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ENVIRONMENTAL VARIABILITY ASSOCIATED WITH EASTERN LITTLE TUNA [*Eutynnus affinis* (Cantor, 1849)] CATCHES: A CASE FOR THE NORTH INDRAMAYU WATERS, JAVA SEA

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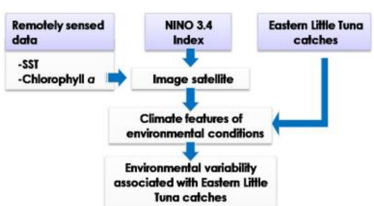
Graphical abstract



Abstract

Environmental variability during El Niño Southern Oscillation (ENSO) derived from satellite imagery of Sea Surface Temperature and Chlorophyll *a* were investigated during 2010 to 2014. This study investigates how ocean climate variability of ENSO affects environmental conditions and further addresses their relations with Eastern Little Tuna catches. Changes in environmental conditions during ENSO events resulted in perceivable variations in catches, with an average catches of 839.6 t during El Niño. The La Niña event, with an average catches of 602.6 t was less favorable for catches. Major fishing location located around 3.22-6.59°S and 108.20-109.67°E could have been suggested as the most favorable environmental condition to Eastern Little Tuna catch in the North Indramayu waters, Java Sea.

Keywords: Catch, chlorophyll *a*, eastern little tuna [(*Eutynnus affinis* (Cantor, 1849)], el niño, la niña, sea surface temperature

1.0 INTRODUCTION

Lying between Australia and Asian continents as well as Pacific and Indian Oceans causes the weather and environmental conditions in the Indonesian seas to be affected directly by El Niño/La Niña Southern Oscillation (ENSO) and also monsoon as dominant forcing mechanism in this region [1, 2]. The directly monsoon-driven circulation in the surface layer of Java Sea contributes an important oceanic connection between the tropical Pacific Ocean and the Indonesian seas. As a source and sink of the Java Sea's surface flow, the South China Sea is believed to play an important role in the connection [3].

On interannual time scales, the inflow of cold relatively fresh South China Sea water through Karimata Strait has its maximum strength around the mature phase of El Niño [3]. The Java Sea's surface water seasonally travels according to monsoonal winds. Those make the regions very dynamic and conducive to the migration of small pelagic fish.

The ENSO is a large-scale pattern of climate variability that strongly influences much of the globe. In the Pacific, the ENSO cycle causes warm phases (El Niño) and cool phases (La Niña), which have been understood to affect the catches in tuna fisheries [4, 5]. The Eastern Little Tuna [*Euthynnus affinis* (Cantor, 1849)] represents a dominant catch in the Java Sea. The Eastern Little Tuna is an epipelagic, neritic species inhabiting water temperatures ranging from 18 °C to 29 °C and tend to form multispecies schools by size. The Eastern Little Tuna is largely confined to continental shelves and islands of the western Pacific and the Indian Ocean [6].

The climate variations will change the dynamics of the environmental variability and therefore change the distribution of Eastern Little Tuna catches in the North Indramayu Waters, Java Sea. Therefore, understanding the effect of ocean climate variability on environmental conditions and Eastern Little Tuna catches is an essential step towards the sustainable management of Eastern Little Tuna resources in the Java Sea. This study investigates how ocean climate variability of ENSO affects environmental conditions and further addresses their relation with Eastern Little Tuna catch rate in the North Indramayu Waters, Java Sea.

2.0 MATERIAL AND METHODS

2.1 Study Area

The study area was in the North Indramayu Waters, Java Sea in the Indonesian Seas region focusing on geographical coordinates of 3 °S to 7 °S and 108 °E to 110 °E, as shown in Figure 1. The environmental condition in the study area is affected by the monsoon wind reversal drives the surface layer of the Java Sea southeastward, bringing relatively cool, fresh South China Sea water into the region [7].

