# Ocean-Climate Interaction of South Eastern Indian Oceanfor Tuna Fisheries & Its Socio-Economy Impacts

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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. A periodic ENSO and non-periodic IOD affects 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 South Eastern Indian Ocean based on archive data of the climate - sea survey, and also describes sustainable tuna habitat based on tuna catches surveys 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 ocean dynamics for the sustainable tuna fisheries.*

**Keywords:** Ocean-climateinteraction, South Eastern Indian Ocean, tuna fisheries, socio-economic.

## 1. 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 It linkages 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-airinteraction, which was allegedly very closely related to the sustainability of fisheries. Particularly in the south of Java, there is a "semi-peRmanentjAvacoasTal Upwelling" (RATU), that goes around of July until October in every year, that causes the high productivity in its region [1]. An existing of Eddies current is then pulling out primary productivity from coastal zone to the open seas, where tuna habitats exist there [2], [3].

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 discussion and reviews particularly for its social and ecosystem impacts.

## 2. Methodology

We used three types of data. We used Mixed Layer Depth (MLD) data ($\Delta T=0.5$°C) and temperature data derived from WOA 2009 [4], [5] 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 Republic of Indonesia. An ocean current prediction dataset from HYCOM data archieve [6] is also used to investigate the tuna catchment area and its relation to eddy current.

## 3. Results and Discussion

### 3.1 Relation 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 1 and Figure 2. Using a Pearson test, MLD and Tuna catch has a high positive relationship (corr. +0.891). This shows that the depth of the MLD and the catch of tuna have a strong positive linear correlation. This shows that the deeper the MLD, the more the tuna catch, particularly for big eye tuna. For TransitionalSeason 1 (March-May), it has the highest temperature at about 28.47°C but produces the lowest catch of 12,973 fishes. This is presumably due to the dissolved oxygen content in Transitional Season 1 in the distribution of tuna has a sufficiently low value, thus resulting in reduced number Tuna.
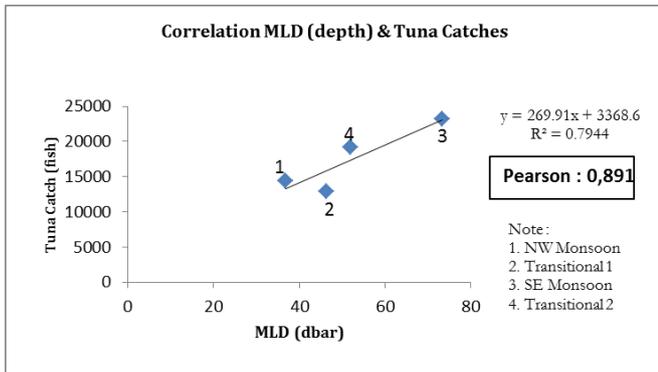
**Figure 1:** Corellation between Mixed Layer Depth [dbar] and Tuna Catchment [fish unit]
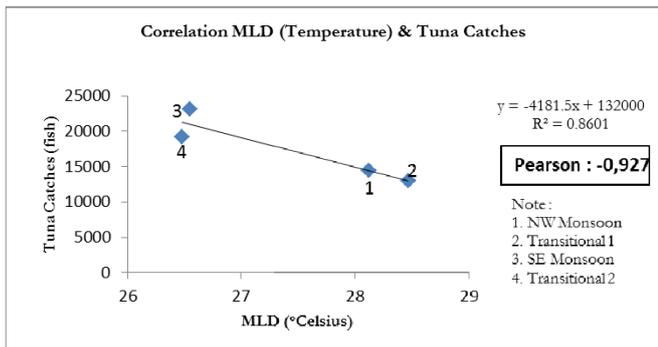


**Figure 2:** Corellation between Mixed Layer Depth [°C] and Tuna Catchment [fish unit]

For each season, we overlaid the MLD with tuna catch distribution. Catch distribution data is gathered bytuna observer of LPPT. Red line denoted the regional Fisheries Management Area (FMA) boundary. South Java Seain the South Eastern Indian Ocean belongs to the FMA 573.During North WestSeason (December-February), the tuna catch distribution is mostly at the MLD of 40 dbar or 40.79 meter with an average temperature around 29°C (see Figure 3 and Figure 4). The map shows that there are more tuna catch is outside the RFM (open seas). During the Transitional Season, tuna are distributed at the MLD of 50-60 dbar or 51-61 meters with average temperatures ranging from 28.5 – 29°C (see Figure 3 and Figure 4).

