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How do El Niño Southern Oscillation events impact on small pelagic fish catches in the west Java Sea

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Abstract. We analyse how oceanographic factors included sea surface temperature (SST), sea surface height anomaly (SSHA), and chlorophyll-*a* influence on small pelagic fish catches during El Niño Southern Oscillation (ENSO) event. The small pelagic fish catches and oceanographic factors derived from satellite imagery were analysed for the 5 years datasets (2010-2014). In this study, we demonstrate two species small pelagic fish consist of Eastern Little Tuna (*Euthynus affinis*) and Spanish Mackerel (*Scomberomorus commerson)* as representative of dominant catch in the west Java Sea. The results showed that Eastern Little Tuna and Spanish Mackerel catches had increment during El Niño than during La Niña, with an average catches of 839.6 t (Eastern Little Tuna) and 273,7 t (Spanish Mackerel) during El Niño event. The average catches during La Niña event were significantly decreased of 602.6 t (Eastern Little Tuna) and 210.3 t (Spanish Mackerel). Further analysis performs the habitat optimum related to higher small pelagic fish catches were correspond with oceanographic conditions of SST ranged from 28-29°C, SSHA from 0-8 cm and chlorophyll-*a* ranged from 0.3 - 0.5 mg.m^{-3}. This inferred that different oceanographic conditions during ENSO events might cause different of small pelagic fish catch rates in the study area.

1. Introduction

The ocean climate variability of ENSO causes warm event (El Niño) and cool event (La Niña) in the tropical Pacific, which have been known to affect the tuna fisheries in some part of the world [1]. The trade winds during El Niño weaken along the equator as atmospheric pressure rises in the western Pacific and falls in the eastern Pacific Ocean. In contrast, the trade winds during La Niña were stronger than normal and the ocean temperature were colder than normal in the tropical Pacific ocean. Impacts of La Niña on oceanographic conditions are opposite to those of El Niño events [2].

Previous studies showed that the oceanographic variability are affected directly by the variability of ENSO as well as the monsoon system [3]. The oceanographic conditions in Java Sea mostly affected by monsoon that driven ocean circulation in the surface layer. During mature phase of El Niño the relatively cold water mass of South China Sea through the Karimata Strait was maximum on inter-annual time scale [4]. 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. Climate variability of ENSO has demonstrable impacts on the tuna catches and distribution [5]. The effects of climate variability on oceanographic conditions and pelagic fish catches in the eastern Indian Ocean have been reported widely [6,7,8], but less studied in the Java Sea.

The Eastern Little Tuna represents a dominant catch in the Java Sea, followed by the Spanish Mackerel. The Eastern Little Tuna is found in ocean 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 Indian Ocean [9]. The Eastern Little Tuna is a highly migratory species and form schools with other species such Scombrid. There are seasonal spawning peaks varying according to regions: i.e. In Indonesia, from August to October; from the middle of the North West monsoon period to the beginning of the South East monsoon (January to July) off East Africa and in Philippine waters from March to May [10].

The behaviour and survival of Eastern Little Tuna and Spanish Mackerel are related to a range of oceanographic factors, necessitating the need to combine several oceanographic factors to investigate the effects of oceanographic factors on the Eastern Little Tuna catch in the west Java sea. As proxies of potential fishing grounds, sea surface height (SSH) measurement which could indicate oceanic features, as well as measurements of ocean temperature can be used to identify frontal area as a productive area [11]. A high productivity area can also be seen from thermal satellite [12]. Chlorophyll-*a* concentrations have been used as indicator for water mass boundaries that can influence small pelagic fish distribution in the study area.

On the other hand, there seems to be only a few studies of the oceanographic variability impacts on Eastern Little Tuna and Spanish Mackerel distributions in the Java Sea. The satellite data included SSHA, SST and chlorophyll-*a* are used to understand ENSO impacts on two species of small pelagic fish in west Java Sea. Therefore, understanding the effect of ENSO on Eastern Little Tuna and Spanish Mackerel will enhance our ability to minimize the risk of ocean climate impacts and to have sustainable management of small pelagic fish in the Java Sea.

