EFFECTS 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 effects of Indian Ocean Dipole Mode and El Niño–Southern Oscillation events on catches of YellowfinTuna (*Thunnus albacares*) in the Eastern Indian Ocean (EIO) off Java were evaluated 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 El-Nino 2006.Yellowfin Tuna catch data were taken from Palabuhanratu landing place and remotely sensed environmental data were taken from MODIS-Aqua sensor.The result showed that regional climate anomaly Indian Ocean Dipole Mode influenced Yellowfin Tuna catch and its composition. The catches per unit effort (CPUE) of *Thunnus alabacares* in the strong positive dipole mode event in 2006 and weak El-Nino events in 2011 and 2012 was higher. The increase patern of CPUE followed the upwelling process, started from May-June achieved the peak between September-October.Very high increase in CPUE when strong positive dipole mode event (2006) and a weak El-Nino events (2011 and 2012) had a relation with the increase in the distribution of chlorophyll-a indicating an increase in the abundance of phytoplankton (primary productivity) due to upwelling. In contrast, yellowfin tuna CPUE is very low at the La-Nina event (2005), though as the dominant catch when compared to others.

KEYWORDS: Indian Ocean Dipole Mode, YellowfinTuna, Eastern Indian Ocean off west Java

INTRODUCTION

Eastern Indian Ocean (EIO) is the unique waters because geographically influenced by water masses from the western Indian Ocean and the outflow water masses from the Pacific Ocean. Both of these water masses affect the variability of oceanographic conditions in these areas. In addition, the location of its waters is in the monsoon wind system causing conditions oceanographycally affected by monsoon wind system (Wyrtki, 1961). Winds over the Indonesian maritime continent and the position of the Intertropical Convergence Zone 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 takes place (Wyrtki, 1962; Purba, 1995). Reversed conditions occur during the northwest monsoon (November to April) (Gordon, 2005).

EIO off west Java is rich in fishery resources of tunas species which landed in the Palabuhanratu Fishing Port (Mertha, 2006). The tunas species in this area exploited by using various fishing gears, i.e.long line, purse seinne, 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 influence of changes occurred in the monsoon wind system (Wyrtki, 1961; Purba et al., 1997), and is affected by global climate change as and Indian Ocean Dipole Mode (IOD) (Saji *et al*., 1999; Shinoda *et al*., 2004). Saji *et al*. (1999) defines the 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 variability of temperature deviations in the western and eastern Indian Ocean with the wind direction and precipitation deviations. Dipole mode structure is characterized by an anomaly sea surface temperature (SST), warmer than normal in the western Indian Ocean and cooler than normal in the eastern Indian Ocean, which is referred to as positive dipole mode event. Reversely the incidence of so-called negative dipole mode event, is characterized by SST warming in the eastern Indian Ocean and the decline of SST in the western Indian Ocean (Vinaychanran *et al*., 2001). The phenomenon of ENSO or El Nino Southern Oscillation is the phase difference in air pressure of global sea level between

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Indonesia and Southeast Pacific Ocean (Quin *et al*., 1978). Both of these climate phenomena directly affect oceanographic conditions in the Indian Ocean and are believed to also affect 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. The variation in water temperature has an important role in determining the spatial distribution of tuna fish (Laevastu & Rosa, 1963; Squire, 1982). Yellowfin tuna (*Thunnus albacares*) has spread vertically with thermocline constraint (Longhurst & Pauly, 1987), while Albakora and Big eyes usually lives in waters below the thermocline layer (Laevastu & Hayes, 1982) .

Most of the research conducted on tuna in the Indian Ocean generally examined the relationship between several oceanographic parameters, particularly the distribution of Bigeye tuna species (*Thunnus obesus*), as reported by Mohri & Nishida (1999), Song *et al*. (2009), and Song & Zhou (2010). Therelationship between oceanographic factors dealing with the ENSO climate anomalies is reported by Yoder & Kennely (2003); Gaol (2003) and Syamsuddin *et al*.(2013). Meanwhile studies on yellowfin tuna for tuna species has not been widely reported.

