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THE EFFECT OF THE INDIAN OCEAN DIPOLE PHENOMENON AND THE CATCHING OF LONG-JAWED MACKEREL (RASTRELIGGER SPP) IN LAMPUNG WATERS

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ABSTRACT
The Indian Ocean Dipole (IOD) is a symptom of climate aberrations caused by the interaction of the ocean and the atmosphere in the Indian Ocean. IOD can influence oceanographic parameters and the density of chlorophyll-a in the waters, affecting fish catches. In Indonesia, the waters that IOD strongly influences are the waters of Lampung, West Sumatra. Therefore, this study analyzed the effect of IOD, oceanographic parameters (sea surface temperature, sea surface salinity, and sea surface currents), and chlorophyll-a density on the catch of long-jawed mackerel (*Rastreligger spp*) in Lampung waters. The study took place from April 2018 to October 2018 using satellite image data and direct data retrieval at the specified coordinates. The results showed that IOD, oceanographic parameters, and chlorophyll-a density together influenced 58.2% of *Rastreligger spp* catches in Lampung waters at a 99% significance level, while the rest 41.8% was influenced by other variables outside the model. In other words, a positive IOD phenomenon can increase the catch of *Rastreligger spp*, while a negative IOD phenomenon will decrease the catch of *Rastreligger spp* in Lampung waters.

KEY WORDS
IOD, correlation, long-jawed mackerel, Lampung.

Oceanographic-based variations of fishery products are influenced by global climate changes such as ENSO (El Nino-Southern Oscillation) and IOD (Indian Ocean Dipole). IOD is a symptom of climate aberrations caused by the interaction of the ocean and the atmosphere in the Indian Ocean. This interaction produces high pressure in the Eastern Indian Ocean (southern part of Java and West Sumatra), moving the air masses that blow to the west. This sea breeze will push and lift the water mass from the bottom to the surface. As a result, the sea surface temperature around the south coast of Java and the west coast of Sumatra will experience a drastic decline and thus affecting the marine biological resources. Several previous studies have identified that IOD affects marine ecosystems, so it can be concluded that climate variability (IOD) influences species composition, abundance, distribution, recruitment rate, and tropic structure in the waters of West Sumatra (Amri, 2012).

The waters of Lampung cover Sunda Strait, Java Sea, and the Indian Ocean; this area is affected by ENSO, monsoons, and Dipole Mode (DM). According to Amri (2012), the west waters of Sumatra are strongly influenced by IOD in the positive Dipole Mode Index (DMI) phase, occurring in September and October; this phenomenon once happened in 1997 and 2006. This condition makes the mass in Lampung waters very dynamic to climate change, causing sea surface temperature anomalies and affecting fertility variability. In addition, the waters of Lampung (Sunda Strait) are also a transportation route for warmer Pacific Ocean waters (Java Sea) to the Indian Ocean, which causes the two water masses to mix (Ishak and Sari, 2013). As a result, the marine ecosystems will change and encourage the migration of pelagic fish, especially long-jawed mackerel (*Rastreligger spp*). This phenomenon encourages us to study Lampung waters, especially regarding water fertility and the catches of *Rastreligger spp*.

LITERATURE REVIEW

Indian Ocean Dipole Mode (IODM) is a climate anomaly that arises due to the interactions between the ocean and the atmosphere in the Indian Ocean. Saji *et al.* (1999) describe IODM as a phenomenon of warm water displacement in a zonal direction along the equatorial Indian Ocean, similar to the ENSO in the Pacific Ocean. This phenomenon emerges from empirical Orthogonal Function (EOF) analysis and composite analysis of Sea Surface Temperature (SST) data for 40 years, where the first dominant mode is 30% and the second is 12% of the total diversity. Those two modes are called Dipole Mode Events (Saji *et al.,* 1999).

The dipole mode structure is characterized by an SST anomaly, which is warmer in the western part of the Indian Ocean (eastern waters of Africa) and cooler in the eastern part of the Indian Ocean (western waters of Sumatra). At that time, rainfall in the west (eastern tropical Africa) was high, while it was very low (drought) in Indonesia (Saji *et al.,*1999). Vinaychanran *et al.* (2001) define that phenomenon as the *positive* IODM. On the contrary, Vinaychanran *et al.* (2001) describe the opposite event as *negative* IODM, which is reflected by a warmer SST in the eastern part of the Indian Ocean and cooler SST in the western part of the Indian Ocean (Figure 1).

