Seasonal Variations of Oceanographic Variables and Eastern Little Tuna (*Euthynnus affinis*) Catches in the North Indramayu Waters Java Sea

Mega Syamsuddin*, Sunarto, and Lintang Yuliadi

Department of Marine Sciences, Faculty of Fishery and Marine Science
Padjadjaran University, Jl. Raya Bandung–Sumedang KM. 21 Jatinangor 45363
Indonesia

*Email : vegha16@gmail.com

Abstract. The remotely derived oceanographic variables included sea surface temperature (SST), chlorophyll-*a* (Chl-*a*) and Eastern Little Tuna (*Euthynnus affinis*) catches are used as a combined dataset to understand the seasonal variation of oceanographic variables and Eastern Little Tuna catches in the north Indramayu waters, Java Sea. The fish catches and remotely sensed data were analysed for the 5 years datasets from 2010-2014. This study has shown the effect of monsoon inducing oceanographic condition in the study area. Seasonal change features were dominant for all the selected oceanographic parameters of SST and Chl-*a*, and also Eastern Little Tuna catches, respectively. 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 of Chl-*a* concentrations in September to November (0.4 to 0.5) mg m^{-3}. The monsoonal system plays a great role in determining the variability of oceanographic conditions and catch in the north Indramayu waters, Java Sea. The catches seemed higher during the northwest monsoon than in the southeast monsoon for all year observations except in 2010. The wavelet spectrum analysis results confirmed that Eastern Little Tuna catches had seasonal and inter-annual variations during 2012-2014. The SST had seasonal variations during 2010-2014. The Chl-*a* also showed seasonal variations during 2010-2011 and inter-annual variations during 2011-2014. Our results would benefit the fishermen and policy makers to have better management for sustainable catch in the study area.

Key words: Eastern Little Tuna, Oceanographic variables, Seasonal variations

1. Introduction

Oceanographic conditions in the Java Sea is a consequence of the unique position lying between the Indonesian islands of Kalimantan to the north, Karimata strait to its northwest, links it to the South China Sea. Due to its unique position, there is important pathway that allows water entering the Java sea from the South China Sea through the Karimata Strait [1]. The oceanographic 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 [2]. The northwest monsoon peaks in December to February and the southeast monsoon reaches its peak on June to August [3]. The region is rich with sources of interannual, seasonal, intraseasonal ocean variations that have direct impacts on the oceanographic conditions and therefore change the pelagic fish distribution.

The Eastern Little Tuna (*Euthynnus affinis*) 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 [3]. It is a highly migratory species and frequently forms large schools which are often mixed with other scombrid species. Although sexually mature fish may be encountered throughout the year, there are seasonal spawning peaks varying according to regions: i.e. March to May in Philippine waters; from the middle of the North West monsoon period to the beginning of the South East monsoon (January to July) off East Africa; and probably from August to October off Indonesia [4].

The behaviour and survival of Eastern Little Tuna have been related to a range of environmental and ecological factors, necessitating the need to combine several oceanographic factors to investigate the effects of oceanographic factors on the Eastern Little Tuna catch in the Java sea. As proxies of potential pelagic fish fishing grounds, the sea-surface temperature (SST) have been used to investigate productive frontal zones [5]. Thermal or color gradients in satellite images that arise from the circulation of water masses often indicate areas of high productivity [6]. Chlorophyll-*a* (Chl-*a*) data can also be used as a valuable proxy for water mass boundaries that can influence pelagic fish distribution in a region.

This study focus on how the ocean variations in seasonal time scale influenced the Eastern Little Tuna catch and distribution in the north Indramayu, Java sea. The satellite data included SST and Chl-*a* and Eastern Little Tuna catches are used as a combined dataset to understand the seasonal variation of oceanographic variables and Eastern Little Tuna catches in the north Indramayu waters, Java Sea. Therefore, understanding the effect oceanographic conditions and Eastern Little Tuna catches is an essential step towards the sustainable management of Eastern Little Tuna resources in the Java Sea.

2. Study area

The study area was located 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 (Figure 1). Java Sea is relatively shallow water with average depth about 40 m. It will result in good mixing of water mass creating homogenous layer from the surface to the bottom [3].

