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IMPACT OF DIPOLE MODE AND EL-NINO EVENTS ON CATCHES OF YELLOWFIN TUNA (*Thunnus albacares*) IN THE EASTERN INDIAN OCEAN OFF WEST JAVA

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ABSTRACT

The impact of Indian Ocean Dipole Mode (IOD) and El Niño-Southern Oscillation (ENSO) events on catches of yellowfin tuna (*Thunnus albacares*) (YFT) in the Eastern Indian Ocean (EIO) off Java was analyzed through the use of remotely sensed environmental data (sea surface temperature/ SST and chlorophyll-a concentration/ SSC) and yellowfin tuna catch data. Analyses were conducted for the period of 2003–2012, which included the strong positive dipole mode event in association with weak ENSO in 2006. Yellowfin tuna catch data were based from the report of Palabuhanratu fishing port and remotely sensed environmental data were based from MODIS-Aqua_NOAA. IOD has a significant effect on the catch composition and proportion of YFT. In the strong positive dipole mode event in 2006 and weak ENSO events in 2011 and 2012 the catch of YFT was higher than normal period. An increasing Catch Per Unit Effort **(**CPUE) of YFT started from May-June and reached the peak on September-October was noted, this might be due to upwelling evident before the increasing trend observed. High increase of YFT-CPUE occurred during strong positive dipole mode event (2006) and a weak ENSO events (2011 and 2012) might be related to the increase of abundance and distribution of chlorophyll-a and phytoplankton in those period. In contrast, YFT- CPUE was very low at the La-Nina event in 2005 while this species was still dominant in the catch composition compared to other tuna species.

Keywords: *Indian Ocean Dipole mode, yellowfin tuna, Eastern Indian Ocean off west Java*

INTRODUCTION

Eastern Indian Ocean (EIO) is the unique water because of its geography influenced by water masses in the Western Indian Ocean (WIO) and the outflow water masses from the Pacific Ocean. Both of these water masses affect the variability of oceanographic conditions in this area. In addition, the location of its waters are in the monsoon wind system causing conditions of oceanographic is affected by monsoon winds system (Wyrtki, 1961). Winds over the Indonesian maritime continent and the position of the Intertropical Convergence Zone (ICZ) are dominant features of strong monsoon signatures in this area. During the southeast monsoon (May to October), southeasterly winds from Australia generate upwelling along the southern coasts of Java and Bali. Upwelling events led to the concentration of chlorophyll-a increased so that the primary productivity (Wyrtki, 1962; Purba, 1995). These conditions are reversed during the northwest monsoon (November to April) (Gordon, 2005). EIO off west Java is rich in fishery resources of tuna species and landed in the Palabuhanratu Fishing Port (Mertha, 2006). The tuna species in this area exploited by using variety of fishing gears: long line, purse seine, gillnet, troll line and pelagic Danish seine.

Variability of water masses in the EIO is very high, associated with the intrusion of water masses from other regions such as the Indonesian Through Flow (ITF), the dynamic of monsoon wind system (Wyrtki, 1961; Purba et al, 1997), and global climate change and Indian Ocean Dipole Mode (IOD) (Saji et al, 1999; Shinoda et al, 2004). Saji et al, (1999) defines IOD as a symptom of climate aberrations due to the interaction of the sea and the atmosphere at certain times which shows the pattern of temperature deviations variability in the western and eastern Indian Ocean. It is associated with wind direction and precipitation deviations. Dipole mode structure is characterized by anomaly of Sea Surface Temperature (SST). Positive dipole mode event occurs when WIO warmer than normal and EIO cooler than normal. Furthermore, negative dipole mode events cause the opposite effects. While El Nino Southern Oscillation (ENSO) is phase of difference air pressures that global sea level between Indonesia and Southeast Pacific Ocean (Quin et al. 1978). Both of these climate phenomena directly affect oceanographic conditions in the Indian Ocean and it is believed also affect to the distribution and abundance of fish resources, including the tuna species.

Various studies suggest that the distribution and abundance of tuna are influenced by several oceanographic parameters. Variations in water temperature have an important role in determining the spatial distribution of tuna species (Laevastu and Rosa, 1963; Squire, 1982). Yellowfin tuna (*Thunnus albacares*) are spreaded vertically constrained by thermocline (Longhurst and Pauly, 1987), while albakora and big eyes tuna usually live below the thermocline (Laevastu and Hayes, 1982).

Most of the tuna research in the Indian Ocean are generally examined the relationship between several oceanographic parameters particularly the distribution of bigeye tuna (*Thunnus obesus*), as reported by Mohri and Nishida (1999), Song et al, (2009), Song and Zhou, (2010). As for the relationship between oceanographic factors linked with the ENSO climate anomalies reported by Yoder and Kennely (2003); Gaol (2003) and Shamsuddin et al, 2013. While study for yellowfin tuna have not been widely reported.

This paper aims to examine the influence of climate anomalies (IOD) and ENSO in the Indian Ocean waters, especially in the eastern part of West Java (EIO off west Java) to catch of yellowfin tuna (*Thunnus albacares*).

MATERIALS AND METHODS

The study area was located in the EIO, south of West Java, spanning between 100^0 - $110.^0$ BT and 7.0^0 - 12^0 LS (Figure 1).

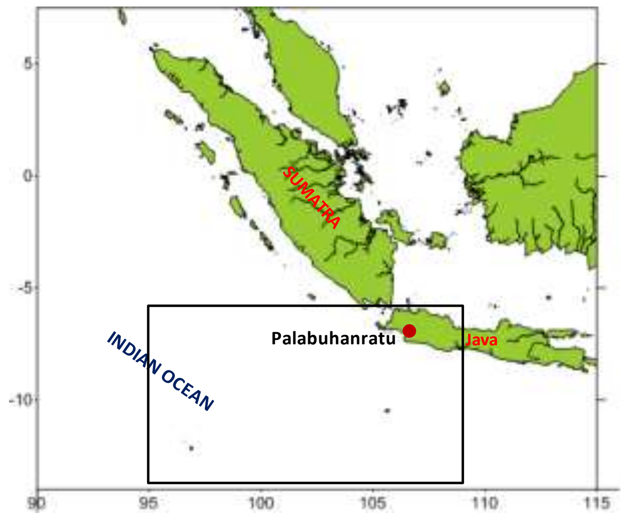


Figure 1. Map of the EIO, with the inset box representing the study area in the West Java

For this study, we used yellowfin tuna catches data and oceanographic data consist of SST and chlorophyll-a or Sea Surface Chlorophyll-a (SSC) satellite remote sensing measurements. Yellowfin tuna catches data and oceanographic satellites data used for observation of the 10-year period from 2003 to 2012. During this period there are IOD and ENSO events (Table 1): 2003 (weak positive IOD), 2005 (weak La-Nina), 2006 (strong positive IOD and weak ENSO), 2007 (weak positive IOD and moderate La-Nina), 2008 (weak positive IOD); 2009 (moderate El-Nino), 2010 (strong La-Nina), 2011 and 2012 (weak). In 2006, 2007 and 2008 were the triple consecutive positive IOD events.

Table 1. List of IOD and ENSO Events 2003-2012

Dipole mode		Association	ENSO		Normal	Year
Positive	Negative		El-nino	La-nina		
						2003
					normal	2004
				weak		2005
strong		+	weak			2006
weak		+		Moderate		2007
weak						2008
			Moderate			2009
				strong		2010
			weak			2011
			Weak			2012

Climate anomalies (IOD and ENSO) are being indicated from SST. SST satellite images were used in this study measured by the MODIS sensor (Moderate Resolution Imaging Spectroradiometer) aqua satellite during 2003-2012 (http://gdata1.sci.gsfc.nasa.gov/). SST is estimated using MODIS standard algorithm 11 lm NLSST Algorithm (http://nasa.gsfc.gov).