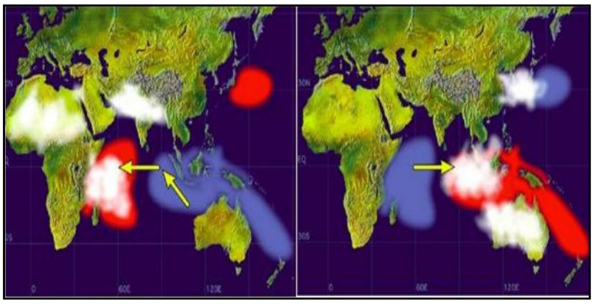

Figure 1 – Schematic diagram of SST anomaly of positive IODM (left) and negative IODM (right). The red SST shows warmer conditions, while the blue SST portrays the cooler area. The white color indicates an increased convection activity, while the arrows point out the wind direction (http://www.jamstec.go.jp/frcgc/ 2012)

The IODM phenomenon is related to the wind movement pattern moving from southeast to northwest in the eastern Indian Ocean, and when it reaches the equator, the wind turns west. The wind pushes warm water from the west equator of the Indian Ocean to the east waters of the African continent. Under normal conditions, this warm water is located in the east of the Indian Ocean, but due to the SST anomaly, the east wind pushes this warm water to the west along with the increase in the convection zone that carries water vapor and has the potential to cause rain during the warm water movement. Saji *et al.* (1999) mention that the development of IODM is slightly different from El Nino-La Nina; El Nino-La Nina reaches its peak at the end of the year, from December to February.

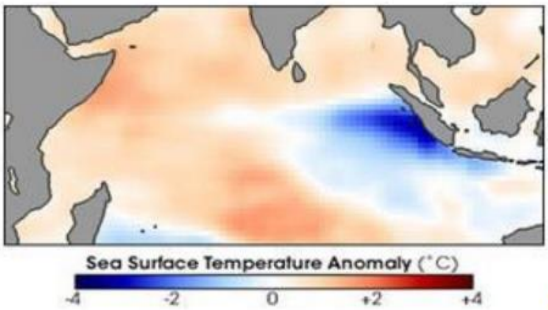

Figure 2 – SST Anomaly of the eastern Indian Ocean is lower than the western part when the DMI is positive (https://www.esrl.noaa.gov/psd/gcos_wgsp/)

Rastreligger spp is one of the most potential pelagic fish spread in almost all Indonesian waters. *Rastreligger spp* is a type of *pelagic-neritic*, *oceanodromous* fish, and lives at an average depth of 20 to 90 meters in tropical climates at a temperature of 20º to 30º. However, *Rastreligger spp* prefers to live at a temperature of 27º. The concentration of chlorophyll-a near the coast is strongly influenced by nitrate and phosphate from the shore (Zulkarnaen *et al.,* 2015), which act as food sources for fish.

Figure 3 – Types of *Rastreligger spp*. (a) *Rastrelligger kanagurta* (b) *Rastrelligger brachysoma,* (c) *Rastrelligger faughni* (http://www.fishbase.org/, 2018)

METHODS OF RESEARCH

This study was conducted in the waters of Lampung and its surroundings at 103º12'-105º50' East Longitude and 03º20-06º05' South Latitude. The data was collected from April to October 2018. To compare water conditions in the last three years, we used satellite data of the oceanographic parameter and chlorophyll-a data in 2015-2017. For data validation, we used the in-situ data of September 2018.

