



# **The Influence of Indian Ocean Dipole on Production of Tembang Fishing (*Sardinella fimbriata*) at Sunda Strait Indonesia**

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## **Authors' contributions**

*This work was carried out in collaboration among all authors. Author DMA design the studies and wrote the first draft of the manuscript. Authors YM, AMAK and HH managed the analyses of the study. All authors read and approved the final manuscript.*

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## **ABSTRACT**

Tembang is a pelagic fish which is important in Indonesia and the development on the Sunda Strait. The Indian Ocean Dipole could affect oceanography and at the same time will affect the population of fishes. The aim of this study was to determine the effect of IOD and oceanographic factors on the catch of Tembang fish. This research was conducted in the Sunda Strait waters by looking at the Dipole Mode Index (DMI) and oceanographic ocean conditions such as sea surface temperature and chlorophyll as well as the production of fish catches for 11 years from 2008-2018. IOD affects the catch of Tembang fish by 35.8%. Temperature influences the catch of Tembang fish in the Sunda Strait by 9.48%. Klorofil-a influences the catch of Tembang fish in Sunda Strait by 38.6%. DMI, Temperature, and Chlorophyll affect fish catches by 26.9%.

**Keywords:** *Indian Ocean Dipole; Sardinella fimbriata; Sunda Strait; temperature; Klorofil-a.*

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## 1. INTRODUCTION

Indonesia's geographical condition includes the meeting of the two largest oceans in the world, namely the Pacific Ocean and the Indian Ocean. The Sunda Strait is an important one in the mass circulation of water in Indonesia. The dynamics of the water mass are influenced by the flow of two air masses, namely the Java Sea and Indian Ocean air masses. Sunda Strait, including the composition of nutrients (nutrients), chlorophyll-a, phytoplankton and suspended solid / seston. Sunda Strait also has global phenomena such as the Indian Ocean Dipole (IOD) phenomenon that occurred in the Indian Ocean. IOD was first discovered by Dr. Saji and Prof. Yamagata and other researchers who joined the Climate Variation Research Program (CVRP) of the Border Research Center for Global Change (FRCGC) in 1999 [1]. Indian Ocean Dipole (IOD) is a phenomenon that occurs due to interactions between the ocean and the atmosphere in the Indian Ocean and is formed by two poles of sea surface temperature anomaly (SST), between South Kalimantan and West Sumatra using Africa [2]. The IOD phenomenon is a pattern variation in the Indian Ocean that causes lower SSTs to be found off the West coast of Sumatra and warmer SSTs in the West Indian Ocean caused by wind and rain anomalies [3].

Indian Ocean Dipole (IOD) can be identified by using the Dipole Mode Index (DMI) which illustrates the difference in SST anomalies between the western west of the Indian Ocean and the southeast of the tropical Indian Ocean and has a 70% accuracy in identifying IOD [4]. Extreme positive DMI value is an indication of IOD. IOD is divided into two phases namely positive IOD and negative IOD. Positive IOD occurs when surface air pressure over the West Sumatra region is relatively higher pressure than the eastern region of Africa which is relatively low pressure, so that air flows from the western part of Sumatra to the eastern part of Africa which results in the formation of convective clouds in the African region and generates rainfall. Rain is above normal, whereas in Sumatra there is a drought, and vice versa with negative IOD [3]. IOD has a large positive and negative impact on the productivity of water. Indonesia's vast sea has great marine resource potential, but the availability of these resources differs depending on water productivity. Productive waters will have an impact on the fisheries production of an area. Setyadji and Amri [5] stated that catches increased due to population surges as a result of

successful spawning during intensive upwelling when positive IODs were strong in 2006 which continued in 2007 and 2008 (negative IODs were weak). IOD affects the production of Tuna (*Euthynnus affinis*) according to the phases that occur. The positive IOD phase increases the value of fish production and the negative IOD phase decreases fish production in the waters of South West Java but not directly but has a time lag [6].