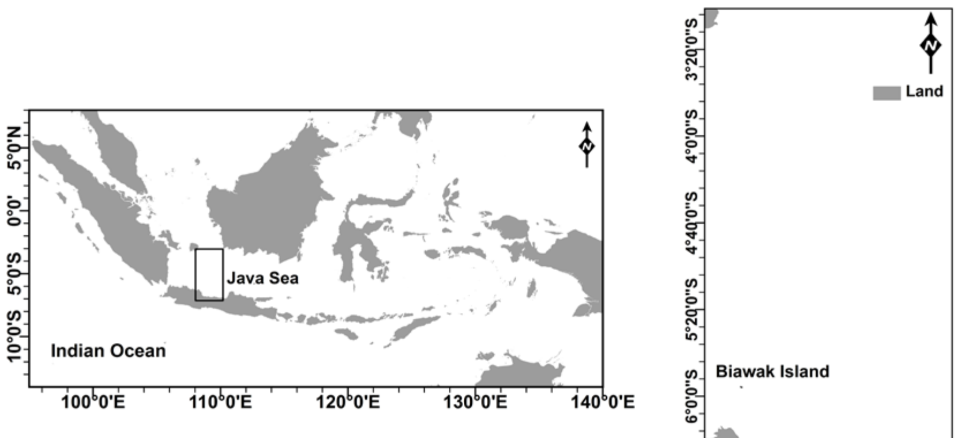

Figure 1. Map of Indonesian Seas with the inset box representing the study area

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3. Data and methods

3.1 Data

A time series of Eastern Little Tuna catch data were obtained from fishing logbooks provided by the Fishing Port Indramayu, West Java and the Ministry of Marine Affairs and Fisheries Indonesia. Data included fishing position (latitude and longitude), operational dayas, fish weight (in kilograms) and number of vessel. The remotely sensed data consist of sea-surface temperature (SST) and Chlorophyll-*a* (Chl-*a*). The SST and Chl-*a* were derived from satellite imagery of Aqua Modis and downloaded from http://oceancolor.gsfc.nasa.gov. The SST and Chl-*a* data had spatial and temporal resolutions of 4 km and monthly, respectively. For data analysis, all SST, and Chl-*a* were composed into monthly data. In this study, the fish catch and satellite remotely sensed data were analyzed for the 5 years datasets from January 2010-December 2014.

3.2 Methods

3.2.1 Wavelet Spectrum Analysis

In this study, the wavelet spectrum analysis was applied on the monthly Eastern Little Tuna catch data, SST and Chl-*a* data. The wavelet transform analysis (WT) was performed in order to obtain a more detailed structure of the variability in time and frequency domain. Wavelet analysis is used to perform a time-frequency analysis of the dominant signal and decompose the signal in different time scales and identify how these signals vary in time. The cross wavelet spectrum (XWT) was applied to find region in time frequency space where the time series show high common power .

The spectra are significant at the 95% confidence level assuming a background red noise. High energy variances are represented in red and low values are in blue as shown in the colorbars that represent different wavelet amplitude. The black line (solid contour) shows the 95% confidence level and a thin black line shows the cone of influence (COI) and are the region of the wavelet spectrum in which edge effects become important [7].

4. Result and Discussion

4.1 Mean monthly climatology of Eastern Little Tuna cathes and oceanographic variables

In more detailed understanding of catches variations and their association with oceanographic variables, we examined mean monthly climatology of SST and Chl-*a* in relation to Eastern Little Tuna catch. This study has shown the effect of monsoon inducing oceanographic condition in the west Java Sea. Seasonal change features were dominant for all the selected oceanographic parameters of SST and Chl-*a*, and also Eastern Little Tuna catches, respectively. Seasonal change features were dominant for all the selected oceanographic. The time series plots on Figure 2 showed that the Eastern Little Tuna catch rates have the peak season in March and October (900 to 1000) ton that corresponded with the value of SST ranging from 29 °C to 30 °C following the decreasing Chl-*a* concentrations in September to November (0.4 to 0.5 mg m^{-3}). The declined catches of Eastern Little Tuna in September were observed for SST values 31ºC and Chl-*a* ranging from 0.6-0.65 mg m^{-3}.