Chlorophyll-a concentration estimates obtained with OC3M based on algorithm (O'Reilly et al., 2000). The data has spatial resolution 4 km and monthly format.

Yellowfin tuna catches report were obtained from the Nusantara Fishery Port/ Pelabuhan Perikanan Nusantara (PPN) Palabuhanratu, West Java. The data is landing vessels datasheet owned by tuna fishing companies (with longline fishing gear) and individuals or groups of fishermen (longline, gillnet and troll line). It consists of catches number per month (in kilograms) by fishing gear, boats and the number of trips per month and the number of trapping sites and locations where operations FADs ships troll line. Figure 2 shows fishing ground of troll line and long line which have fishing base in Palabuhanratu. The fishing ground of troll line is generally laid close to fish aggregating devices (FADs).

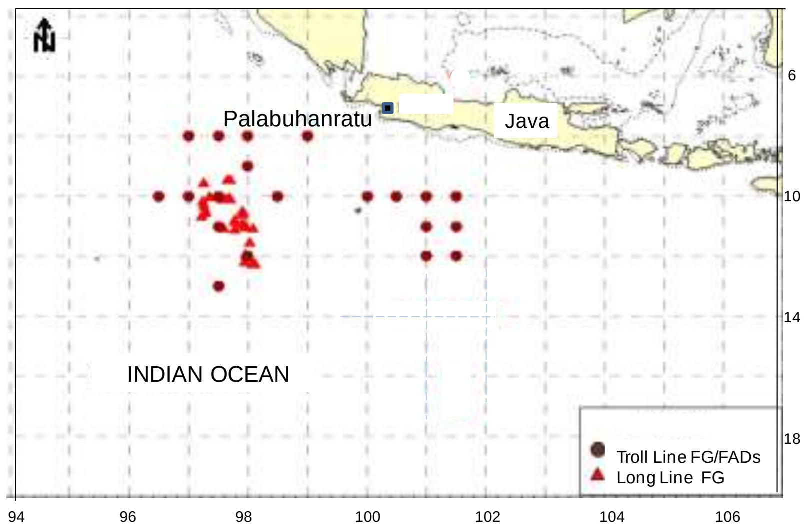


Figure 2. Map of the fishing ground of yellowfin tuna (fishing gear: longline and troll line) in EIO off West Java

The data was analyzed descriptively by comparing the pattern of catches between the years with the IOD and ENSO events on yellowfin tuna catches.

RESULTS

Features of oceanographic conditions

This area has complex dynamic currents and wave systems (Syamsuddin *et al*, 2012). The dominant current and wave features consist of (Figure 3): 1) ITF, outflow water from the Pacific Ocean (Molcard *et al*., 2001; Gordon *et al*., 2010); 2) the seasonally reversing South Java Current (SJC) along the southern coast of the Indonesian Sea (Sprintall et al., 2010); 3) the Indian Ocean South Equatorial Current (SEC) flows from the southern Indian Ocean to an area off southern Java (Zhou et al., 2008); 4) downwelling Indian Ocean Kelvin Waves (IOKWs) that propagate to the east along the coasts of west Sumatra, Java, and the Lesser Sunda Islands (Syamsudin et al., 2004); and 5) westward Rossby Waves propagation at 12–15°S (Gordon, 2005; Sprintall et al., 2009). Besides those current and wave systems, winds over the Indonesian maritime continent and the position of the ICZ are dominant features of strong monsoon signatures. During the southeast monsoon (May to October), southeasterly winds from Australia generate upwelling along the southern coasts of Java and Bali. While the opposite was observed during the northwest monsoon (November to April) (Gordon, 2005).

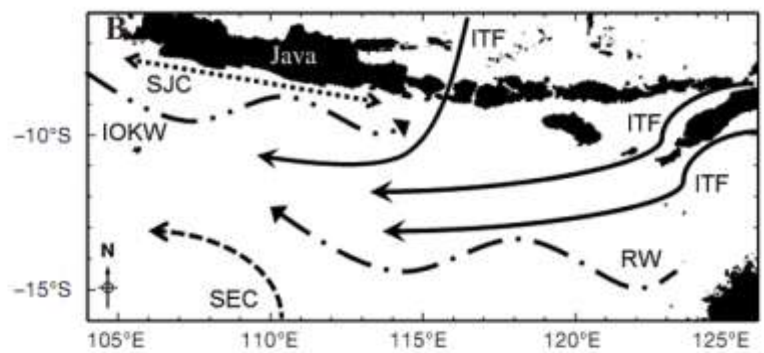


Figure 3. The wave and current systems in the East Indian Ocean off Java are indicated by the dotted line for the South Java Current (SJC), solid lines for the Indonesian Throughflow (ITF), the line with dashes and 2 dots for the Indian Ocean Kelvin Waves (IOKWs), the line with dashes and 1 dot for the Rossby Waves (RWs), and the dashed line for the Indian Ocean South Equatorial Current (SEC) (source: Syamsuddin *et al*, 2012)

Intensity of upwelling in southern Java-Bali increases when the climate anomaly and a positive IOD or El - Nino occurs, while upwelling have not found during negative IOD and La Nina events (Gaol, 2003; Amri et al., 2012). Furthermore, SPL had observed lower than normal (negative anomalies) during positive IOD event, (Saji et al., 1999; Webster et al., 1999).

Upwelling is triggered by the strengthening wind anomalies along the southern coast of Sumatra and Java and east winds along the equator indicated by positive IOD events. The strengthening winds push water away from the coast or the mass of the equator, hence vacant water masses occurs along the southern west coast of Sumatra and Java. The surface layer of waters are replaced by bottom layer of water (upwelling occurs). Upwelling brings nutrient -rich water mass to the surface, thus increasing the primary productivity, marked increase in the distribution of chlorophyll-a (phytoplankton). Upwelling areas are generally having high productivity of fish.

Figure 4 shows the SST images in EIO waters off west Java. Relative high intensity upwelling is indicated by the decrease of SST. It is occurred in 2003 (weak positive IOD), 2006 (strong positive IOD and weak El - Nino), 2007 (weak positive IOD and moderate La - Nina), 2008 (weak positive IOD) and 2009 (moderate El - Nino). High intensity of upwelling also occurs during El - Nino events in 2011 and 2012. Highest upwelling intensity is indicated by low SST in certain area reached the most extensive water mass was occurred in 2006, associated with strong positive IOD by mid-year and followed by a weak El - Nino events at the end of the year. In contrast, during the negative IOD/ La - Nina events the upwelling was not occured: 2005 (weak

La - Nina) and 2010 (strong La - Nina). In a normal year (2004) upwelling occurs with normal intensity (low).