One of the techniques to find correlations between variables was developed by Karl Pearson. A correlation coefficient is a statistical measurement of covariance or an association between two variables. This analysis determines the relationship between IOD phenomena, oceanographic parameters, and chlorophyll-a density. The value of the correlation coefficient ranges from +1 to -1. A correlation coefficient shows the strength of a linear relationship and the direction of the relationship between two random variables. The two variables have a unidirectional relationship if the correlation coefficient is positive. We used the following criteria to ease the interpretation of the relationship between the two variables (Sarwono, 2008):

a. If the value of *significance correlation product moment* (Sig.r) is less than 0.05, then Ho is rejected, meaning that there is a correlation between the IOD phenomenon with oceanographic parameters and chlorophyll-a;
b. If the value of *significance correlation product moment* (Sig.r) is more than 0.05, then Ho is accepted, meaning that there is no correlation between the IOD phenomenon with oceanographic parameters and chlorophyll-a;
c. Based on the *Pearson Correlation* value, it can be interpreted that:
    - Pearson Correlation value of 0.00-0.20 means no correlation;
    - Pearson Correlation value of 0.21-0.40 means weak correlation;
    - Pearson Correlation value of 0.41-0.60 means moderate correlation;
    - Pearson Correlation value of 0.61-0.80 means strong correlation;
    - Pearson Correlation value of 0.81-1.00 means perfect correlation.

RESULTS AND DISCUSSION

A positive IOD occurs if the positive DMI value is greater than the standard deviation value of 1, while a negative IOD occurs if the negative DMI value is less than 1 for at least three consecutive months (Saji *et al.,* 1999). Based on the data on https://www.esrl.noaa.gov/psd/gcos_wgsp/Timeseries/Data/dmi, the variation of DMI value from 2015 to 2017 is as follows.

After being calculated with SPSS 24 software, the correlations of the variables above are presented in Table 2. The r_{table} of DF (n-2) at the significance level of 90% and 95% is 0.2785 and 0.3291, respectively.

Table 1 – Dipole Mode Index (DMI) Value from 2015 to 2017

Month	Year		
	2015	2016	2017
January	0.077	0.438	0.099
February	-0.165	0.066	0.283
March	-0.076	0.161	0.528
April	0.186	0.341	0.703
May	0.451	0.104	0.751
June	0.495	-0.229	0.633
July	0.527	-0.435	0.826
August	0.856	-0.145	0.643
September	0.668	-0.055	0.414
October	0.858	0.017	0.396
November	0.599	-0.093	0.55
December	0.49	-0.075	0.342

Source: www.esrl.noaa.gov.

Table 2 – The Correlation Values of Oceanographic Parameters, Chlorophyll Density, and DMI

n/n		DMI	SST	SSS	Current	Chlorophyll-a
DMI	Pearson Correlation	1	-.508**	.480**	-.019	.395*
	Sig. (2-tailed)		.002	.003	.911	.017
	N	36	36	36	36	36
SST	Pearson Correlation	-.508**	1	-.711**	-.354*	-.588**
	Sig. (2-tailed)	.002		.000	.034	.000
	N	36	36	36	36	36
SSS	Pearson Correlation	.480**	-.711**	1	.180	.419*
	Sig. (2-tailed)	.003	.000		.295	.011
	N	36	36	36	36	36
Current	Pearson Correlation	-.019	-.354*	.180	1	.093
	Sig. (2-tailed)	.911	.034	.295		.590
	N	36	36	36	36	36
Chlorophyll-a	Pearson Correlation	.395*	-.588**	.419*	.093	1
	Sig. (2-tailed)	.017	.000	.011	.590	
	N	36	36	36	36	36
***. Correlation is significant at the 0.01 level (2-tailed).*						
**. Correlation is significant at the 0.05 level (2-tailed).*						

The cross-correlation between IOD and SST in Lampung waters shows that the variables have a negative correlation value (Table 2). This means that an increase in the intensity of IOD causes a decrease in the SST of Lampung waters. The correlation value between DMI and SST is -0.509 (Table 2). This indicates a moderate relationship with a negative trend (Pearson Correlation value of 0.41 - 0.60). The value can be accepted at the 99% confidence level by testing $r_{count} > r_{table}$ at a significance level of 0.01. The force of the water lifts the water mass to the bottom so that an SST anomaly occurs in the waters of West Sumatra - this condition is known as positive IOD. Conversely, this IOD phenomenon can cause a buildup of water mass in the waters of West Sumatra and South Java due to the force of water mass from the western Indian Ocean—this condition is called negative IOD.