The largest pelagic fish landing in the Sunda Strait is at the Fishery Port Labuan with the main commodity being Tembang Fish (*Sardinella fimbriata*). Tembang fish is one of the important economical fish resources in the waters of the Sunda Strait. Important economic value and increasing utilization make this fish as one of the main targets of fishing in the Sunda Strait [7]. The distribution of Tembang fish is strongly influenced by oceanographic factors such as SST and chlorophyll. IOD will affect the distribution of SST and chlorophyll-a which is thought to affect the catch of Tembang fish. Therefore, research is needed to find out how much influence the IOD has on Tembang fish catches in the Sunda Strait.

## 2. MATERIALS AND METHODS

This research was conducted in August 2019 until April 2020, in the Sunda Strait and the Port of the Fisheries of Labuan, Banten. The location selection was done purposely with the consideration that the Sunda Strait with location coordinates 5°53'5.36"S - 6°50'48.54"S and 104°7'46"E - 105°45'21.92"E are places of utilization fisheries resources. The study was conducted using SPSS software, QGIS 3.2.2, and Ms. Excel uses monthly SST and Chlorophyll-a for 11 years from [oceancolor.gsfc.nasa.gov/cms/](http://oceancolor.gsfc.nasa.gov/cms/), Dipole Mode Index (DMI) from [Jamstec.co](http://Jamstec.co) and the Tembang Fish landing data obtained from Port of the Fisheries of Labuan, Banten. The relationship between oceanographic factors and the Dipole Mode Index (DMI) value and the abundance of Tembang fish catches at the Labuan fishing port in quantity can be determined by using multiple linear regression analysis. Multiple linear regression analysis was performed using SPSS software. Multiple linear regression analysis is used to measure the magnitude of the influence between more than one predictor variable (independent variable), namely oceanograi factor and the DMI value of the dependent variable, namely the catch of Tembang fish [8]. The

calculation can be produced from the following equation:

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + e$$

- Y = Fish Catches (dependent variable)
- a = constanta
- x1 = Dipole Mode Index (independent variable)
- x2 = Sea Surface Temperature (independent variable)
- x3 = Chlorophyll-a (independent variable)
- b1-b5 = regression coefficient
- e = error

### 3. RESULTS AND DISCUSSION

#### 3.1 Sunda Strait Geographic Condition

The fishing ground of the Labuan fishermen includes the waters of the eastern part of the strait, stretching from north to south starting from the waters around Merak / Cilegon to around Panaitan Island, Ujung Kulon [9]. Sunda Strait waters has an area of more or less 8,138 km<sup>2</sup>. The strait is shaped like a funnel, the northern part of the strait is narrower (±24 km) and

shallower (≤80 m), while the southern part has a width of about 100 km and depths reaching 1,575 m (Birowo 1983).

#### 3.2 Indian Ocean Dipole (IOD)

During the period 2008-2018 IOD occurred in several years. Table 1 shows the time when IOD occurred.

Positive IOD occurred in 2011, 2012, 2015 in July to November and in 2017 in March to August. Negative IOD occurred in 2013 in April to June and in 2016 in June to October.

In general, based on the time series analysis the catch of Tembang fish in the Sunda Strait has a trend of continuously decreasing trend can be seen in Fig. 1.

The value of fish catch in Fig. 1 explains that every month the catch of Tembang fish in the Sunda Strait has a fluctuating state. The range of arrest results from February to June is not very broad. Boxplot of the catch value of the tembang fish can be seen in Fig. 2.

Tabel 1. Indian Ocean Dipole time series

Year	Month	Status
2011	July – November	IOD +
2012	July – September	IOD +
2013	April – June	IOD –
2015	July – November	IOD +
2016	June – October	IOD –
2017	March – August	IOD +

