The estimation of bigeye tuna (*Thunnus obesus*, (Lowe, 1839)) fishing season in the East Indies Ocean which is disembarked in Benoa Port, Bali

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ABSTRACT

Prediction about fishing season is needed for fishing operation, so it can help fisherman to catch a big number of fish with effective and efficient. This study was started on May – June 2018. This study aimed to analyze fishing season pattern of big eye tuna in Indian Ocean. Historical data about fish production and fishing effort of long line vessel for 5 years (2013-2017) collected from Indonesia Tuna Longline Association (ATLI) in Benoa Port, was used to calculate monthly CPUEs which were then analyzed using average percentage methods to obtain fishing season index for each month and sea surface temperature (SST) data collected from satellite. The result shows that big eye tuna can be caught along the year, but there was a pattern that fishing season occurs from June – September, December, and April with the peak season in east season. Optimum distribution of sea surface temperature base on big eye tuna’s fishing ground ranged from 27-27.5 °C.

Keywords: Bigeye Tuna, Fishing Season, SST, Indian Ocean, *Thunnus obesus*

1. INTRODUCTION

Indonesian waters, particularly the Indies ocean, have great potential because of its vast oceanic wealth, especially with its big pelagic fishes (Amandê et al., 2012). Benoa Port is the
biggest port in Bali province, which is directly connected to the Indies Ocean. Benoa Port has fishing areas which is also a place for tuna debarkation in Indonesia.

Tuna, specifically the bigeye tuna, is a big pelagic species commercial target and a valuable species in the longline tuna fishing that operates in the Eastern Indies Ocean (ISSF 2012 in Nurdin 2012). Indonesia’s Bigeye tuna production reached 34,259 tons in 2013 (Indies Ocean Tuna Commission, 2015). The bigeye tuna deployment follows the fish migration path, one of which is affected by temperature. The migration path that is based on the temperature includes South Sumatera waters, Southern Java, Bali, Nusa Tenggara, and Banda Ocean.

Bigeye tuna fishing rate is still below the amount of the allowed potential. Therefore, it is necessary to increase effort so that the fishing rate will increase. The knowledge of fishing season patterns is needed in order to increase bigeye tuna productivity. This is also a way in an effort of sustained fishing so that the bigeye tuna potential lasts and its utilization will not exceed the allowed fishing rate. Information about bigeye tuna fishing season is not common in research. Therefore, it is deemed necessary to estimate the bigeye tuna fishing season in the Eastern Indies Ocean based on the amount of catch that is disembarked in Benoa Port and ocean surface temperature distribution.

![Photo 1. Thunnus obesus (Lowe, 1839)](image)

2. MATERIALS AND METHODS

This research was conducted in the waters of Indian Ocean with fishing base in Benoa Port, Bali which will be carried out in April – May 2018. Benoa port is a location to take production of big eye tuna and catching effort data. This research is conducted in 2 phases, which is data gathering and data processing, respectively. This research used survey with descriptive analysis which includes direct data gathering (in-situ) and visual analysis of satellite images (ex-situ). The in-situ data includes the bigeye tuna fishing rate and the fishing trip rate of Benoa port, while the ex-situ data includes the image of ocean surface temperature (OST) from MODIS image detection satellite using Aqua sensor (MODIS-Aqua)
The obtained data was analyzed using the catch per unit effort (CPUE) (Gulland, 1983, in Edmond, 2017), and the fishing season patterns. The fishing pattern is obtained by calculating the average percentage based on the time series analysis (Spiegel, 2016), and both of the analysis are connected. According to Purwasasmita (1983), the fishing season analysis used the following procedure:

1. Calculate the CPUE value per month

$$\text{CPU}E_i = \frac{C(i)}{f(i)}$$

2. Calculate the monthly average of CPUE in a year

$$\bar{U} = \frac{1}{m} \sum_{i=1}^{m} U_i$$

where:

- $\bar{U} =$ CPUE monthly average in a year
- $U_i =$ CPUE per month (ton/trip)
- $m =$ 12 (the number of months in a year)
3. Calculate the ratio of $U_i$ to $\bar{U}$

$$U_p = \frac{U_i}{\bar{U}} \times 100\%$$

where: $U_p =$ Ratio of $U_i$ to $\bar{U}$

4. Calculate the season index

$$IM_i = \frac{1}{t} \sum_{t=1}^{T} U_p$$

where: $IM_i =$ $i^{th}$ Season Index  
$t =$ the sum of year from the data

5. If the $IM_i$ is not 1200% (12 month × 100%), then an adjustment is required by using the following formula:

$$IMSi = \frac{1200}{\sum_{i=1}^{m} IM_i} \times IM$$

where: $IMSi =$ The Adjusted $i^{th}$ Season Index

6. While calculating, if the $U_p$ has an extreme value, then the $U_p$ value is discarded from the Season Index (IM) calculation, and the IM median (Md) will be used as a substitute. If the Md is not 1200%, then an adjustment is required by using the following formula:

$$IMMdSi = \frac{1200}{\sum_{i=1}^{m} Md_i} \times Md_i$$

where: $IMMdSi =$ The Adjusted $i^{th}$ Season Index median

7. If the IM is more than 1 (>100%) or greater than the average value, then it is fish season, and if the IM is less than 1(<100), then it is not. Lastly, If the IM is equal to 1 (= 100%), then it is in a normal or balanced state.