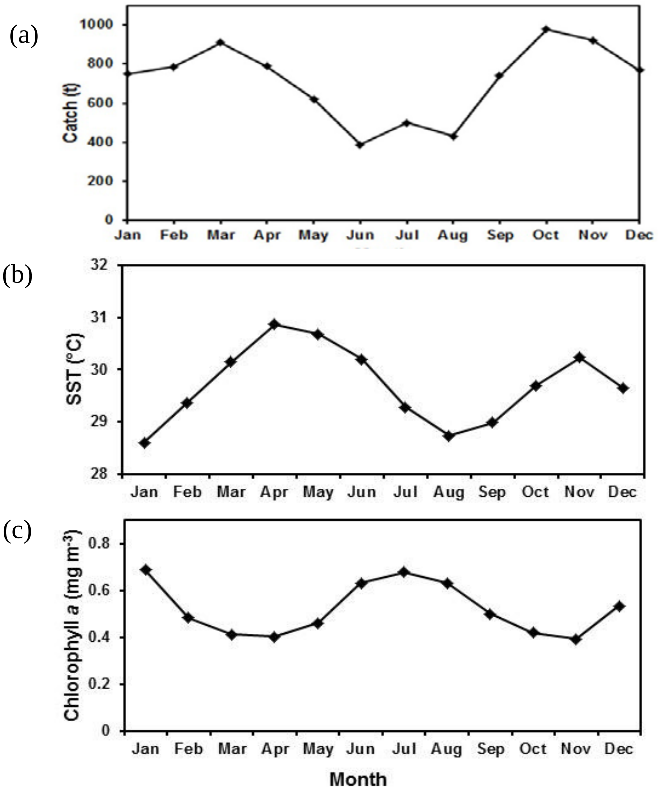

Figure 2. Mean monthly of (a) catch rate of Eastern Little Tuna, (b) SST, (c) Chl-*a* concentrations during 2010-2014. The x-axis represents the month, and y-axis shows the variable value.

4.2 Seasonal variations of Eastern Little Tuna Catches and distributions

The seasonal catch variations in Eastern Little Tuna is presented in Figure 3. In general, the total catch in northwest monsoon is higher (131000 kg) than southeast monsoon. Eastern Little tuna seemed higher during the northwest monsoon (September-February) than in the southeast monsoon (March-August) for all year observations except in 2010 due to La Niña event. SST during La Niña in November 2010 (northwest monsoon) showed warmer SST (30 °C to 33 °C) concentrating along the coast and offshore of the Java Sea, and resulted in lower catch during northwest monsoon 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 favourable for Eastern Little Tuna catches [8].

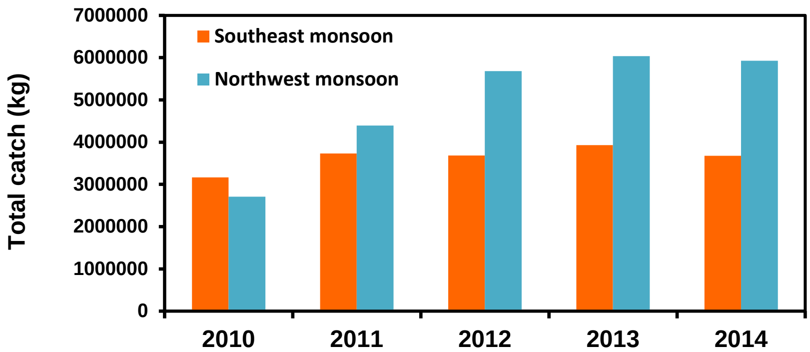

Figure 3. The seasonal variations of Eastern Little Tuna catches during 2010-2014

Based on the seasonal pattern, we differentiated between southeast and northwest monsoon over the data period 2010-2014 that displayed together in Figure 4. Eastern Little Tuna fishing locations were consistently observed between 3°15’00”S - 6°40’00”S and 108°15’00”E - 110°15’00”E, with minor variability in latitude and longitude between season and years. During northwest monsoon, Eastern Little Tuna tuna fishing location having more conducted location as sparse in 3°15’00”S - 6°40’00”S and 108°15’00”E - 110°13’00”E, than during southeast monsoon between 3°40’00”S - 6°40’00”S and 108°0’00”E - 110°15’00”E.