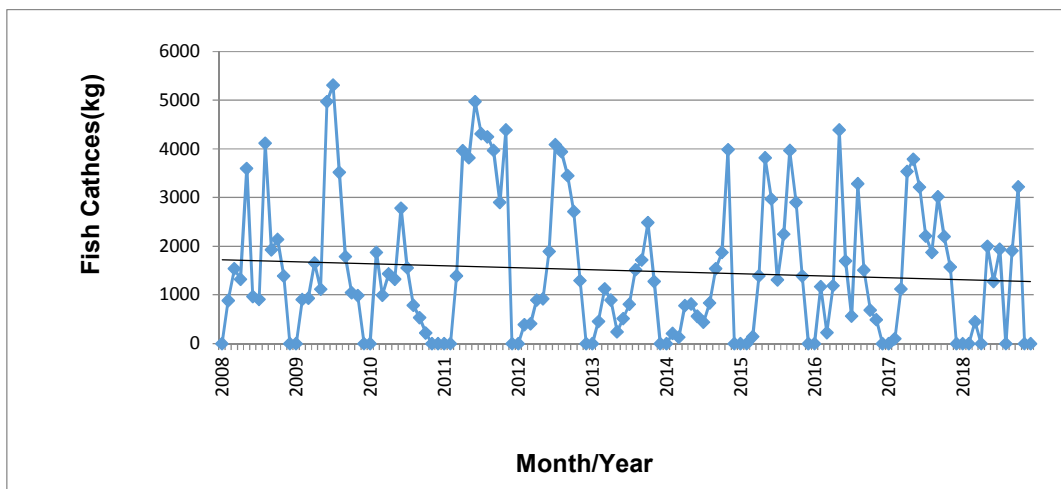
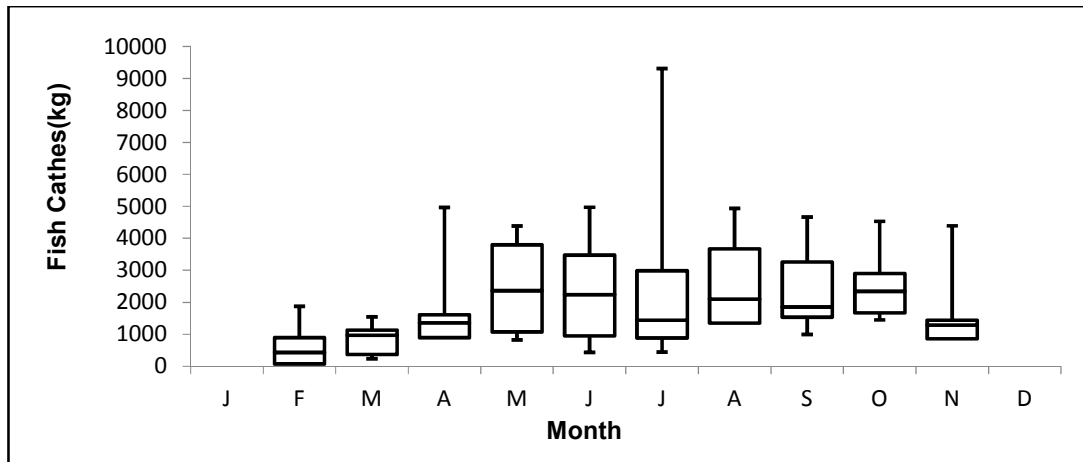


Fig. 1. Monthly average graph of catches of the tembang fish 2008-2018



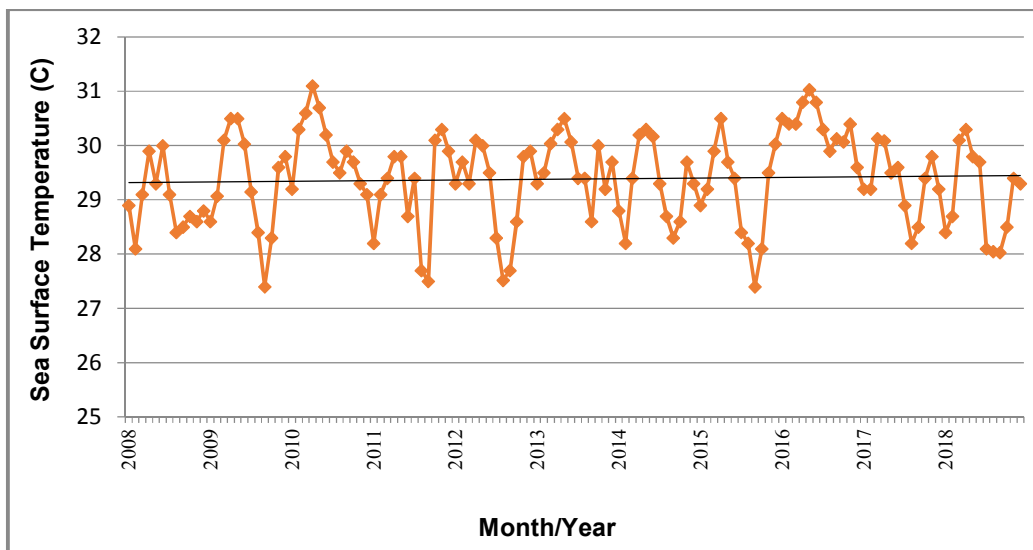
**Fig. 2. Monthly average boxplot of catches of the tembang fish 2008-2018**