2. Research area

The research area was in the west Java Sea in the Indonesian Sea region focusing on geographical coordinates of 3 °S to 7 °S and 108 °E to 110 °E (figure 1).

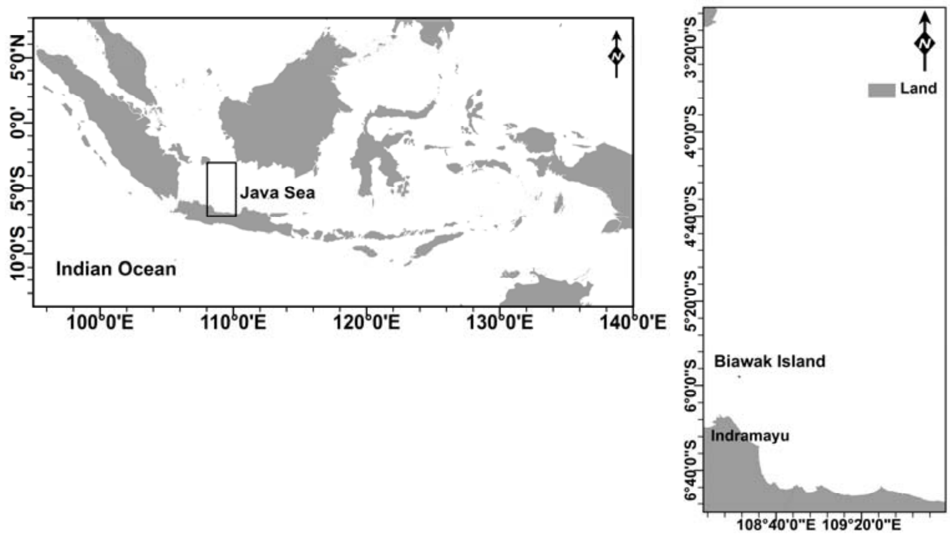

Figure 1. The study area in the west Java Sea, Indonesian Seas.

3. Data and methods

3.1. Data

In this study, we utilized fish catch and oceanographic parameter derived from remote sensing data. The fish catch data provided by the Fishing Port Indramayu, Indonesia. Data consist of the fishing position and total monthly catches. The remotely sensed data consist of SST, SSHA and chlorophyll-*a* concentrations. 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 resolutions of 4 km and temporal resolutions of monthly data. The SSHA data derived from the TOPEX and Poseidon ERS-1/2 altimeters which are downloaded at http://aviso.altimetry.fr. All oceanographic parameter resampled into 9 km spatial resolution and were analyzed for the 5 years datasets from January 2010-December 2014 during ENSO events. We used the climatic index of Niño 3.4 as indicator of ENSO based on SST anomaly in the Niño 3.4 region.

3.2 Methods
In this study, the continous wavelet transform (CWT) analysis was applied on the monthly of small pelagic catches, SST, SSHA, and chlorophyll-*a* data. The wavelet transform analysis (WT) was performed to obtain the temporal distributions the ocean variability during 2010-2014. Wavelet analysis performs 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 wavelet transform has been successfully applied in climate studies [13].

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) [14].

4. Result and discussion

4.1. Climate feature of oceanographic conditions
We have chosen the month that represents the La Niña (October 2010) and El Niño (November 2014) events based on the Niño 3.4 index values during ENSO events in 2010 to 2014. The result on figure 2 shows snapshots of monthly mean of SST represented the El Niño and La Niña.

During La Niña in 2010, the SSHA value tends to be higher in the range of 1-25 cm. In contrast, during El Niño, the SSHA showing a lower value range from (-15) to (-10) cm (figure 2a). In general, the SST along the coast and offshore region shows a contrast conditions during El Niño and La Niña events. SST during La Niña in October 2010 showed warmer SST (30 °C to 31 °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 (figure 2b). Our result is similar with the research finding of Qu *et al*. [3] who reported there was maximum inflow of cold relatively fresh South China Sea water during the mature phase of El Niño event. It seems that the magnitude of El Niño affects the cold water distribution in the region.