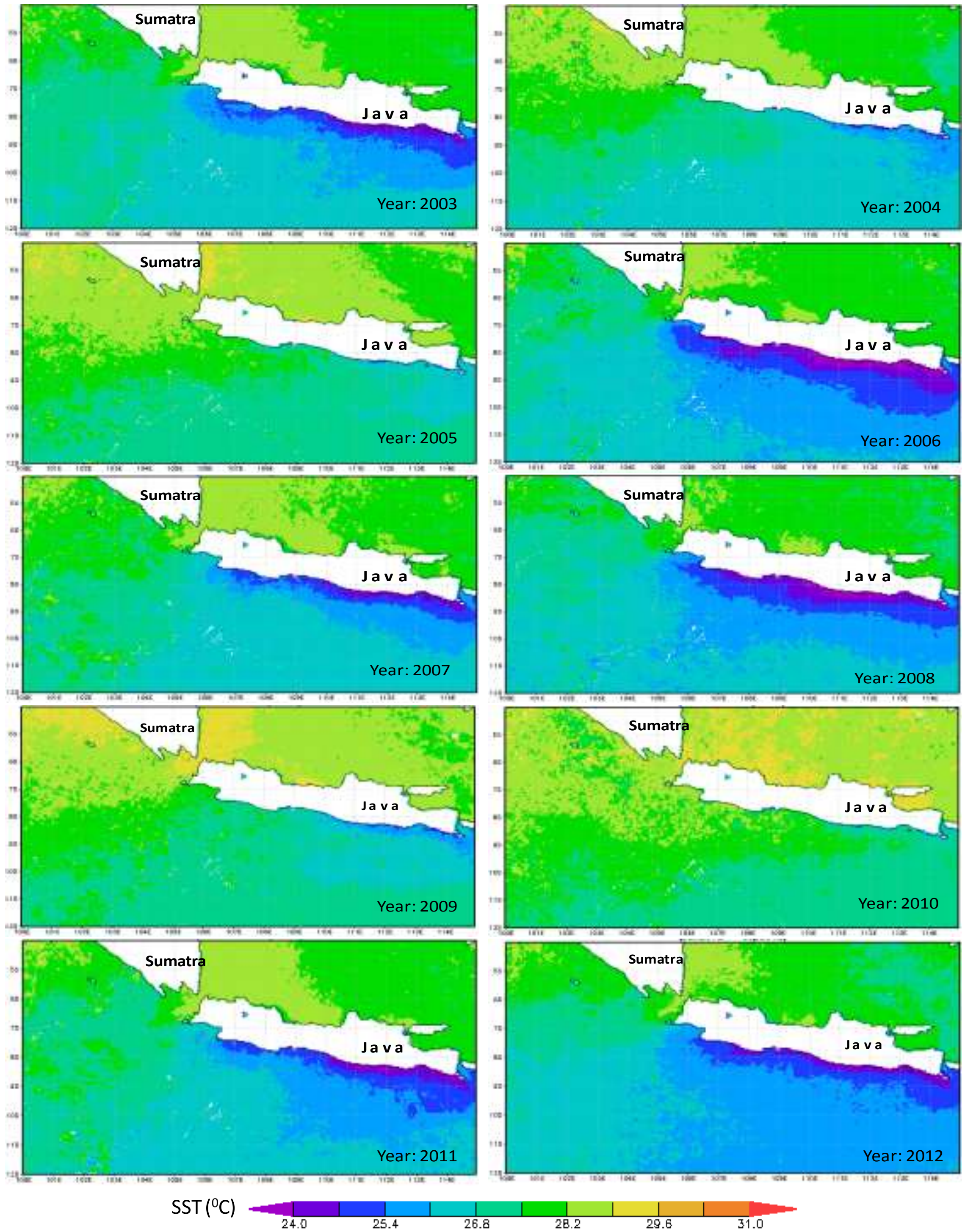


Figure 4. SST images (blue color indicated that upwelling water mass with lower SST on Positive IOD/ El-Nino events) in EIO off West Java

SST distribution value at the location of fishing ground of longline and troll line in the southern west Java (Appendix 1) in 2003 ranged from 26.8-29.12 ^{0}C (average 27.91 ^{0}C); 2004 26.51-29.06 ^{0}C (average 27.88 ^{0}C); 2005 ranged from 27.10 - 29.92^{0}C (average 28.05^{0}C); 2006 25.30-29.22 ^{0}C (average 27.65^{0}C); 2007 ranged from 27.17 - 29.21^{0}C (average 27.97^{0}C); 2008 ranged from 26.73 - 29.07^{0}C (average 27.72^{0}C); 2009 ranged from 27.02 - 29.04^{0}C (average 28.24^{0}C); 2010 range from 27.33 - 30.06^{0}C (average 28.65^{0}C); 2010 range from 25.91 - 29.00^{0}C (average 27.69^{0}C) and 2012 ranged from 26.12 - 28.59^{0}C (average 27.52^{0}C). Low average value of SST distribution occurs when the positive IOD events (2003, 2006, 2007, and 2008) as well as the El - Nino events (2011 and 2012). High average value of SST were observed during weak and strong La-Nina events (2005 and 2010). Figure 5 shows the average value of SST distribution in the Southern West Java by IOD and ENSO events. The lowest average value of SST distribution were found during positive IOD event (year 2006: 27.65^{0}C) and El - Nino event (year 2012 : 27.52^{0}C), while the highest value of SST were found during the strong La - Nina events (year 2010: 28.65^{0}C).

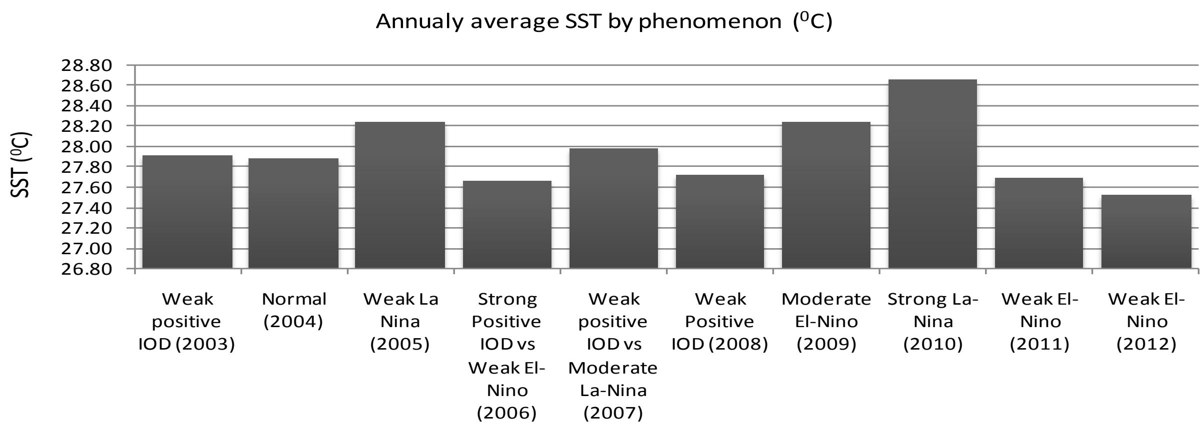


Figure 5. Annual average of SST during anomaly phenomenon in EIO off west Java 2003-2012

Figure 6 displays the image of the surface distribution of chlorophyll-a (SSC) of EIO waters off west Java. Increasing value of chlorophyll-a distribution correspond with high spread value and distribution of a wide area occurred in the years of intensive upwelling is the positive phase of the IOD events (2003, 2006, 2007, and 2008) as well as the El-Nino events (2009, 2011 and 2012). Distribution of chlorophyll-a value of the lowest found in the La-Nina events (2005 and 2010). Value distribution of chlorophyll-a in the La-Nina events is lower than the normal phase (2004). The location of the increased value of the distribution of chlorophyll-a is identical to the location of the SPL reduction proving that enrichment of chlorophyll-a occur due to upwelling events.