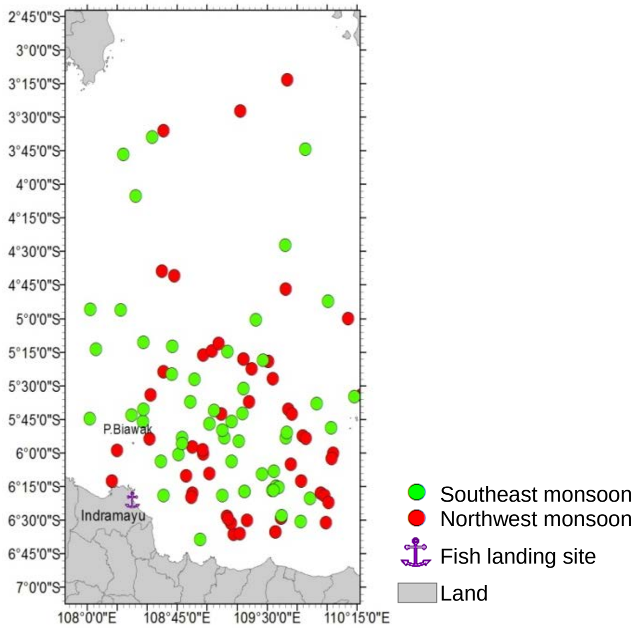

Figure 4. Seasonal variations in fishing position of Eastern Little Tuna

4.3 Wavelet spectrum analysis (CWT)

In order to clarify the physical characteristics of the seasonal change, we performed the wavelet spectrum analysis to confirm dominant signals related to amplitude (variance) and phases of Eastern Little Tuna catch, SST and Chl-*a* during 2010-2014 (Figure 5). The wavelet analysis revealed the seasonal (6 months) signal for all parameters. Eastern Little tuna catch showed seasonal signal during 2013-2014 and Chl-*a* during 2010-2011. The SST had also seasonal signal along the period of observation (2010-2014). Eastern Little Tuna showed strong interannual signal during 2013-2014. Also, Chl-*a* showed strong interannual signal occurrence for the years 2011-2014.