During South East Season (June-August), tuna are found more in 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 previous 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°C (see Figure 3 and Figure 4). This low MLD temperature could be due to upwelling, the cold seawaterfrom deep carried to shallowerlayer. This upwelling is also accompanied by nutrient flow to the MLD layer. This makes the MLD layer becomes more high productivity. This explains why the high tuna catch distribution at MLD layer is happened duringSouth East Season than any other seasons.

DuringTransitional Season 2 (September-November), tuna is found more distributed at MLD of 50 – 60 dbar (~51 - 61 m), having temperatures ranging from 26 to 27°C (see Figure 3 and Figure 4). The MLD of this season is shallower than during South East Season. This is in accordance with smaller tuna catch distribution.

There are even more interesting evidence 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) 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 5.

### 3.2 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 (2016-2019/2020), 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 [7]. 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 [7], [8].But this article is now only further discuss about 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 [7], [8]. 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 minimizing 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.

There are 3 primary fishing ports/landing sites of South East 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-atmosphere interaction. Merely also at least 6artisanals (i.e. 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 South East Indian Ocean. In facts, July and October the fishing location are distributedat off of Cilacap Artisanal Fishing Port.The gillnet base isobserved during 2008-2010,its peak of production shows closely compared to April [9]. According to the upwelling index, July is the upwelling peak, and its follows by the peak of fish landed, in Cilacap,in October [10].

South Java Sea of Indonesian territory (FMA 573) which connected to South East Indian Ocean is a spawning area and a nursery ground of the Southern Bluefin Tuna (SBT).They have two spawning peaks, i.e. during October-November and January-February [11].According [11], juveniles migrate

seasonally southwards along the west coast of Australia and stay in the coastal waters of the South West, South, and South East of Australia; and also in the central part of Indian Ocean. Furthermore [11] said that, as the fish grow area, 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[12], [13], [14]. Those are very important knowledge to understand the sea and fisheries resource variability in order to better sustainabilityincluding its management [14].
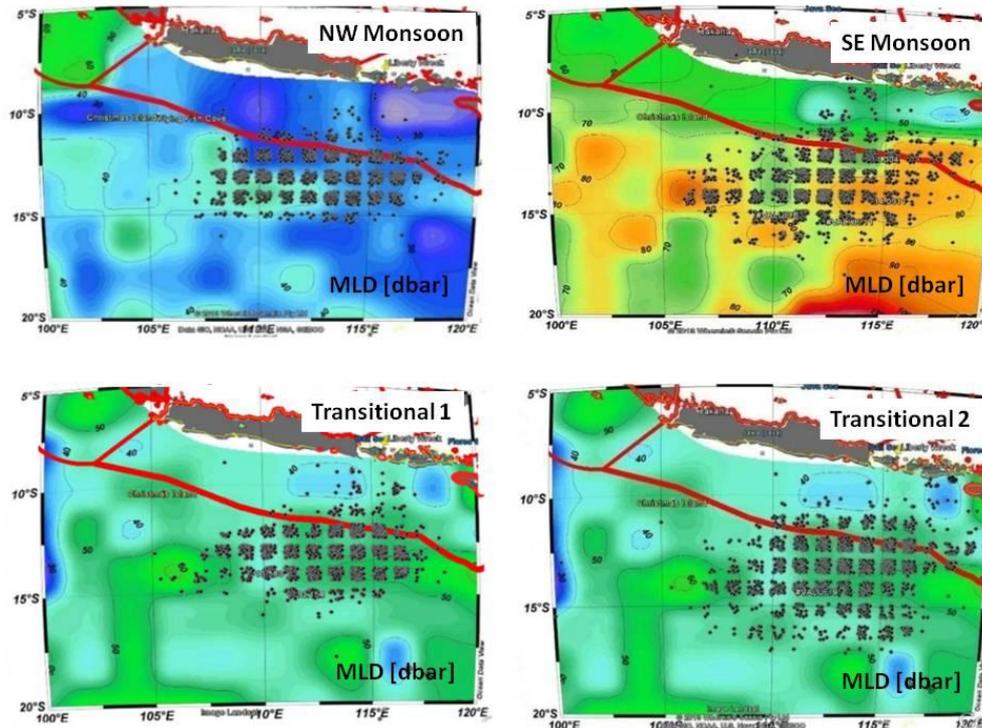


