional physical-biogeochemistry dynamics will be important to enhance the second level of the Marine Ecoregion Map. In the near future second level of the map, the marine characteristic aspects will help to define delineation of the sub marine ecoregion of the mostly of the Eastern Indian Ocean West Sumatra (EL-1), South Java (EL-2), and South Bali-Nusatenggara-Savu sea-Timor Sea (EL-9).

CONCLUSION & RECOMMENDATION

The Mixed Layer Depth (MLD) and the catch of tuna has a strong positive linear correlation. High tuna catch distribution at MLD layer is happening during Southeast Season than any other seasons.

In Northwest season, the tuna catch distribution is mostly at the MLD of 40 dbar or 40.79 meter with an average temperature around 29 ^{o}C. On the transision season, tuna are distributed at the MLD of 50-60 dbar or 51-61 meters with average temperatures ranging from 28.5 – 29 ^{o}C. On Southeast season, Tuna are found more at the MLD of 70-90 dbar or 71,39 – 91,79 meters. In this season, the catch distribution is larger than those of the two previos seasons.

The southern part of Indian Ocean is a high primary productivity area for tuna because there is a periodic Java upwelling system occurred between June and October annually,

and the eddy current system encourages nutrients and chlorophyll from the coast towards the open sea. This is an excellent tuna habitat for the sustainable production of tuna fisheries.

ACKNOWLEDGMENT

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