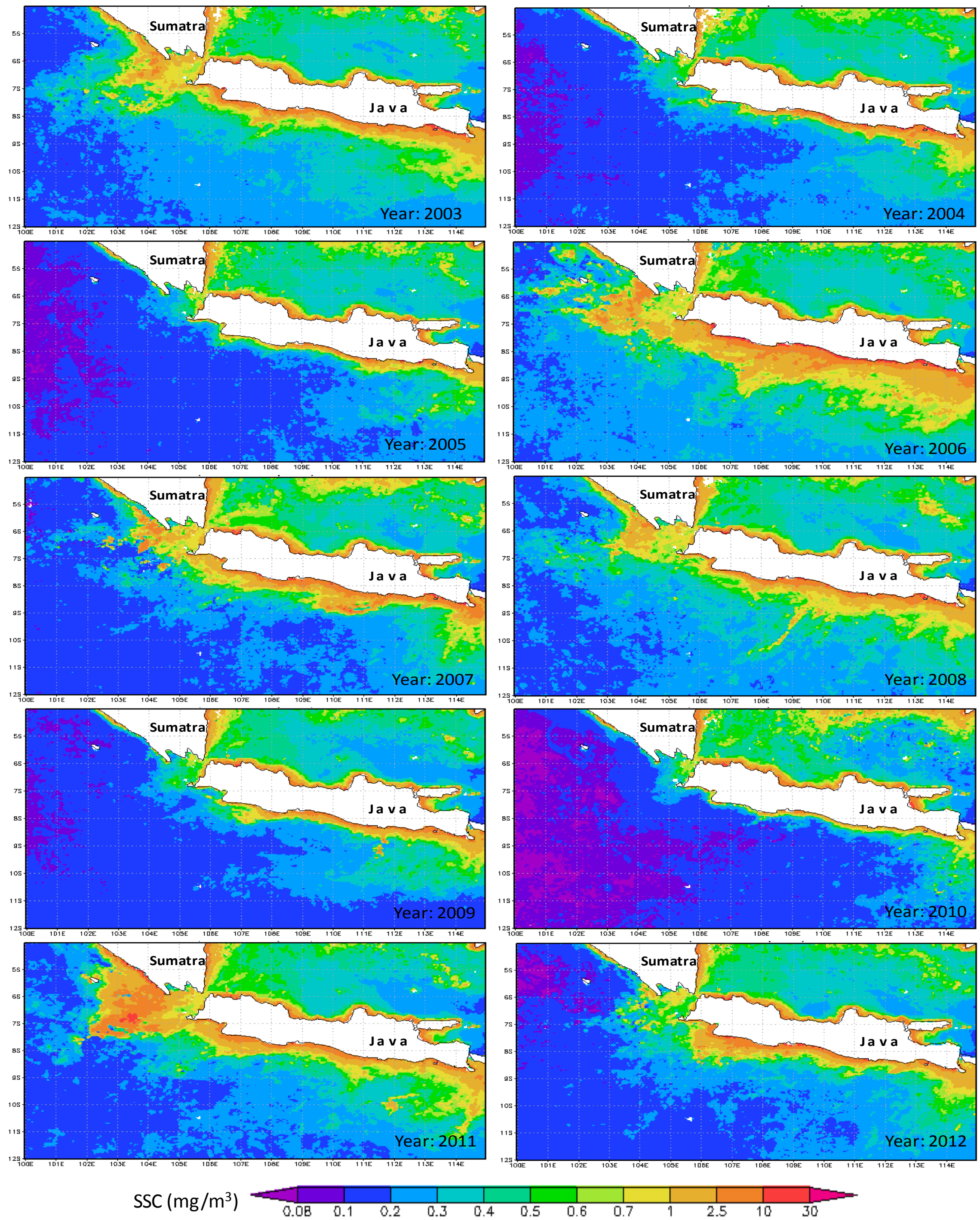


Figure 6. SSC images (yellow and red color indicated that higher chlorophyll-a concentration as effect of upwelling process) in EIO off west Java

SSC spread value in the location of fishing ground troll line and long line the waters off southern west Java (Appendix 2) in 2003 ranged 0.0874-0.2421 mg/m^3 (average 0.1434 mg/m^3); 2004 ranged 0.0913-0.2155 mg/m^3 (average 0.131817 mg/m^3); 2005 ranged from 0.0846 - 0.1955 mg/m^3 (average 0.1282 mg/m^3); 2006 is about 0.0956 - 0.2909 mg/m^3 (average 0.1949 mg/m^3);

2007 ranged from 0.1050 - 0.2314 mg/m^3 (average 0.1594 mg/m^3); 2008 range 0.0911 - 0.2577 mg/m^3 (average 0.1538 mg/m^3); 2009 ranged 0.0799-0.1955 mg/m^3 (average 0.1266 mg/m^3); 2010 range from 0.0890 - 0.1318 mg/m^3 (average 0.1045 mg/m^3); 2011 ranged from 0.1000 - 0.2310 mg/m^3 (average 0.1526 mg/m^3), and 2012 mg/m^3 range 0.0890-0.1818 (average 0.1253 mg/m^3).

The average value of the distribution of SSC highest in positive IOD events (2003, 2006, 2007 and 2008) as well as the El-Nino events (2011 and 2012). Average spread value was lowest in the SSC weak and strong El - Nino events (2005 and 2010). Figure 7 displays the average value of the distribution of SSC in southern west Java by IOD and ENSO events.

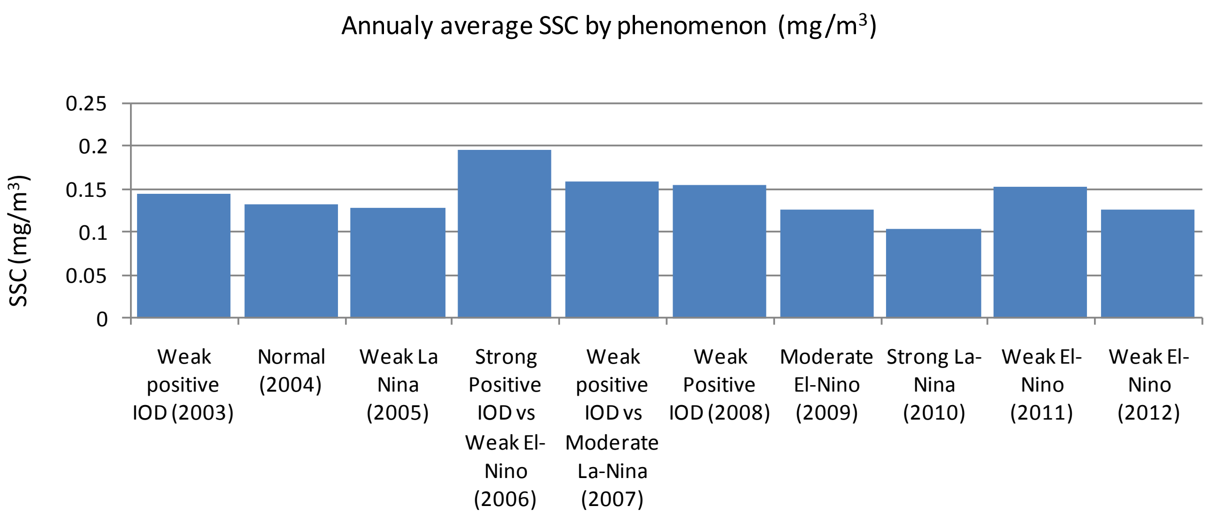


Figure 7. Annualy average of SSC in EIO off west Java by phenomenon 2003-2012

Catch rates of yellowfin tuna

Of the total fish landed catches of fishermen in Palabuhanratu, around 22% are other types of tuna (Yellowfin, Bigeye and Albacora). The skipjack tuna occupies portions 8% and neritic tuna (Kawakawa, bullet tuna, longtail tuna and frigate tuna) reached 7%. Group catches the largest (64%) dominated by pelagic fish species are small and mostly small demersal fish species (Figure 8).