Figure 2c 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 1.5) mg.m^{-3} than in the offshore (0.1-0.9) mg.m^{-3}.

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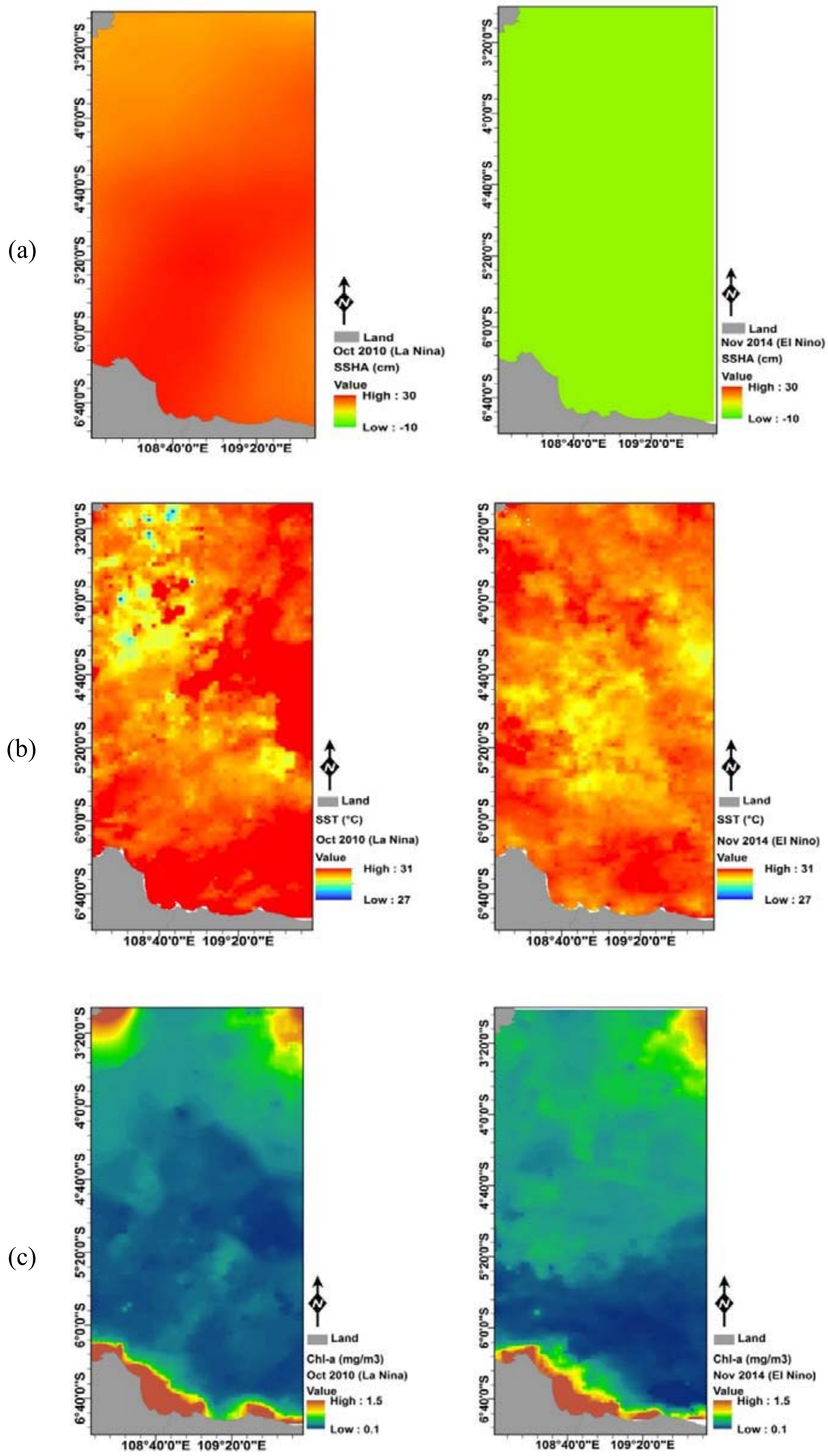


Figure 2 Mean Monthly of oceanographic factors of (a) SSHA, (b) SST and (c) Chlorophyll-*a* in October 2010 (La Niña) and November 2014 (El Niño).