IOD and Sea Surface Salinity (SSS) in Lampung waters show a positive correlation value, meaning that an increase in the intensity of IOD can increase the SSS in Lampung waters. The correlation value between IOD and SSS is 0.473. This indicates a moderate relationship with a positive trend (Pearson Correlation value of 0.41-0.60). Result is accepted at the 99% confidence level by testing $r_{count} > r_{table}$ at a significance level of 0.01.

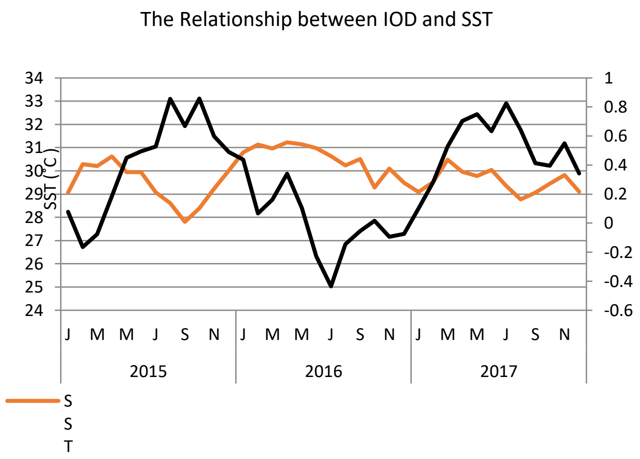

Figure 4 – The Relationship between DMI Value and SST in 2015, 2016, and 2017

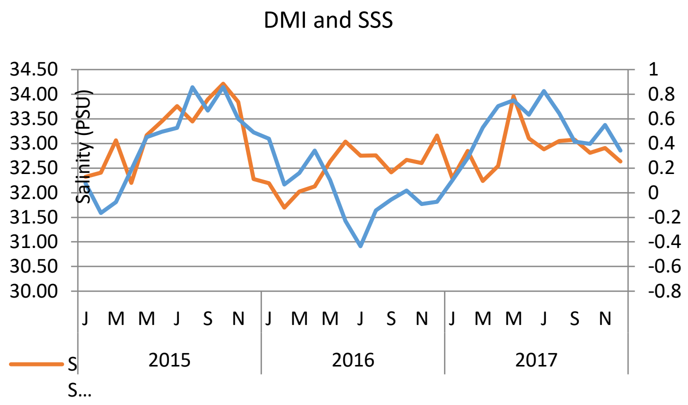

Figure 5 – The Relationship between DMI Value and SSS in 2015, 2016, and 2017

DMI and current velocity show a negative correlation, which means that an increase in DMI will decrease the surface currents in Lampung waters. The correlation value between IOD and current velocity is -0.019 (Table 2). It can be interpreted that there is no relationship between the DMI value and the current velocity at the 90% confidence level because $r_{count} < r_{table}$ is at a significance level of 0.10 ($r_{table} = 0.2785$).

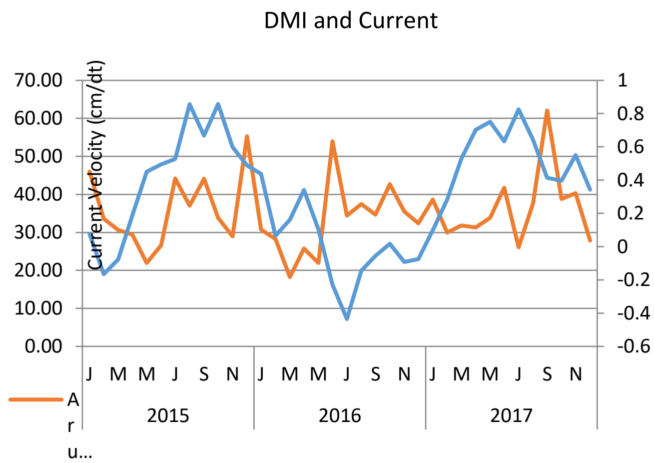

Figure 6 – The Relationship between DMI Value and Sea Surface Current in 2015, 2016, and 2017

The cross-correlation between IOD and the chlorophyll-a concentration in Lampung waters indicates that the two variables have a positive correlation value (Table 2). This means that an increase in the intensity of IOD leads to an increase in chlorophyll-a concentration. The correlation value between IOD and chlorophyll-a concentration is 0.395. This indicates a weak relationship with a positive trend (Pearson Correlation value of 0.21 - 0.40). The value can be accepted at the 95% confidence level by testing $r_{count} > r_{table}$ at a significance level of 0.05.