Fig. 2 explains that in February to June the catches tend to be stable every year. The range of catch value in July is very wide with the upper limit value (> 6000 kg) and the lower limit (<1000 kg) far. Fig. 2 also shows that the fishing season from May to August is evidenced by the high average value compared to other months and the highest catch is in August. August is one of the most frequent months of positive IOD.

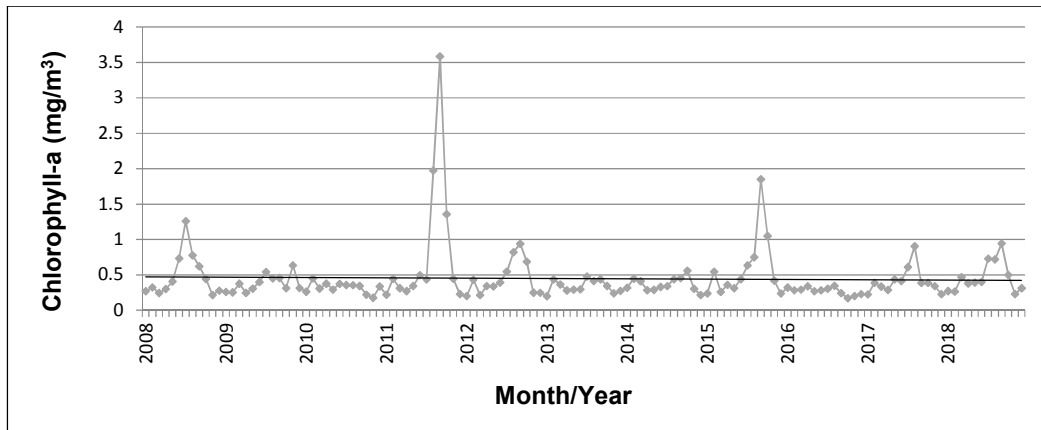
SST value occurred in September 2009 with an SST value of 27.4°C and the highest in April 2010 with an SST value of 31.1°C. The average SST value for 11 years in the Sunda Strait is 29.3°C. SST values in each month have a fluctuating state with a decrease in temperature in the monsoon transition II (August-October) and again increase in the monsoon west (November-January) to reach the highest temperature in the monsoon transition I (February-April) in April by 31.1°C. Based on the analysis of time series from 2007 to 2018, the lowest value was found in September, which has the lowest median value of 28.2°C. Graph of Chlorophyll-a values during the period 2008 - 2018 can be seen in the following Fig. 4.

The graph of sea surface temperature values in 2008 - 2018 can be seen in the following Fig. 3.

SST values during 11 years in the Sunda Strait ranged from 27.4°C - 31.1°C (Fig. 3). The lowest



**Fig. 3. Monthly average graph of sea surfaces temperature 2008-2018**



**Fig. 4. Monthly average graph of Chlorophyll-a 2008-2018**

Based on the analysis of the time series from 2008 to 2018, the lowest value occurred in December, with a median value of 0.3 mg/ m<sup>3</sup> and the highest median value in August of 0.7 mg/m<sup>3</sup>. High or low median monthly chlorophyll-a concentration is due to the tendency of the dominance of chlorophyll-a concentration values in these waters. Table 2 shows the effect values between variables using multiple linear regression.