**Figure 3:** A seasonally climatological Mixed Layer Depth [dbar] (shows in shaded colors) in South Java of the Eastern Indian Ocean overlayed with Tuna vessels distributions. Red lines is An Indonesia Fisheries Management Area's boundaries (FMA-573)
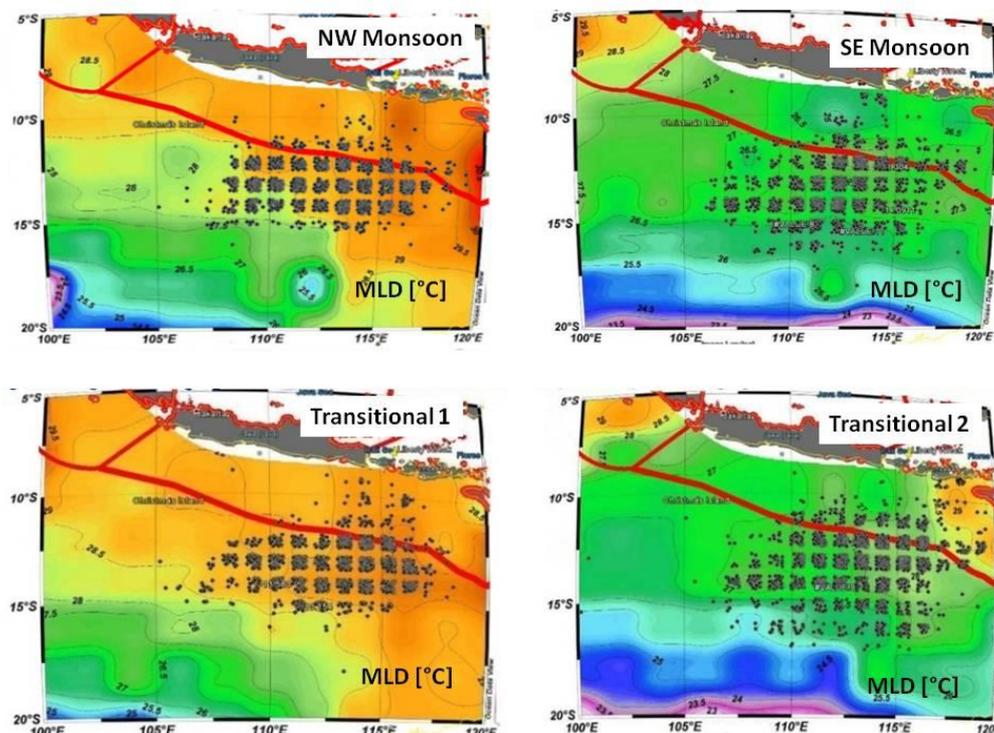