4.2. Oceanographic factors associated with small pelagic fish cathes

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 SSHA, SST and chlorophyll-*a*, and also small pelagic fish catches, respectively. The time series plots on figure 3 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 SSHA from 4 to 8 cm, SST from 29 °C to 30 °C following the decreasing chlorophyll-*a* concentrations in September to November (0.4 to 0.5 mg.m^{-3}). Spanish Mackerel catch peaks in December with relatively high SSHA conditions 12 cm, SST ranging from 29-30˚C, and chlorophyll-*a* concentration from 0.4 - 0.5 mg.m$^{-3.}$

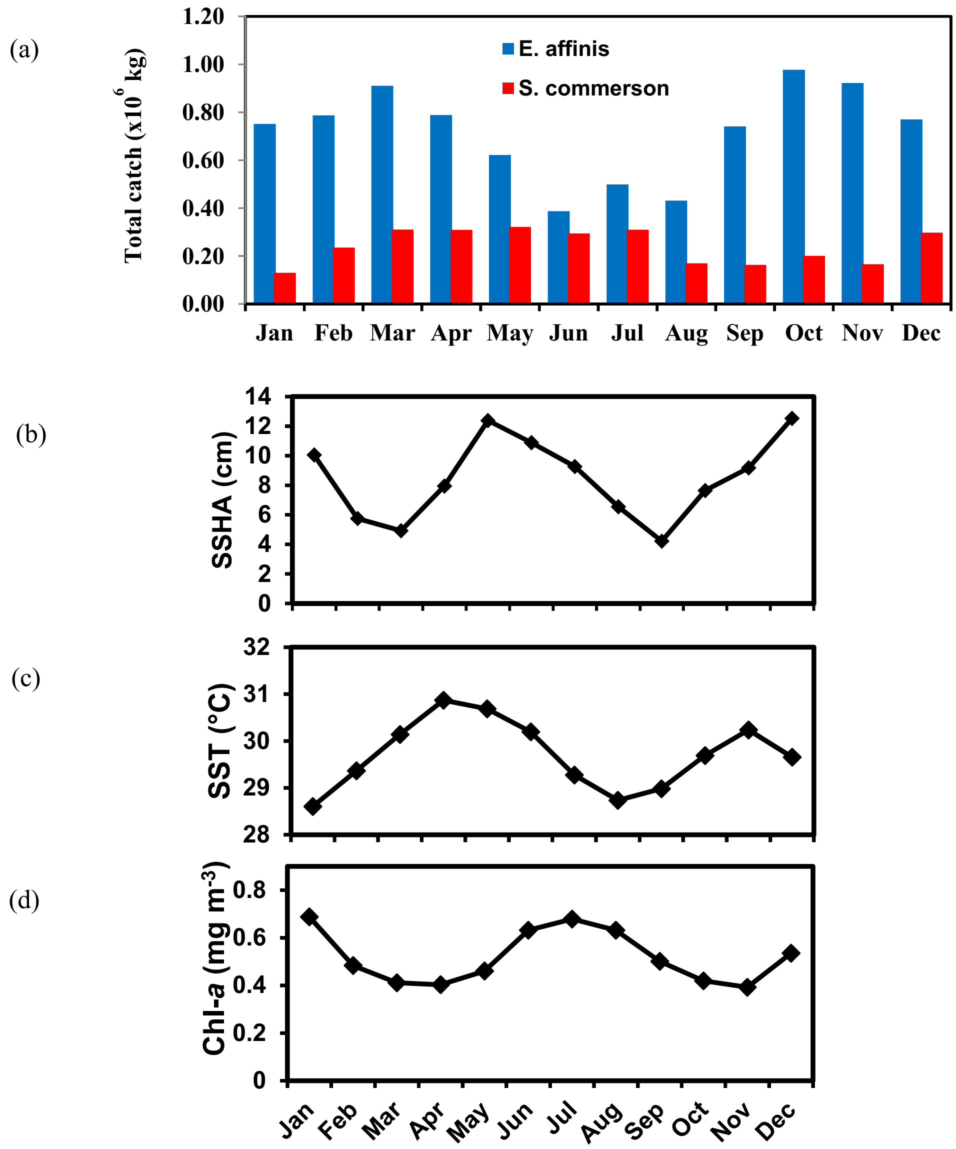


Figure 3 Mean monthly of (a) catch rate of Eastern Little Tuna and Spanish Mackerel, (b) SSHA, (c) SST, (d) Chlorophyll-*a* concentration during 2010-2014.

4.3. Variability of small pelagic fish and oceanographic conditions during ENSO events

The annual catch rates of small pelagic fish catches (Eastern Little Tuna and Spanish Mackerel) and Niño 3.4 index during 2010 to 2014 are shown in figure 4a. Catch rates varied temporally relatively significant over year-round. The oceanographic condition are change during ENSO events and associate with the Eastern Little Tuna and Spanish Mackerel catches, with higher catch rates during El Niño event. Catches are higher 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).