The regression equation from the results of the multiple linear regression analysis in Table 1 is  $Y = -3891,654 + 19331,282X_1 + 148,546X_2 + 1067,806X_3$ . The significance value for SSST is 0.328 or greater than 0.05 which means that the SST has no significant effect on fish catches while the significance value of chlorophyll-a and DMI is lower than 0.05 which means that the DMI value has a significant effect on the catch of Tembang fish in Sunda Strait.

The relationship between dependent and dependent variables can be seen in the following Table 3.

Based on Table 3, R value is 0.519 which means that there is a moderate relationship between

DMI, SST and Chlorophyll-a on the catch of Tembang Fish and R Square value of 0.269, which means that 26.9% of DMI, SST and Chlorophyll-a simultaneously affect fish catch value. The correlation coefficient between variables can be seen in Table 4.

Based on Table 4, the effect of the DMI value on the catch is 30.2% and is directly proportional, meaning that if the DMI value increases, the fish catch is predicted to increase. The effect of DMI on Chlorophyll-a is 29.7% directly proportional and the effect of DMI on SST is 21.2% inversely which means that if the DMI value decreases then the SST value increases and likewise if the DMI value increases then the SST value decreases. The effect of SST on catches is 5.3% and is inversely proportional. An increased SST value will decrease the value of the catch and vice versa. The effect of SST on Chlorophyll-a was 28.7%. The percentage of the influence of chlorophyll-a on fish catches of Tembang is 38.9% directly proportional, meaning that if the value of chlorophyll-a increases, the fish catch will increase and if the value of chlorophyll-a decreases, fish catch will decrease.

**Table 2. Multiple linear regression analysis**

Model	Coefficients <sup>a</sup>			T	Sig.
	Unstandardized coefficients		Standardized coefficients		
	B	Std. error	Beta		
(Constanta)	-3891,645	4536,996		-0,858	0,393
DMI	1931,282	437,806	0,372	4,411	0,000
SST	148,546	151,415	0,086	0,981	0,328
Chlorophyll-a	1067,806	329,459	0,290	3,241	0,002

**Table 3. Relations between variabel**

Model summary				
Model	R	R square	Adjusted R square	Std. error of the estimate
1	0,519 <sup>a</sup>	0,269	0,252	1236,26346

**Table 4. Correlation coefficient**

R <sup>2</sup>	HT	SPL	Klorofil-a	DMI
DMI	0,302	-0,212	0,297	1,000
SPL	-0,053	1,000	-0,287	-0,212
Klorofil	0,389	-0,287	1,000	0,297
HT	1,000	-0,053	0,389	0,302

Positive IOD phases in the Sunda Strait (Western Indian Ocean) often occur in the months from the East Monsoon to the Transition II Monsoon in accordance with Martono's statement [10] that the positive Indian Ocean Dipole event caused a decrease in SST. Positive phases in 2011, 2012, 2015 and 2017 caused a decrease in SST to 1.7°C. The positive IOD phase will last longer in 2017, from March to August. The negative IOD phase has the opposite effect where Sunda Strait experience an increase in SST in the months that experience a negative IOD impact. The highest temperature rise occurred in September as explained by Amri et al. [5] that the evolution of IOD began to occur in June and reached its peak in September.

The fishing season of Tembang is affected by rain which is related to the west monsoon/east monsoon. The catch of Tembang fish in January and December (Fig. 1) is 0 because in January and December it is the rainy season so fishermen do not go to catch the fish on the sea. The biggest catch was in 2011. Research by Kunarso [11] and Amri et al. [5] shows that the phenomenon of IOD influences the catch variability associated with high chlorophyll-a and SST and upwelling intensity with a higher DMI value will also have a stronger impact on catch variability. The increase in catches in May to August is due to coincide with upwelling in South Java and the Sunda Strait [12]. Indonesia is affected by rain related to the west and east monsoons [5]. The wind blows between March and September in the East Monsoon when temperatures begin to decline and fishermen start fishing at sea [13] otherwise from October to February (west season), temperatures start to increase and the concentration of chlorophyll-a decreases.