The positive IOD in 2015 triggered the winds to flow from Eastern Indian Ocean to Western Indian Ocean continuously. This phenomenon was strengthened by the southeast winds in the East monsoon (June - August), resulting in the lifts of water masses from the bottom to the surface of West Sumatra and South Java waters. As a result, these waters are rich in nutrients. This was followed by an increase in the concentration of chlorophyll-a in the waters of West Lampung. The highest chlorophyll-a concentration in the waters of West Lampung was 2.28 mg/L and occurred in September 2015.

From the data of this study, the average catch of *Rastreligger spp* in 2016 was 8,593 kg; it was lower than the catch in 2015. This occurred due to the influence of negative IOD, which caused the SST to increase in the West monsoon until the transition season I. In addition, the IOD also caused a decrease in the concentration of chlorophyll-a in 2016. Both of these things made the catch of *Rastreligger spp* in Lampung waters decline.

However, in 2017, the catches of *Rastreligger spp* in Lampung waters increased again due to the positive IOD. The catch then reached 26,830 kg, with the highest catch in July 2017 (10,828 kg) and the lowest in December 2017 (6,314 kg). On the other hand, the highest chlorophyll-a concentration in 2017 was in August at 1.22 mg/L, and the lowest was in November at 0.55 mg/L.

The spatial and temporal data of SST, SSS, sea currents, chlorophyll-a, and DMI proved that the variables above could influence the catches of *Rastreligger spp* in Lampung waters. Those data are processed using SPSS 24 software, and the results are as follows:

Table 3 – The Model Summary of Data Analysis using SPSS 24 Software

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.763[a]	.582	.512	55.71270
a. Predictors: (Constant), DMI, Current velocity, chlorophyll_a, SSS, SST				

Table 3 shows that the correlation coefficient value is 0.763. Therefore, it can be said that these parameters have a strong influence on the catches of *Rastreligger spp* in Lampung waters. These parameters simultaneously influence the catch of *Rastreligger spp* by 58.2% and refer to the value of R-Square at a significance level of 95%.

Table 3 – Anova Calculation Results

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	129470.598	5	25894.120	8.342	.000[b]
	Residual	93117.158	30	3103.905		
	Total	222587.756	35			
a. Dependent Variable: Catch						
b. Predictors: (Constant), DMI, Current velocity, chlorophyll_a, SSS, SST						

Based on the analysis of t_{count} for each parameter, SST has a t_{count} value of 2,000, Chlorophyll-a has a t_{count} value of 4.184, SSS has a t_{count} value of 3.084, current velocity has a t_{count} value of 0.057, and DMI has a t_{count} value of 0.116. From these values, a t_{test} was carried out. Meanwhile, the t_{table} value at a significance level of 0.05 was 1.753, so it can be concluded that chlorophyll-a, SST, and SSS affected the catch of *Rastreligger spp* with a significance level of 0.05 ($t_{count} > t_{table}$). On the other hand, current velocity and DMI had no significant effect on the catch of *Rastreligger spp* because $t_{count} < t_{table}$. Therefore, we concluded that current velocity and DMI did not affect the catch of *Rastreligger spp*. However, surface currents could influence the distribution of chlorophyll-a and the movement of *Rastreligger spp* but did not affect the catches. DMI (IOD phenomenon) was also found not to affect the catches of *Rastreligger spp,* even though it affected the changes in SST and SSS.

CONCLUSION

IOD, oceanographic parameters, and density of chlorophyll-a together affected 58.2% of long-jawed mackerel (*Rastreligger spp)* catches in Lampung waters at a significance level of 99%. Meanwhile, the other 41.8% was influenced by other variables outside the model. From this study, it can be concluded that a positive IOD phenomenon can increase the catch of *Rastreligger spp*, while a negative IOD phenomenon will decrease the *Rastreligger spp* catches in Lampung waters.

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