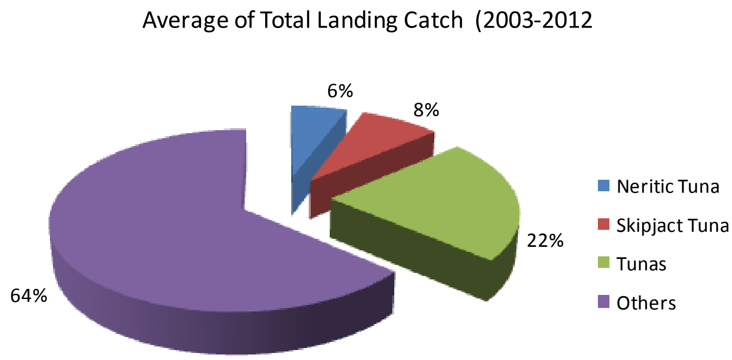


Figure 8. Catch composition (all species) were landed Palabuhanratu 2003-2012

Since 2003, data recording tuna catches are separated into species that yellowfin tuna (*Thunnus albacares*), Bigeye tuna (*Thunnus obesus*) and Albacora (*Thunnus alalunga*). Bigeye tuna is the largest with a share of the catch reaches 50% of the total tuna catch. Yellowfin tuna catches occupies portions of 39% and Albacora 11% (Figure 9).

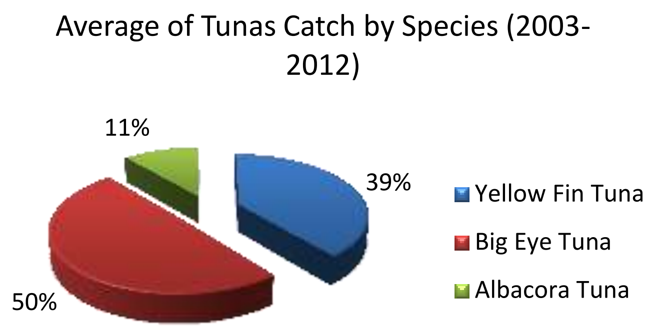


Figure 9. Catch composition of tunas were landed Palabuhanratu 2003-2012

Yellowfin tuna species landed in Palabuhanratu fishermen generally caught up with some of the gear: longline, troll line, gillnet, seine and pelagic danish. Dominant fishing gear caught yellowfin tuna is a long line with a portion of the catch reaches 70%, followed by troll line (22%) and gill net 8% (Figure 10). Payang catch is relatively small, because the operational areas closer to the coast.

Figure 10. Catch composition of yellowfin tuna by gears

Total annual catch yellowfin tuna during the period 2003-2012 as shown in the graph (Figure 11). High catches in 2005 (1,495 tons), 2010 (1,718 tons) and 2012 (1,675 tons). Lowest catches occurred in 2003 (178 tons).

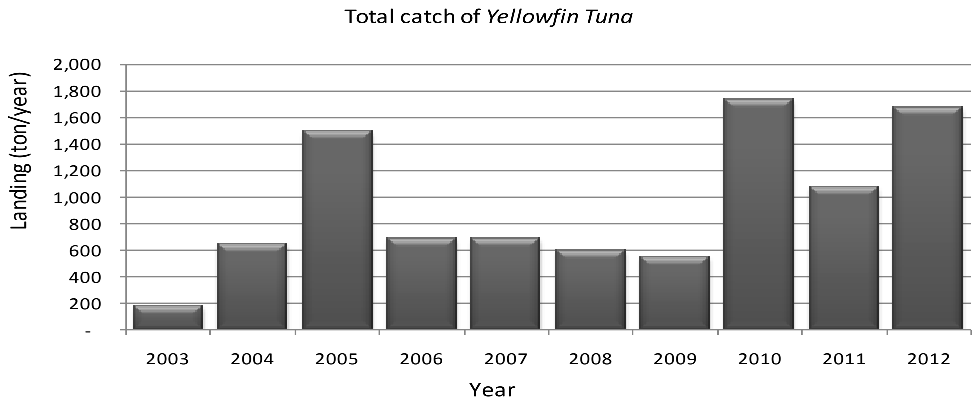
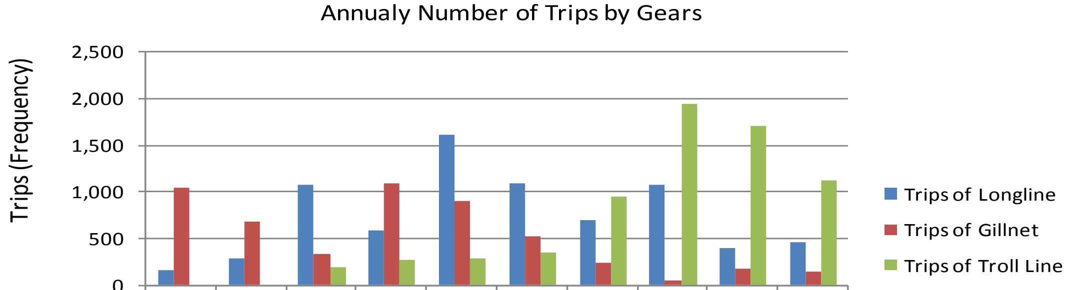


Figure 11. Annually total catch of yellowfin tuna 2003-2012

Number of trip per month with a major in Palabuhanratu (gear: longline, gillnet and troll line) shown in Figure 12 (A and B). Highest total trip took place in 2007 and 2010, respectively 2,789 trips and 3,056 trips. Lowest Trips in 2004 of 956 trips ((APPENDIX 3). Trips longline highest in 2007 (1,611 trips) and the lowest in 2003 (164 trips). Trips highest gillnet occurred in 2005 (1,082 trips) and the lowest in 2010 (52 trips). Trips troll line was highest in 2010 (1,927 trips) and the lowest in 2005 (188 trips). Seen trips troll increasing trend line from 2009.

(A)



	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Trips of Longline	164	281	1077	584	1611	1079	694	1077	398	455
Trips of Gillnet	1035	675	329	1082	892	515	235	52	177	142
Trips of Troll Line	0	0	188	264	286	350	940	1927	1699	1121

(B)

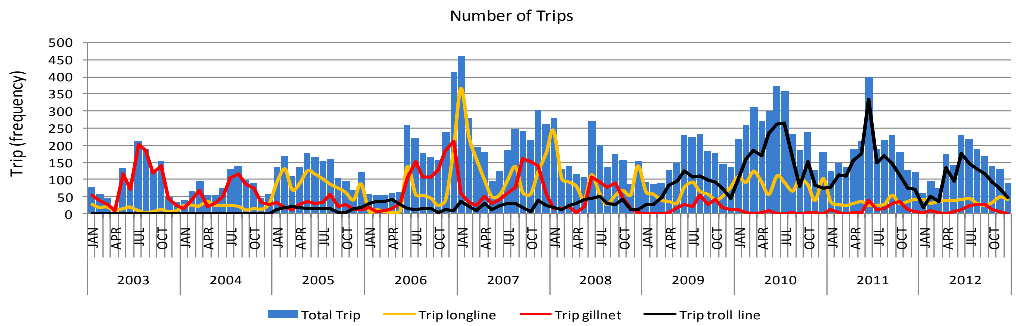


Figure 12. Annually total trips (above) and monthly trips (below) by fishing gears 2003-2012

Catch Per Unit Effort (CPUE) of yellowfin tuna

CPUE of yellowfin tuna from 2003 to 2012 as shown in the graph (Figure 13). Yellowfin tuna highest CPUE occurred in 2006 when the strong positive IOD event in 2011 and 2012 as well as a weak El-Nino events. Lowest CPUE occurred in 2005 (weak La-Nina event).