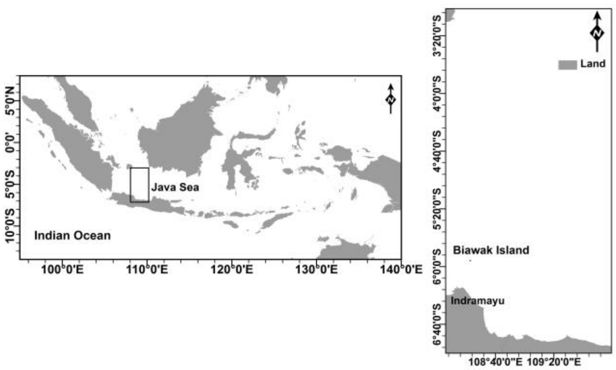


Figure 1 Map of Indonesian Seas with the inset box representing the study area in the North Indramayu Waters, Java Sea

2.2 Data Sources and Processing

This study utilized sea-surface temperature (SST), Chlorophyll *a*, Niño 3.4 index and Eastern Little Tuna catch data. The SST and Chlorophyll *a* were derived from satellite imagery of Aqua Modis and downloaded from http://oceancolor.gsfc.nasa.gov. The SST and Chlorophyll *a* data had spatial and temporal resolutions of 4 km and monthly, respectively. A time series of Eastern Little Tuna catch data were collected from fishing logbooks provided by the Fishing Port Indramayu, West Java and the Ministry of Marine Affairs and Fisheries Indonesia. The Niño 3.4 index was used as a climatic index of ENSO indicators based on SST. The index is the average SST anomaly in the region bounded by 5 °N to 5 °S and 120 °W to 170 °W. The Niño 3.4 index is available at the NOAA Climate Prediction Center (http://www.cpc.ncep.noaa.gov). El Niño and La Niña events were identified if the 5 mo running average of the Niño 3.4 index exceeded + 0.5 °C for El Niño or – 0.5 °C for La Niña for at least five consecutive month.

In this study, the fish catch and satellite remotely sensed data were analyzed for the 5 yr datasets from January 2010 to December 2014 and emphasized the differences of climate conditions during ENSO events.

3.0 RESULTS AND DISCUSSION

3.1 Climate Features of Environmental Conditions

The following results are presented to show how the different phases of ENSO affected environmental conditions in the North Indramayu Waters, Java Sea. The month that represents the La Niña (November 2010) and El Niño (November 2014) events were chosen on the basis of the month with the highest individual values in the Niño 3.4 index during El Niño and La Niña events in 2010 to 2014. The result on Figure 2 shows snapshots of monthly mean of SST during El Niño and La Niña events in the North Indramayu Waters, Java Sea.

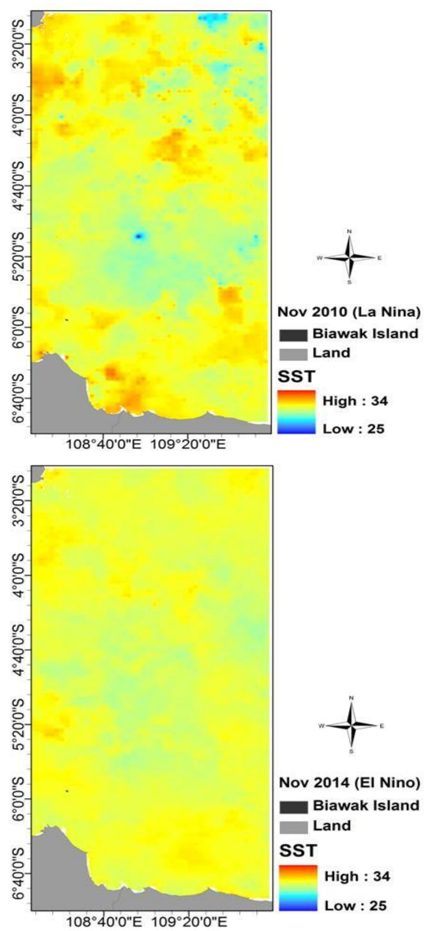


Figure 2 Mean Monthly of Sea Surface Temperature (SST) during November 2010 (La Niña) and November 2014 (El Niño)