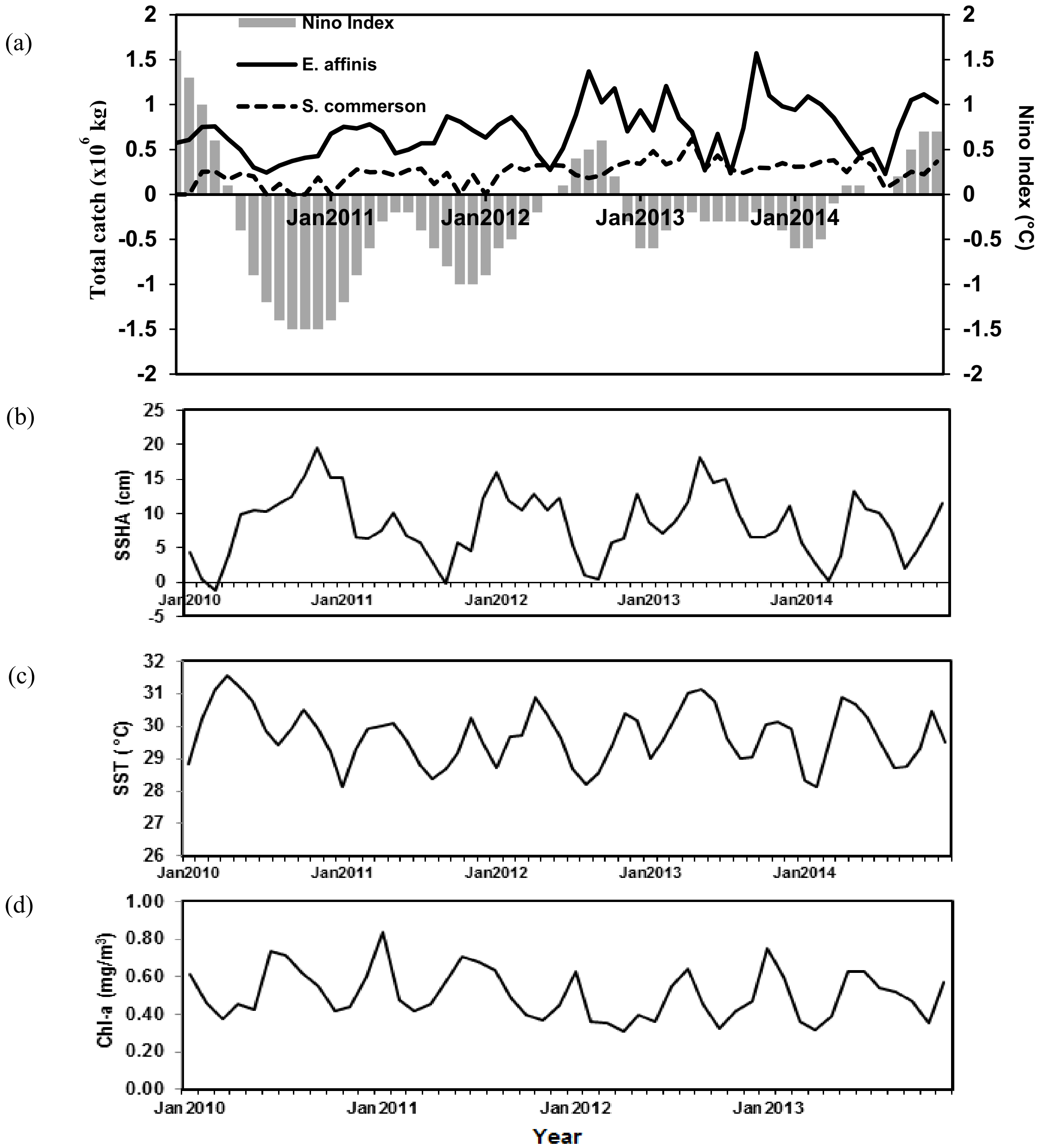


Figure 4 (a) Eastern Little Tuna (solid line) and Spanish Mackerel (dash line) catch rates and Niño 3.4 index during 2010 to 2014 (grey bars); (b) SSHA; (c) SST; (d) Chlorophyll-*a.*

Figures 4b-d showed the temporal variability of the oceanographic parameters of SSHA, SST and chlorophyll-*a*, respectively. During La Nina (July 2010-April 2011 and September 2011-March 2012), positive values of SSHA ranging from 2-20 cm following with increasing SST value ranging from 29.5-31°C, and decreasing Chl-*a* concentration from 0.4-0.7 mg · m^{-3}. The oceanographic variables in January 2010-April 2010 and October 2014-December 2014 (El Nino) showed in contrast condition with