The decline in SST values in the Sunda Strait in August and September is also due to this month

being the peak of Upwelling with low-value SST and as the month changes from September to November the intensity of the upwelling power decreases and causes the SST value to increase [14]. The highest median SST was in April at 30.3°C. High and low median monthly SST value is due to the tendency of the SST value in these waters. Transition II Monsoon, namely from July to October, the range of the upper and lower limit of the SST is quite wide due to the influence of the SST which tends to be warm in the north and the contribution of the low value of SST in the South. The temperature rise is marked by the West Monsoon, which is from November to January, as seen in those months the SST tends to increase with a narrow range of values, the meaning that in those months the distribution of SST tends to be high in all parts of the sea. This high temperature has a fairly long period of time until June, in other words, the West Monsoon to the East Monsoon (November - July) SST conditions in the Sunda Strait region tend to be warm with a range of 29.0°C - 30.3°C. Based on research conducted by Amri [5], it is clear that in the transition II monsoon the SST conditions in the Sunda Strait have a lower tendency so that it increases the value of chlorophyll-a compared to the West Monsoon, Transition I and East Monsoon.

The results of data analysis taken from satellite images show that the concentration of chlorophyll-a in Sunda Strait tends to increase along with the decrease in SST as well as the concentration of chlorophyll-a in eastern Indonesian sea [15]. Variation in chlorophyll-a concentration in the Sunda Strait is also caused by the influence of 2 characteristics of water masses from northern Java and the Indian Ocean. Indian Ocean tend to have low chlorophyll-a concentrations compared to the northern Java Sea, this is because the Indian Ocean are offshore. The high concentration of

chlorophyll-a in offshore can be indicated by the occurrence of upwelling phenomena in the sea [5]. According to Birowo [16] upwelling occurs by identifying a decrease in the SST and the high nutrient content of the area compared to the surrounding area. Increased levels of nutrients can stimulate the growth and development of phytoplankton on the water surface. Increasing phytoplankton is a sign of high water productivity, the upwelling process is always associated with an increase in phytoplankton abundance and water productivity followed by an increase in fish abundance in these waters and becomes the basis in estimating fishing areas. The relationship between chlorophyll and SST is inversely proportional [15]. An increased SST value causes a decrease in the value of chlorophyll-a and a decreased SST value will increase the value of chlorophyll-a. Aquatic productivity will increase along with an increase in the value of chlorophyll-a [17].

Correlation analysis between SST and fish catches did not show a significant value in accordance with research conducted by Khan [15] in Eastern Indonesia. Chlorophyll increases with decreasing SST and decreases along with increasing SST value [15]. A high SST value will cause a decrease in the value of chlorophyll-a and a low SPL value will cause an increase in the value of chlorophyll-a. Anomalies that occur in the Indian Ocean namely IOD affect the dynamics of oceanographic parameters such as SST, Chlorophyll-a and upwelling intensity [5]. Positive IOD causes a decrease in the SST value and an increase in the value of Chlorophyll-a, causing increased aquatic productivity and increased fish catches. A negative IOD causes an increase in the SST value so that the Chlorophyll-a value decreases and the catch decreases.

#### 4. CONCLUSION

IOD affected SST by 21.2%, Chlorophyll-a by 29.7% and Tembang fish catch by 30.2%. SST affects the catch of Tembang fish in the Sunda Strait by 5.3% and Chlorophyll-a affects the catch by 38.9%. DMI, Temperature, and Chlorophyll-a simultaneously affect fish catches by 26.9% while 73.1% are influenced by other variables outside this regression equation or variables not examined. IOD + results in a decrease in the temperature value and an increase in the value of Chlorophyll-a and the catch of Tembang Fish. IOD- resulted in an increase in the temperature value and a

decrease in the value of chlorophyll and the catch of Tembang Fish.

Based on the research results obtained, it is necessary to conduct further research on the effect of IOD and oceanographic factors on the production of Tembang (*Sardinella fimbriata*) fish catches in the Sunda Strait waters by considering CPUE (Catch per Unit Effort) because of effective capture other than good water conditions for habitat fish, fishing efforts are also needed to be able to get optimal results..

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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