In general, there are contrasting conditions of SST along the coast and offshore region of the Java Sea during La Niña and El Niño events. SST during La Niña in November 2010 showed warmer SST (30 °C to 33 °C) concentrating along the coast and offshore of the Java Sea due to changing monsoon from southeast to northwest, the cold SST changing to warm SST. SST during El Niño (November 2014) showed in contrasting condition with La Niña events where cold SST ranged from 27 °C to 29 °C concentrated in the offshore and 29 °C to 30 °C in the coastal area. This result is consistent with the finding of Qu *et al*. [3] who reported that the inflow of cold relatively fresh South China Sea water through Karimata Strait has its maximum strength around the mature phase of El Niño. It seems that the magnitude of El Niño affects the cold water distribution in the region.

Figure 3 shows snapshot of mean monthly of Chlorophyll *a* concentration during November 2010 (La Niña) and November 2014 (El Niño). The Chlorophyll *a* concentrations were much higher in the coastal area (1 to 3) mg m^{-3} than in the offshore (0.1 to 0.9) mg m^{-3}.

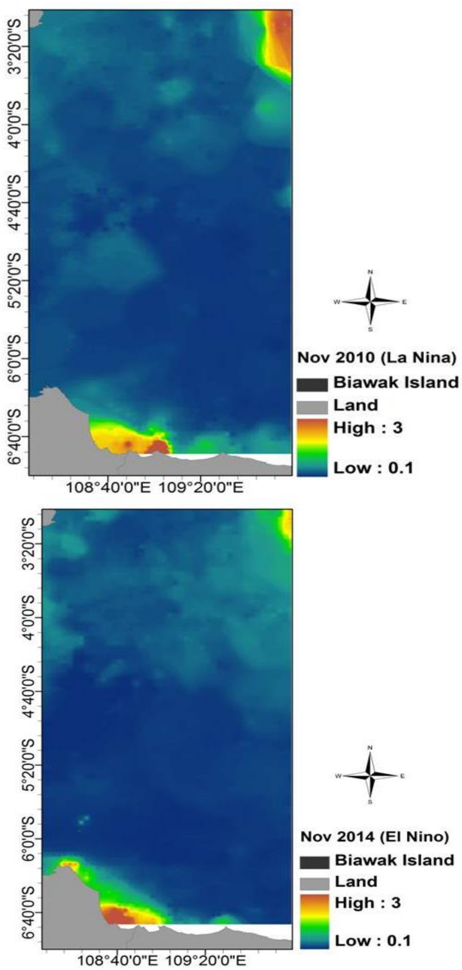


Figure 3 Mean monthly of Chlorophyll *a* concentrations during November 2010 (La Nina) and November 2014 (El Niño)

During La Niña event, higher Chlorophyll *a* concentration (1 to 3) mg m^{-3} was only found in narrow zone of the coast of Java and decreased toward offshore (0.5 to 1) mg m^{-3}. In contrast, during El Niño event, Chlorophyll *a* concentrations were higher (1 to 3) mg m^{-3} along coastal regions than they were during La Niña event. In the offshore, higher Chlorophyll *a* concentrations (0.5 to 1) mg m^{-3} spread much wider than during La Niña event.

3.2 Environmental Variability Associated with Eastern Little Tuna Catch Rates

This study has shown the effect of monsoon and ENSO events inducing environmental condition in the Java Sea. Seasonal change features were dominant for all the selected environmental parameters of SST and Chlorophyll *a*, and also Eastern Little Tuna catches, respectively. The time series plots on Figure 4 showed that the Eastern Little Tuna catch rates have the peak season from September to December (700 to 1000) ton that corresponded with the value of SST ranging from 29 °C to 30 °C following the decreasing Chlorophyll *a* concentrations in September to November (0.4 to 0.5) mg $\cdot$ m^{-3}.