La Nina events where negative and lower SSHA -2 to 9 cm corresponding with colder SST of 29-30.5, and Chl-*a* concentration ranging from 0.4-0.6 mg · m^{-3}.

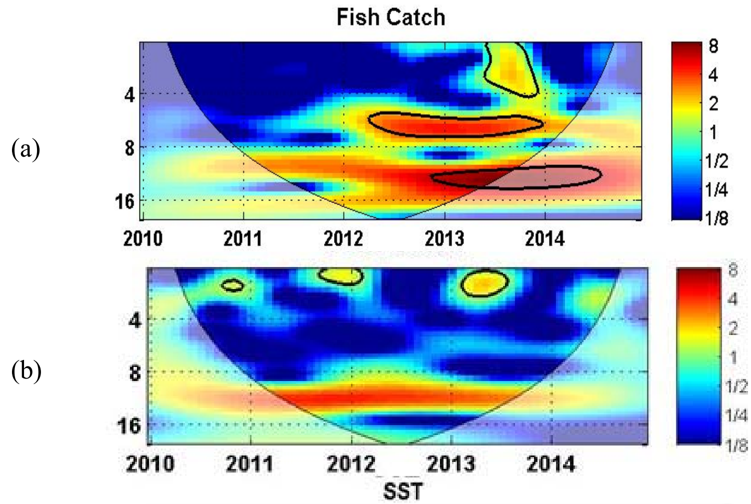
The conducive oceanographic conditions during El Niño resulted in increasing of fish catches, with an average catches of Eastern Little Tuna of 839.6 t and Spanish Mackerel of 273,7 t. The catch rates of both species were decreased with an average catches of 602.6 t (Eastern Little Tuna) and 210.3 t (Spanish Mackerel) during La Niña event. We also found that the peak season of total catch of small pelagic fish varied from year to year during ENSO events. 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).