The monthly sea surface temperature data that has the same period with the bigeye tuna fishing period is obtained from MODIS Aqua sensor with a spatial resolution of 4 km. The data are then combined (overlay) with the fishing ground coordinates from the fishing logbook. The results of the data are analyzed descriptively to identify the correlation between temperature distribution with bigeye tuna productivity in the Eastern Indies Ocean.
3. RESULTS

3.1. Temperature Distribution Analysis in The Indies Ocean

Temperature is an oceanographic factor that affects fishing rate. Weilan (2013) stated that a low or high temperature will affect the fishing productivity. Every fish will adjust with the temperature that is ideal to its metabolism.

In this research, the temperature distribution is divided into each season, this is done to identify the best season that has the ideal temperature to fish bigeye tuna. Indonesian waters are highly related with ENSO and affected by the west monsoon or wet season which occur from December to February, followed by the transitional season I from March to May, whilst the east monsoon or dry season occur from June to August followed by the transitional season II from September to November (McBride and Nicholls 1983; Haylock and McBride 2003; Hendon 2003).

Overall, the temperature distribution of Indies Ocean surface is within the range of 24-30 °C. In the east monsoon (June-August) from 2013 to 2017, the temperature is relatively warm in the western offshore ranging between 28-29 °C. Upwelling occurs at the coastal area in east monsoon, such as the one that occurred in 2015. Therefore, the temperature tends to be colder and ranging between 24-25 °C (Pictured in Figure 2). East monsoon has a colder Ocean Surface Temperature (OST), this is due to the water current from Eastern Australian waters flows into Indonesian waters. Based on these, the season indicates that it is the ideal season for tuna distribution because of the temperature distribution that tends to be low offshore.

The OST in the early transitional season II is seen to be affected by the east monsoon, and as the transitional season II approaches the end (November), the temperature gradually increases. The warm temperature in transitional season II ranges between 29-31 °C, which generally distributed in the eastern offshore (Pictured in Figure 3), and in coastal area, it tends to be colder with the temperature ranging between 25-28 °C. This is due to the upwelling, as stated in a research by Goela (2016), that is, upwelling causes the ocean surface having lower temperature.

In the west monsoon from 2013 to 2017, the OST in Indies Ocean ranges between 24-35 °C. The OST distribution of west monsoon is relatively warmer. This warmer temperature spreads across the eastern offshore and ranging between 28-32 °C, and the lower temperature spreads across the western waters and ranging between 25-27 °C (Pictured in Figure 4). The warmer OST in the western season could be caused by the effect of the west monsoon which moves to southeast and bringing warmer current temperature. The uneven low temperature is affected by the South Equatorial Current (SEC) which then causes upwelling.

Entering the transitional season I, that is the transition from west monsoon to east monsoon, causes the OST starting to decrease. The current moving from the west near the equator, that occurred in this season, causes the water temperature to be warm although the degree keeps decreasing.

The temperature in this season ranges between 26-34 °C (pictured in Figure 5). The warm temperature in this season spreads more on the eastern offshore (28-30 °C), and colder temperature spreads on the western waters, with the exception in May of 2005 and 2017 which is indicated to have upwelling in the coastal area.
Figure 2. The Ocean Surface Temperature (OST) Distribution in East Monsoon in 2013-2017
Figure 3. The Ocean Surface Temperature (OST) Distribution in Transitional Season II in 2013-2017
Figure 4. The Ocean Surface Temperature (OST) Distribution in West Monsoon in 2013-2017
Figure 5. The Ocean Surface Temperature (OST) Distribution in Transitional Season I in 2013-2017
3. 2. Bigeye Tuna Production Analysis in Benoa Port, Bali

The catch in Benoa Port mainly consists of tuna, one of which is the bigeye tuna. swordfish, *cakalang* (skipjack tuna), escolar and squid are other types of catch in Benoa Port. The catch of bigeye tuna in Benoa Port for 5 year period (2013-2017) based on the data below showed a fluctuating result every month (Pictured Below).