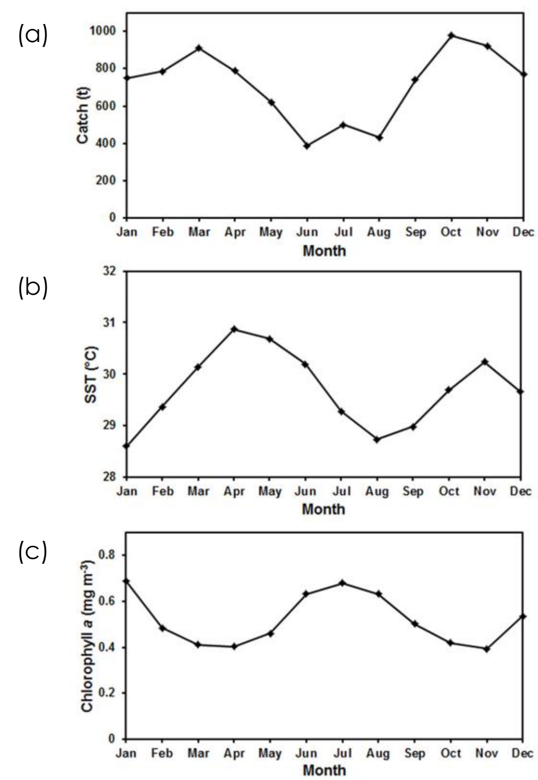


Figure 4 Mean monthly of (a) catch rate of Eastern Little Tuna, (b) SST, (c) Chlorophyll *a* during 2010-2014. The x-axis represents the month, and y-axis shows the variable value

The monsoonal system plays a great role in determining the variability of environmental conditions and catch in the Java Sea. The Eastern Little Tuna peaks during the transition season from southeast to northwest monsoon (September–December) and decreases during southeast monsoon (June to August).

The annual catch rates of Eastern Little Tuna and Niño 3.4 index during 2010 to 2014 are shown in Figure 5. Catch rates varied temporally relatively significant over year-round. Changes in environmental conditions during ENSO events resulted in perceivable variations in Eastern Little Tuna catches, with an increasing catch rates during El Niño. Catches had significant increment during El Niño (January to April 2010 and October to December 2014) compared to during La Niña events (July 2010 to April 2011 and September 2011 to March 2012). The averaged catch of 839.6 t was recorded during El Niño and 602.6 t during La Niña. Further analysis indicated that the peak season of total catch varied from year to year under different regional climatic conditions. The maximum peak of Eastern little tuna catch rates were found in April 2010 (757.5 t), October 2011 (869.4 t), September 2012 (1 368.5 t), October 2013 (1 570.9 t) and November 2014 (1 113.9 t).

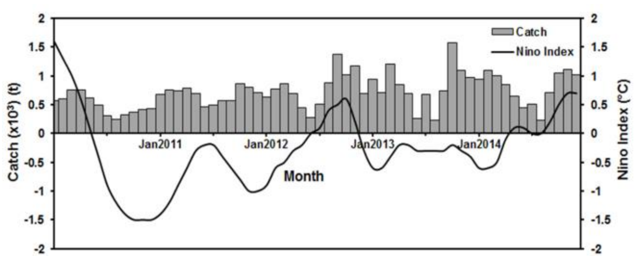


Figure 5 Variability in catch rates of Eastern Little Tuna (*Euthynnus affinis*) (grey bars) and SST anomalies from the Niño 3.4 index during 2010 to 2014 (solid line)

The peak season of Eastern Little Tuna occurred in September-December and the maximum catches occurred in April 2010 and October to December 2014 during the years of strong and moderate El Niño events, respectively. This inferred that different ocean climate events might cause different oceanographic conditions favorable to Eastern Little Tuna catches in the Java Sea. The La Niña event was less favorable for Eastern Little Tuna catches.