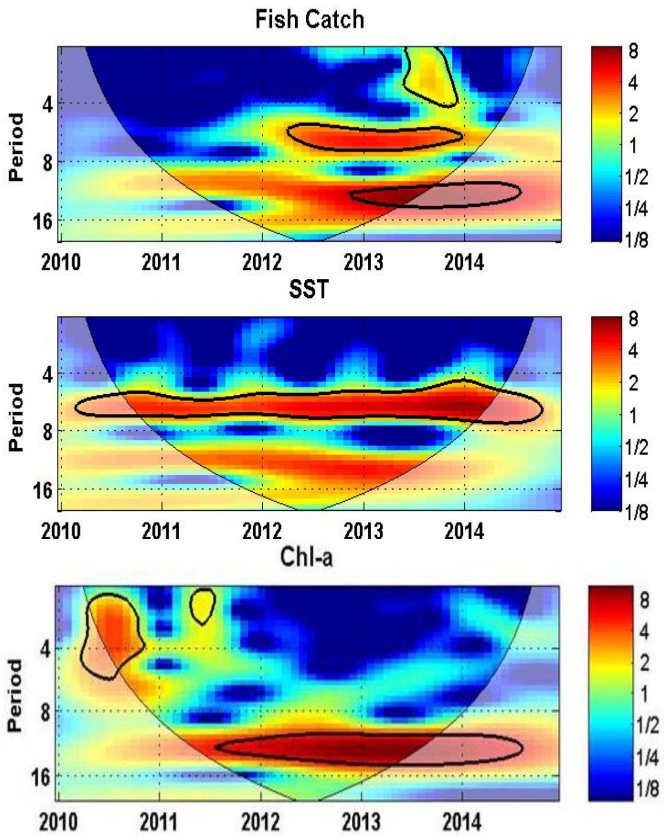

Figure 5. Wavelet Spectrum Analysis during 2010-2014

The Cross Wavelet Transform (XWT) finds regions in time frequency space where the time series show high common power. The XWT showed correlations of Eastern Little Tuna catch with SST and Chl-*a* from 2010 until 2014. The XWT signal revealed the interannual signal with the period of 16 months for all parameters (Figure 6). The XWTs between Catch and Chl-*a* indicated correlations within interannual signal of period 16 months during middle of the year of 2011-2014. The XWT between Catch and SST were also showed that there was a strong correlation within seasonal signal of period 4-8 months and interannual signal of 16 months during the year of 2012-2014. It was interesting to note here that all parameters revealed seasonal signal, and interannual signal could only been seen on Eastern Little Tuna catches and Chl-*a*. The interannual signal related to the climate regime such El Niño Southern Oscillation (ENSO) [9].

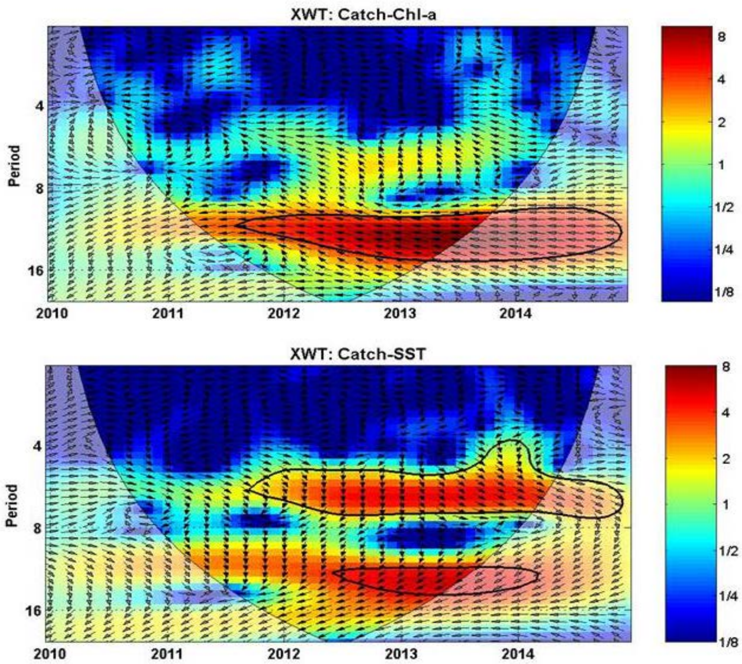

Figure 6. The cross wavelet spectrum (XWT) for Eastern Little Tuna catch in relation to SST and Chl-*a* during 2010-2014. The y-axis is represented a period (monthly) and x-axis showed the time (year). Colorbars represented different wavelet amplitude, the black line (solid contour) showed the 95% confidence level and a thin black line showed the cone of influence.

The monsoonal system plays a great role in determining the variability of oceanographic conditions and catch in the north Indramayu waters, Java Sea. Our results clearly indicated that the northwest monsoon had the most favorable oceanographic conditions to increase the Eastern Little Tuna catches in the study area. Our findings also could be used to point out the fishing ground and its changing from season to season, thus this result will be useful to know when is the best fishing season and the information will be useful for the policy maker to have sustainable fishing management of Eastern Little Tuna in the study area.

5. Conclusion

This study has shown the effects of monsoonal systems induced oceanographic conditions on Eastern Little Tuna catch and distribution in the Java Sea. The continuous wavelet analysis confirmed that all parameters (Eastern Little Tuna, SST and Chl-*a*) had seasonal variations. The cross wavelet spectrum analysis showed very clear relationship between Eastern Little Tuna catches and all oceanographic parameters to seasonal change and the interannual time scale. We recommend to have further investigations through the use of long-term historical time series to predict fishing ground locations and an emerging need to improve our climate understanding and forecast skill to conserve small pelagic catches.

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