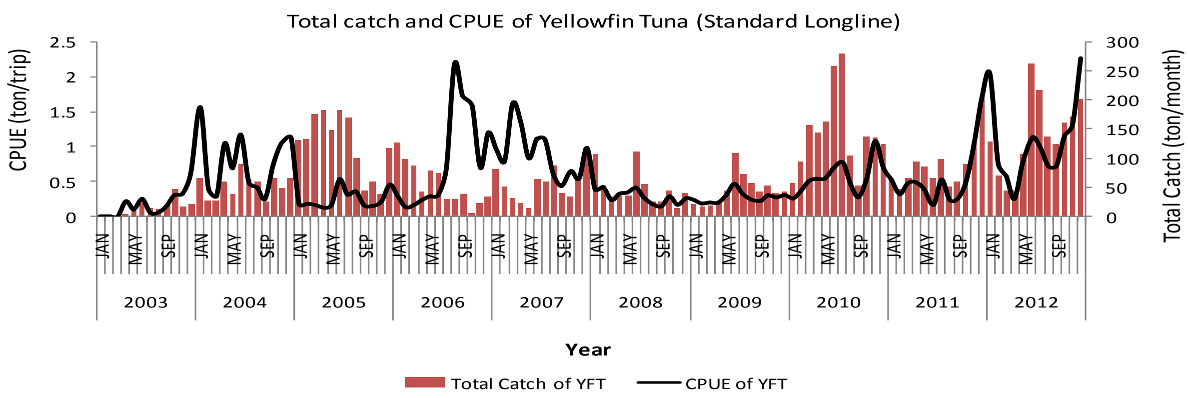


Figure 13. Monthly CPUE of yellowfin tuna (standard long line) everlain with total catch 2003-2012

DISCUSSION

Figure 14 shows the temporal variability of SST and SSC in the EIO off west Java overlain with inter-annual indices (DMI index and NINO 3.4 index). Moreover, in 2006 (strong positive IOD Association with weak El-Nino event), a decline in the average value of the distribution of SST are very low (around 25 ^{0}C), indicates intense upwelling process. As the positive impact of the upwelling process, at that time an increase in the value of the distribution of chlorophyll-a (0.35 mg/m^3), which indicates an increase in marine primary productivity. Same thing with a lower intensity also occurred in 2011 and 2012 during a weak El-Nino event. In contrast, during weak La-Nina event (2005) and the strong La-Nina event (2010), the average value of the distribution of SST were higher than normal (> 29 ^{0}C) and in the same period the average value of the distribution of chlorophyll-a were very low (<0.1 mg/m^3).

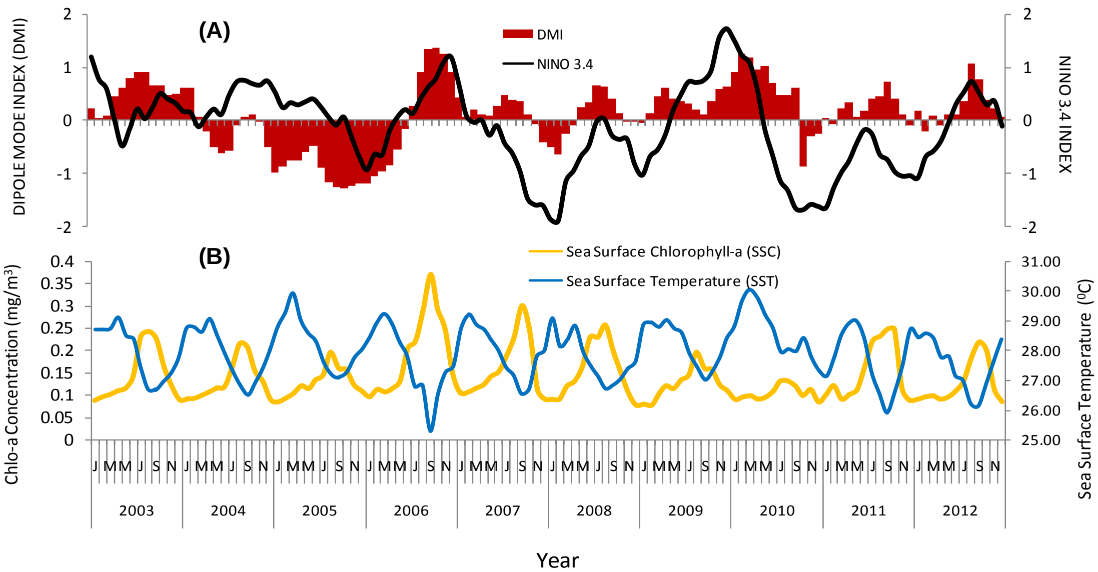


Figure 14. Temporal variability of SST (blue line) and SSC/ chlorophyll-a (yellow line) in the EIO off West Java), overlain with inter-annual indices, DMI index (shaded in magenta) and NINO 3.4 index (black line)

Very low value of SST distribution in 2006 occured due to period of half phase of strong positive IOD years during that time, continued by the end of the year and followed by weak El-Nino event of SST and SSC imagery visible upwelling water masses characterized by low SST and chlorophyll-a high spread quite widely. Intense upwelling was indicated at the time could be seen from the thermocline profile measurements used EIO buoy in the waters off the west Java as shown in Figure 15. On the chart showed the vertical distribution of sea temperature from June until the end of the year (November) associated with thermo cline layer depletion, which indicates that the thermocline layer water masses during EIO move to the surface layer, due to the upwelling of water masses encouragement.

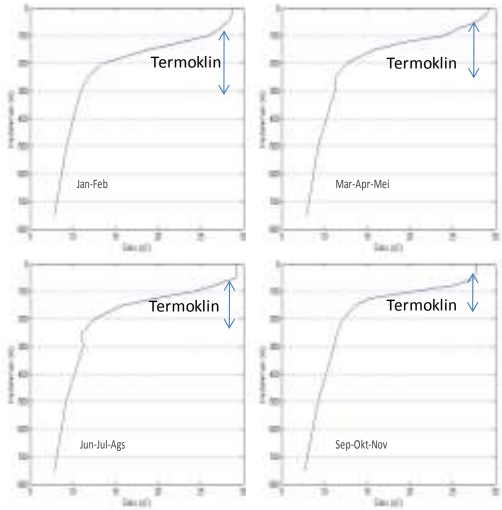


Figure 15.The vertically distribution of sea temperature according to the monsoon in EIO is taken from buoys instrument data at the strong positive IODM event which is associated with a low El Niño event 2006)

Analysis of CPUE during phenomenon phases indicates that the positive IOD events (2003 , 2006, 2007, 2008) and El - Nino events (2011, 2012) correlated with increasing of CPUE from mid-year and until the end of the year (Figure 16). Such a pattern is identical to the pattern of decline that indicates the ongoing SST upwelling followed by an increase in the value of the distribution of chlorophyll - a. The linkage pattern of distribution of tuna with oceanographic conditions as described Laevastu and Rosa (1963), moreover Squire (1982) suggest that variations in water temperature has an important role in determining the spatial distribution of tuna fish.

Very high increase in CPUE when strong positive IOD event (2006) and a weak El - Nino events (2011 and 2012) also allegedly associated with an increase in the distribution of chlorophyll-a value that indicates an increase in the abundance of phytoplankton (primary productivity). It makes yellowfin tuna migrate to the site associated with the availability of food. Furthermore, depletion of the thermocline layer replaces the surface layer, closer yellowfin tuna as a species that live in between the layers epipelagis - mesopelagis, the fishing gear such as longline, troll line and gillnet operating, so at this point abundant catches are characterized by increased CPUE. This condition is consistent with Longhurst and Pauly (1987), which described that yellowfin tuna vertical distribution is limited by the depth of thermocline layer.