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 El Niño events. It seems that the oceanographic conditions was less favorable for small pelagic catches during La Niña than during El Niño. Our research concluded that ENSO events might cause different oceanographic conditions favourable to Eastern Little Tuna and Spanish Mackerel catches in the Java Sea.

4.4. Wavelet spectrum analysis

The dominant periods related to the amplitude and phase time series were computed by the wavelet analysis. The wavelet analysis confirmed dominant signals related to amplitude (variance) and phases of small pelagic fish catches, SSHA, SST and chlorophyll-*a* during 2010-2014 (figure 5).

The wavelet analysis revealed the seasonal (6 months) signal of Eastern Little Tuna, Spanish Mackerel, SST (period of 2010-2014), SSHA (middle of 2012-2014) and chlorophyll-*a* (April-October 2010, and May-July 2011). Strong interannual signal (16 months) was observed in Eastern Little Tuna catches, SSHA and Chl-a. The seasonal signal of Spanish Mackerel indicated that this species does not have direct correlation with ENSO because inter-annual signal could only be seen on Eastern Little Tuna catches.



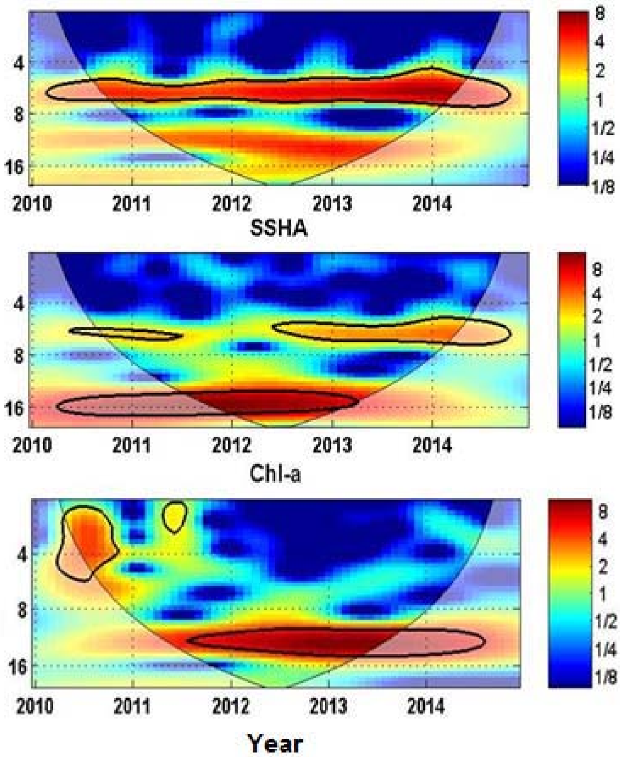


Figure 5. Wavelet power spectrum for small pelagic fish catches (a) Eastern Little Tuna; (b) Spanish Mackerel (c) SST; (d) SSHA; and (e) Chlorophyll-*a* based on raw data (monthly mean) during 2010-2014. The y-axis is represented a period frequency (monthly) and x-axis showed the time (year). Colorbars represented different wavelet amplitude, the black line (solid contour) showed the 95% confidence level and a thin black line showed the cone of influence.

5. Conclusion

The results of present study further highlight both seasonal and interannual (ENSO) patterns affecting the the small pelagic fish catches and oceanographic conditions in the study area. Higher catch rates of Eastern Little Tuna and Spanish Mackerel catches occurred during El Niño event. The wavelet analysis confirmed that Eastern Little Tuna, SSHA and Chl-*a* affected by the ENSO in inter-annual signal.

We recommend to have further investigations by using long-term time series datasets to predict fishing ground locations and an emerging need to improve our climate understanding and forecast skill to conserve small pelagic catches in the region.

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