Spatial distribution of Eastern Little Tuna catches during El Niño and La Niña is presented together in Figure 6. The spatial variation showed that during El Niño event, Eastern Little Tuna fishing location having more conducted location as sparse in 3.22 °S to 6.59 °S and 108.20 °E to 09.67 °E than during La Niña event between 5.39 °S to 6.60 °S and 108.64 °E to 109.22 °E. The warmer SST (31 °C to 33 °C) in the offshore during La Niña was not favorable to Eastern Little Tuna in the region as we could infer from the much less catches during this period. This condition influenced the coverage of spatial distribution of Eastern Little Tuna that spread near the coastal areas. This indicates that the environmental condition during El Niño was more conducive to Eastern Little Tuna than in La Niña events and resulted in higher catch rates during El Niño than during La Niña events.

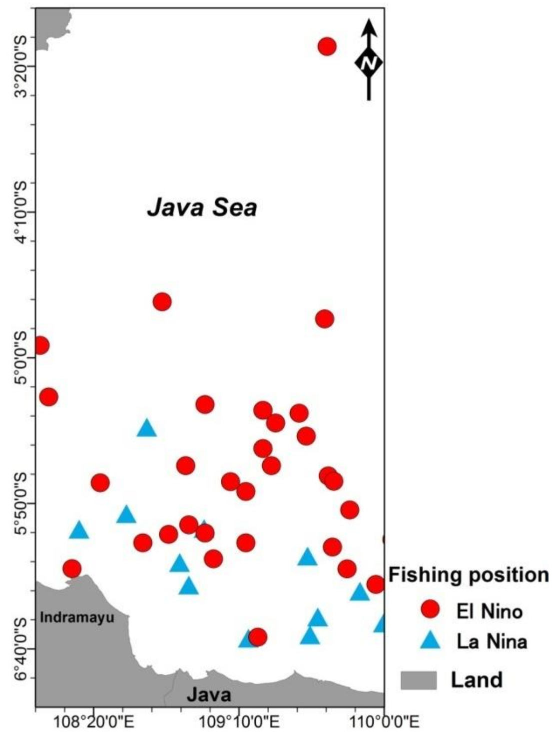


Figure 6 Spatial variation in fishing location of Eastern Little tuna (*Euthynnus affinis*) in the North Indramayu Waters, Java Sea during El Niño (red dots) and La Niña (blue triangles)

The results of present study further highlight both seasonal and interannual (ENSO) patterns affecting the environmental variability in the study area. The highest catches during El Niño and northwest monsoon are most favorable to Eastern Little Tuna catches with a specific range of SST 29 °C to 30 °C. Higher chlorophyll *a* concentration does not seem to directly influence the Eastern Little Tuna catches as shown in Figure 3. The lag time in food chain processes may explain the rather weak effect of Chlorophyll *a* concentration on Eastern Little Tuna catches [8]. Thus, SST could be considered as the main indicator of the forcing mechanisms responsible for El Niño event and Eastern Little Tuna catches. The atmosphere over the maritime continent is highly sensitive to changes in SST. SST variability is a consequence of the unique position of Indonesian seas at the confluence of the Pacific and Indian equatorial and coastal waveguides [9]. Therefore, the SST in the region can be influenced by remote equatorial wind in the Pacific and Indian Oceans.

This mechanism allows the ENSO to influence regional SST [10, 11].

The present study could identify the favorable environmental condition for Eastern Little Tuna based on the changing of climate during ENSO. Further investigations into prediction of fishing ground locations through the use of long-term datasets and additional species are needed. This information will be useful for the fishermen and policy maker to have sustainable fishing management.

4.0 CONCLUSION

This study has shown how remotely sensed data SST and Chlorophyll *a* could be used to monitor the environmental variability during ENSO events associated with Eastern Little Tuna. Catch rates of Eastern Little Tuna varied over a range of time scales and apparently in relation to environmental changes and climate variability. The monsoonal and interannual patterns play a great role in determining the environmental variability associated with Eastern Little Tuna catches in the Java Sea. The El Niño gave more favorable environmental conditions on significant high catch rates difference of Eastern Little Tuna compared to the La Niña events.

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