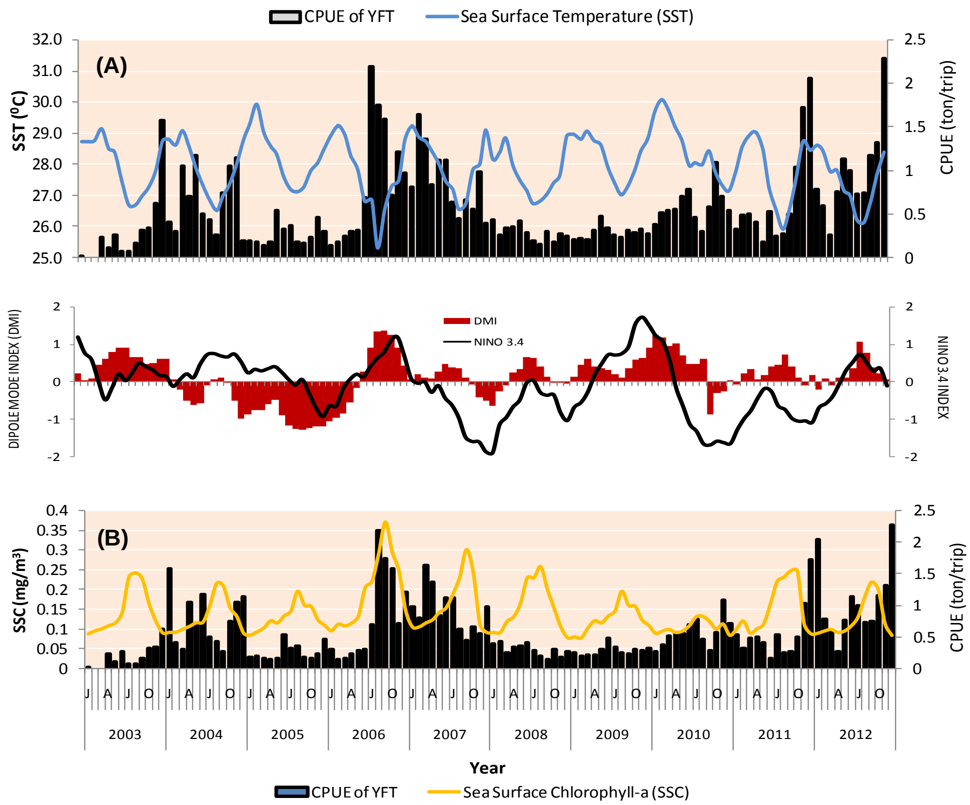


Figure 16.Correlation of SST (above) and SSC (below) with CPUE of yellowfin tuna

Based on the analysis of the composition of the catch per year (Figure 17), it appears that the yellowfin tuna caught by fishermen in Palabuhanratu is dominant during normal climatic conditions in 2004 (80.8%) and weak La-Nina event in 2005 (78.2%). In 2006 (strong positive IOD Association with weak El-Nino) yellowfin tuna proportion catches percentage reached 48.99%. In the years of weak positive IOD and El-Nino event, the composition of yellowfin tuna catches ranged between 29-33% lower, in this event is dominatd by bigeye tuna (51-69%). While during 2004-2012 years of observation, albacora was caught in small percentage (1-14%) of the total tuna catches landed in Palabuhanratu.

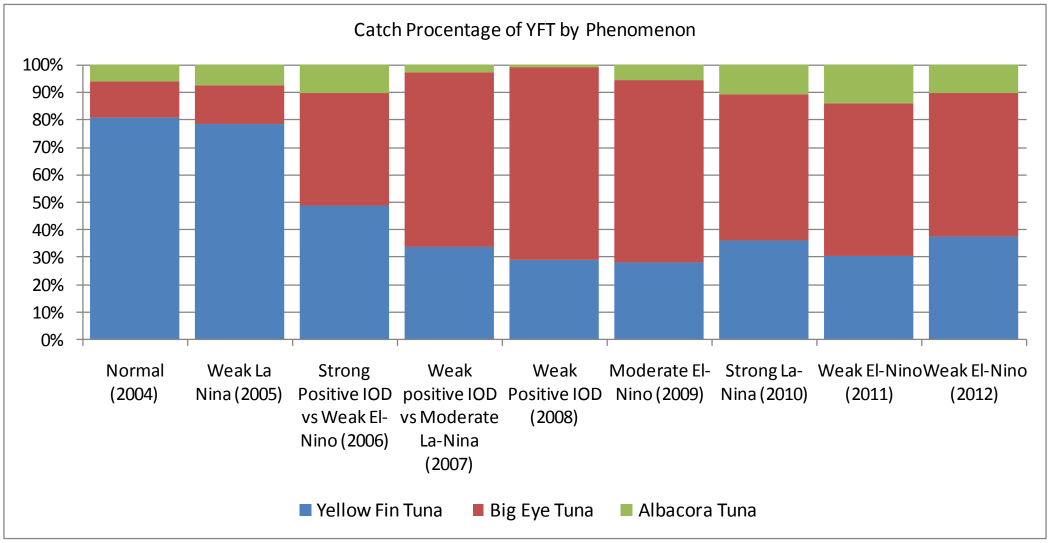


Figure 17. Catch composition (%) of tunas in Palabuhanratu 2003-2012

The biological aspects of yellowfin tuna caught in the EIO off west Java in 2012 showed that the size (fork lenght / FL) of longliner-yellowfin tuna (January-November 2012) ranged from 3-163 cmFL with mode: 113 and 123 cmFL. Trollliner-yellowfin tuna ranged from 73-158 cmFL, with 93 cmFL mode. The cumulative length (L_{50}) of longline is 122.1 cmFL, while troll line catches L50 99.5 cmFL (Anonymous, 2013).

CONCLUSION

This study found an indication of the influence of regional climate anomalies IOD and ENSO events correlated with oceanographic conditions (SST and SSC) in the waters of the EIO off west Java. Changes in oceanographic conditions during climate anomalies were affecting the catch of yellowfin tuna and its composition. CPUE of yellowfin tuna in the strong positive dipole mode event on 2006 and a weak El - Nino events in 2011 and 2012 were higher. Increase number of CPUE was following pattern of the upwelling process, started from May - June and get the peak on September - October. Relative very high increase of CPUE when strong positive dipole mode event (2006) and a weak El - Nino events (2011 and 2012) might related to the increase of in the distribution of chlorophyll - a associated with increasing of phytoplankton (primary productivity) abundance due to upwelling. In contrast, CPUE of yellowfin tuna is relative very low during La - Nina event (2005), though the dominant catch when compared to other types of tuna in this area. Further investigations regarding the prediction of fishing ground of yellowfin tuna through time series and historical information of environmental circumstances are needed to give better understanding of the effects of climate variability.