**Figure 4:** A seasonally climatological of Mixed Layer Depth [°C] (shows in shaded colors) in South Java of the Eastern Indian Ocean overlayed with Tuna vessels distributions. Red lines is An Indonesia Fisheries Management Area's boundaries (FMA-573)
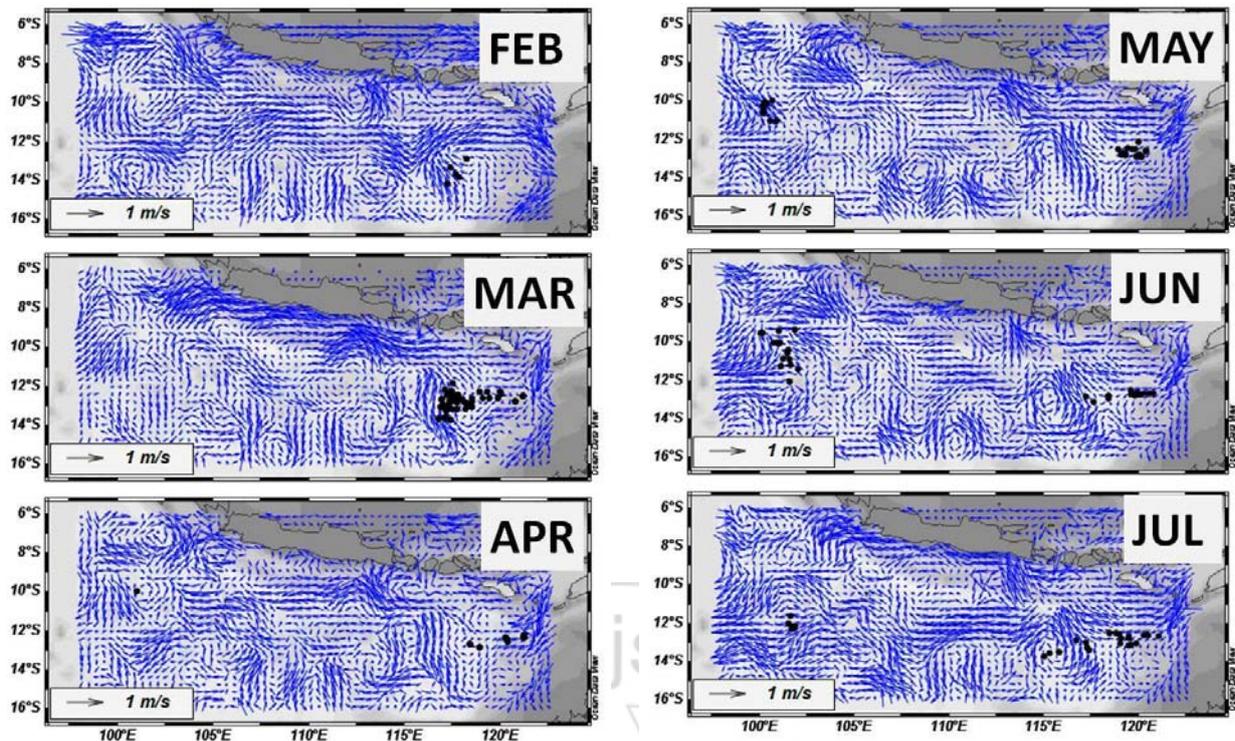
**Figure 5:** Tuna vessels (black dots) are mostly fishing in the eddies curents zone, during February – July 2013. Coordinate tuna vessels collected by LPPT, while ocean current is derived from HYCOM archieve dataset

[15] in his article, assume that is not only environmental factors influencing tuna catch season. 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 be depending both on the functional role of the fish being harvested and the magnitude of the removals from the system. [15] 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 a high linearly followed by decreasing the catch rate.Current total removals for the Indian Ocean are estimated more than 600,000 mt[15], [8]. 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 catchment quota regulation [16].

### 3.3 Physical-Biogeochemistry Dynamics and The Development on Marine Protected Management

In order to complimentary to the Fisheries Management Area (RMA), Government of Indonesia published the Indonesia Marine Ecoregion (Ekoregion Laut or EL, in Bahasa) Map which purpose to be a reference for the development of the management long-term plan of marine protected area. The marine ecoregion map is mainly generated by the geographical condition, seawater properties characteristic, and the biodiversity/ecosystems [17]. There 18 marine ecoregion (EL) for Indonesian seas territory. The FMA 573 is correlated with EL-2 (South of Java) and EL-9 (South of Bali and Lesser Sunda Islands).

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 2013South Java Upwelling 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 [18].

Ecoregion map may also serve as a reference area for the further control and management plan offishing season. The South Java Sea is a nursery ground for southern 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 harvest tuna to the country that keeps the nursing ground in healthy.

Sumatra-Java-Timor high biodiversity which influenced by a regional physical-biogeochemistry dynamics will be an important knowledge to enhance the second level of the Marine Ecoregion Map. In the near future second level of the map, the comprehensive vertical layering variability of marine characteristic aspects will help to define further

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delineation of the sub marine ecoregion of South Java Sea(EL-2), and South of Bali – Lesser Sunda Islands (EL-9).

## 4. Conclusion and Recommendation

The Mixed Layer Depth (MLD) and the catch of tuna in the South Eastern Indian Ocean havea 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 meters with an average temperature around $29^oC$. During the Transitional Season, tuna are distributed at the MLD of 50-60 dbar($\sim$51-61 meters) with average temperatures ranging from $28.5 – 29^oC$. During South EastSeason, tuna are found more at the MLD of 70-90 dbar ($\sim$71.39 – 91.79 meters). In this season, the catch distribution area is larger than those of the two previous seasons.

The South Eastern 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.

## 5. Acknowledgment

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