![Figure 6. The Fluctuating Pattern of Monthly Bigeye Tuna Catch from 2013-2017 in Benoa Port](image)

The highest bigeye tuna catch is in July 2013, with the total of 318 tons, whilst December 2017 has the least bigeye tuna catch with the total of 31 tons. Syamsuddin (2016) stated that the highest fishing rate occurred between June – August, which meant that the catch rate is also the highest in those months. The fluctuation of the bigeye tuna production is caused by a few factor which include the fish availability, the fishing effort, the fishing success rate, the number of manpower, the duration of fishing, and climate changes (Cheung 2010). The bigeye tuna production tends to be higher at mid-year (east monsoon), this indicates that the mid-year has suitable temperature for the tuna’s metabolism.

From the data shown above, the year 2013 has the highest catch rate of 2,214,126 kg and 2017 has the lowest catch rate of 755,888 kg. This decreasing trend could be caused by the trip rate that also decreases each year. This is because the fishing effort affects the results of catch rate as stated before.

The bigeye tuna fishing effort by the fishermen in Benoa Area include using the ship with an array of long line. The size of the ship used in Benoa is between 30 GT (Gross Tonage) to 200 GT. From 2013-2017, the total fishing effort in Benoa is 9097 trip. As the catch rate, the highest fishing effort occurred in July 2013 with the total of 383 trips and the lowest fishing effort occurred in December 2017 with the total trip of 29 trips.

The fishing effort fluctuation is affected by a few factor such as the increasingly further fishing ground potential, and climate changes affected the fishermen decision to make a trip.
In addition, according to The Association of Tuna Longline Indonesia (ATLI), the number of longline fleet decreases each year in the 5-year period. This, in turn, also decreases the fishermen fishing effort.

The bigeye tuna catch and effort catch data is used as the reference data to determine the Catch Per Unit Effort (CPUE) per month (kg/trip) in the 5-year period. The CPUE Analysis showed that there is a correlation between the increase and decrease of the catch with the fishing effort. The highest CPUE is in April 2016 with the rate of 2013 kg/trip and the lowest is in March 2014 with the rate of 441 kg/trip. This is because in 2016, the fishing effort rate tends to be low which increases CPUE, and vice versa in 2014, which has a pretty high fishing effort rate which decreases the catch per trip.

Potier and Boely (1990, in Apriliani, 2018) stated that fishing is affected by season and the water environmental conditions. In this research, the highest CPUE occurred in eastern season (east monsoon). This confirms by Rochman et al. (2017) that stated eastern season has the highest CPUE for bigeye tuna because the climate changes causes relatively low tide and currents, which in turn causes the longline fleet to operate more often.

3.3. The Bigeye Tuna Fishing Season Pattern

The estimation of bigeye tuna fishing season in Eastern Indies waters was based on the average of monthly fishing effort (2013-2017). The obtained season pattern will refer to the catching season index (IMP) calculation. Based on the IMP, it can be seen that bigeye tuna fishing can be done throughout the year. However, fishing season mostly occurred in eastern season. The seasonal pattern can be seen in Figure 7.

Pictured below, the fishing season occurred in April, June, July, August, September, and December. The non-fishing season, occurred when the IMP is less than 100%, is in January, February, March, May, October, and November.

![Figure 7. Bigeye Tuna Fishing Season Index Pattern in Indies Ocean Waters](image-url)

The graph above indicates that the indices are higher in the eastern season, this confirms Nurani et al. (2012) research that showed the tuna fishing season peak in the southern waters...
of Indian Ocean occurred in June and July, which is in the eastern season as evidence by the large number of catches. The results obtained from this research is consistent, this is shown by the highest CPUE is in the eastern season and fishing season mostly occurred in the eastern season, as well.

Based on the calculation of bigeye tuna catch data, fishing season mostly occurred in the eastern season. The temperature distribution in said season is relatively low and ranging between 24-30 °C. Based on the fishing location which are 30 coordinates obtained from the fishing logbook, with August to November 2016 came from KM Surya Terbit – 169 and KM Sari Dewata – 1 which is based in Benoa Port Bali (Pictured in Figure 8), the ideal temperature distribution to fish bigeye tuna ranges between 27-27.5 °C. This temperature range confirms Syamsuddin et al. (2013) research that showed bigeye tuna is mostly fished in waters with a temperature between 24-27.5 °C (Pictured in Figure 9). The logbook data showed that the bigeye tuna fishing are is wider in August with the average temperature distribution of 27 °C.

Figure 8. The Bigeye Tuna Fishing Map in August (a), September (b), October (c), and November (d) 2016 in the Eastern Indies Ocean Waters
4. CONCLUSION

The bigeye tuna fishing activity in the Indies Ocean peaks at eastern season, specifically in July and September. The ideal ocean surface temperature distribution in the Eastern Indies Ocean based on the location of bigeye tuna fishing ranges between 27-28°C, this range is also the temperature distribution in bigeye tuna fishing season.

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