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APPENDIXES

APPENDIX 1. Sea surface temperature (^{0}C)

Month/Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
JAN	28.71	28.74	28.79	28.46	28.75	29.07	28.89	28.82	27.14	28.45
FEB	28.70	28.78	29.27	28.90	29.21	28.15	28.95	29.69	27.79	28.59
MAR	28.74	28.62	29.92	29.22	28.85	28.38	28.80	30.06	28.52	28.41
APR	29.12	29.06	29.02	28.93	28.71	28.82	29.04	29.76	28.91	27.76
MAY	28.48	28.49	28.58	28.28	28.40	27.95	28.73	29.22	29.00	27.79
JUN	28.36	27.89	28.32	27.82	28.01	27.49	28.60	28.75	28.43	27.13
JUL	27.49	27.31	27.59	26.80	27.45	27.12	27.90	27.96	27.24	26.97
AUG	26.68	26.83	27.18	26.83	27.17	26.73	27.44	28.04	26.52	26.21
SEP	26.68	26.51	27.10	25.30	26.54	26.81	27.02	27.98	25.91	26.12
OCT	26.94	26.94	27.27	26.53	26.72	27.04	27.31	28.42	26.61	26.85
NOV	27.23	27.35	27.76	27.28	27.80	27.39	27.82	27.76	27.52	27.65
DEC	27.76	28.01	28.04	27.47	28.01	27.64	28.43	27.33	28.71	28.36
Average	27.91	27.88	28.24	27.65	27.97	27.72	28.24	28.65	27.69	27.52

APPENDIX 2. Sea surface chlorophyll-a (mg/m^3)

Month/Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
JAN	0.087441	0.091307	0.084623	0.095665	0.105049	0.091133	0.079904	0.089036	0.100078	0.089036
FEB	0.095265	0.091927	0.092764	0.112103	0.105346	0.091133	0.077387	0.094746	0.120068	0.094746
MAR	0.100406	0.099662	0.102694	0.107927	0.115231	0.118879	0.102694	0.098838	0.089598	0.098838
APR	0.108252	0.10678	0.120829	0.114798	0.123551	0.131194	0.120829	0.091222	0.100321	0.091222
MAY	0.115425	0.115819	0.115219	0.132465	0.142623	0.164948	0.115219	0.094876	0.111973	0.094876
JUN	0.140861	0.117679	0.133027	0.204909	0.153808	0.229598	0.133027	0.10807	0.162671	0.10807
JUL	0.231081	0.160188	0.145616	0.22037	0.188517	0.229598	0.145616	0.130637	0.219898	0.130637
AUG	0.242109	0.215547	0.195531	0.290956	0.231411	0.257737	0.195531	0.131821	0.231098	0.181821
SEP	0.226273	0.208452	0.160019	0.370927	0.301086	0.199284	0.160019	0.118889	0.247344	0.218889
OCT	0.163689	0.153638	0.156938	0.295359	0.244013	0.151344	0.156938	0.099439	0.24739	0.199439
NOV	0.119966	0.131355	0.122987	0.247477	0.111305	0.104006	0.122987	0.112619	0.113544	0.112619
DEC	0.090324	0.089448	0.109099	0.146191	0.091133	0.077718	0.109099	0.083859	0.087965	0.083859
Average	0.143424	0.131817	0.128279	0.194929	0.159423	0.153881	0.126604	0.104504	0.152662	0.125338

APPENDIX 3. Number of trips

Number of Trip of Tuna Longline Trip (frequency)

Month/Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
JAN	27	25	90	7	365	242	62	109	35	41
FEB	19	26	131	12	224	102	57	92	27	32
MAR	20	24	71	8	160	92	40	124	25	36
APR	11	36	86	4	99	81	37	94	31	40
MAY	16	25	125	9	50	43	33	57	35	39
JUN	20	26	117	137	56	114	79	112	26	43
JUL	9	25	103	57	96	57	92	93	26	45
AUG	4	23	87	53	137	29	67	67	29	32
SEP	8	12	76	44	63	55	57	103	54	24
OCT	14	15	62	24	59	69	41	85	30	33
NOV	7	14	41	40	123	56	50	38	37	49
DEC	9	30	88	189	179	139	79	103	43	41
Amount	164	281	1077	584	1611	1079	694	1077	398	455

Number of Trip of Gillnet (frequency)

Month/Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
JAN	53	17	33	19	59	17	1	13	12	3
FEB	39	42	19	8	33	15	0	5	5	10
MAR	27	70	14	11	25	23	2	2	1	5
APR	10	21	29	17	52	3	5	5	3	2
MAY	116	31	36	30	32	21	19	9	3	7
JUN	72	51	31	105	43	109	27	1	40	14
JUL	204	105	34	151	60	93	23	2	12	26
AUG	184	116	57	107	79	77	55	4	15	28
SEP	119	86	21	108	160	91	27	2	30	27
OCT	141	74	27	129	152	47	42	4	36	13
NOV	44	34	14	186	141	16	20	5	13	6
DEC	26	28	14	211	56	3	14	0	7	1
Amount	1035	675	329	1082	892	515	235	52	177	142

Number of Trip of Troll Line (frequency)

Month/Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
JAN	0	0	13	32	36	18	27	98	78	19
FEB	0	0	18	37	22	12	29	162	115	51
MAR	0	0	23	37	11	25	47	184	111	36
APR	0	0	20	41	30	30	85	169	156	133
MAY	0	0	17	27	13	43	95	234	175	97
JUN	0	0	17	16	24	46	126	261	333	175
JUL	0	0	17	13	30	50	109	264	150	147
AUG	0	0	17	17	31	30	111	164	171	130
SEP	0	0	5	15	20	28	99	80	147	118
OCT	0	0	4	4	6	41	94	152	115	93
NOV	0	0	17	14	38	14	74	83	76	75
DEC	0	0	20	11	25	13	44	76	72	47
Amount	0	0	188	264	286	350	940	1927	1699	1121

Total Number of Trips by Gear

TUNAS OF FISHING GEARS	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Trips of Longline	164	281	1077	584	1611	1079	694	1077	398	455
Trips of Gillnet	1035	675	329	1082	892	515	235	52	177	142
Trips of Troll Line	0	0	188	264	286	350	940	1927	1699	1121
Amount	1199	956	1594	1930	2789	1944	1869	3056	2274	1718

APPENDIX 4. Catches

Total Landing of Yellowfin Tuna (kg)

Month/Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
JAN	1,254	66,128	131,709	6,255	82,878	107,797	21,699	58,970	67,262	128,820
FEB	0	27,557	134,554	22,988	52,619	54,669	16,876	95,455	47,778	71,722
MAR	0	28,221	175,948	35,350	32,598	34,681	18,859	156,963	66,066	44,837
APR	4,836	59,675	183,615	30,525	24,341	37,649	26,059	144,781	94,964	44,847
MAY	14,540	39,247	148,770	29,455	15,807	37,070	44,984	164,770	85,769	107,933
JUN	23,702	90,009	183,898	39,559	65,514	111,189	109,464	258,132	66,383	262,100
JUL	14,331	63,981	171,166	126,785	59,420	56,053	73,287	279,396	99,235	216,723
AUG	12,533	59,649	100,702	99,223	88,757	26,077	57,823	105,972	51,253	138,583
SEP	19,850	25,026	45,235	88,760	41,711	25,387	42,458	53,186	60,818	124,320
OCT	48,302	65,876	60,721	43,687	34,320	45,834	54,571	138,001	90,531	161,194
NOV	16,980	50,337	39,211	80,005	66,423	15,390	40,699	136,522	129,456	171,321
DEC	21,761	65,996	119,546	75,250	118,883	40,913	43,656	125,725	209,923	202,462
Amount	178,089	641,702	1,495,075	677,842	683,271	592,709	550,435	1,717,873	1,069,438	1,674,862

APPENDIX 5. CPUE (Standard longline)

CPUE of Yellowfin Tuna (Standar Long Line): kilograms/trips

Month/Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
JAN	16	1,574	180	292	968	389	241	268	538	2,045
FEB	0	405	189	138	801	424	196	369	325	771
MAR	0	300	166	166	1,629	248	212	506	482	582
APR	230	1,047	134	237	1,360	330	205	540	500	256
MAY	110	701	166	290	836	346	306	549	403	755
JUN	258	1,169	533	306	1,115	413	472	690	166	1,130
JUL	67	492	319	686	1,111	280	327	778	528	994
AUG	67	429	359	2,186	625	192	248	451	238	729
SEP	156	255	172	1,741	443	146	232	287	263	736
OCT	312	740	158	1,585	653	292	308	573	500	1,160
NOV	333	1,049	220	705	545	179	283	1,084	1,027	1,318
DEC	622	1,138	457	1,212	980	264	319	702	1,721	2,275