This paper aims to examine the influence of climate anomalies (Indian Ocean Dipole Mode) and the El Niño - Southern Oscillation (ENSO) in the Indian Ocean, especially in the eastern part of West Java (EIO off west Java) to Yellowfin tuna (*Thunnus albacares*) Catches.

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).

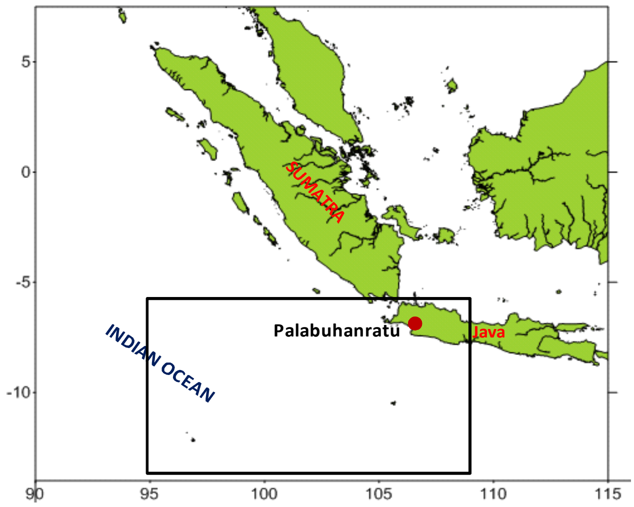


Figure 1. Map of the EIO, with the inset box representing the study area in the West Java.

For this study, we used Yellowfin tuna catches and oceanographic data such as sea surface temperature (Sea Surface Temperature/SST) and chlorophyll-a (Sea Susrface Chlorophyll-a/SSC) satellite remote sensing measurements. Yellowfin tuna catch and oceanographic data used for observation were the 10-year period from 2003 to 2012. During this period there were IOD and ENSO events, i.e. 2003 (weak positive IOD), 2005 (weak La-Nina), 2006 (strong positive IOD and weak El-Nino), 2007 (weak positive IOD and moderate La-Nina), 2008 (weak positive IOD); 2009 (moderate El-Nino), 2010 (strong La-Nina), 2011 and 2012 (weak El-Nino). From 2006-2008 there was triple consecutive positive IOD events in the year of 2006, 2007 and 2008.

Indications of climate anomalies (IOD and ENSO) was seen from Sea Surface Temperature (SST). SST satellite image used in this study measured the MODIS sensor (Moderate Resolution Imaging Spectroradiometer) satellite Aqua, years 2003-2012 (http://gdata1.sci.gsfc.nasa.gov/). SST estimated using MODIS standard algorithm 11 lm NLSST Algorithm (http://nasa.gsfc.gov). Chlorophyll-a OC3M allegedly based algorithm (O'Reilly *et al*., 2000). The data in monthly format with a spatial resolution of 4 km.

Yellowfin tuna catches records were obtained from Nusantara Fishing Port/Pelabuhan Perikanan Nusantara (PPN) Palabuhanratu, West Java. The data were obtained is from is landing vessels owned by tuna fishing companies (with longline fishing gear) and individuals or groups of fishermen (with longline fishing gear and troll line). The data include the number of catches per month (in kilograms) by fishing gear, boats and the number of trips per month and locations where operations FADs ships troll line.

The data were analyzed to get catch per trip (CPUE /Catch per Unit Effort) information. Catches and fishing effort data were obtained from different fishing gears (long line and troll line). Standardization (standard long line) done by calculating the Fishing Power Index (FPI) and Standard Effort. The formula used to calculate CPUE is as follows (Gulland, 1982).

$$CPUE_i = \frac{catch_i}{effort_i} \qquad i = 1, 2, ..., n$$

Were:
$CPUE_i$ = catch per unit effort by year i
$catch_i$ = catch by year i
$effort_i$ = effort by year i

Descriptive analysis was carried out by comparing the pattern of catches between the years with the IOD and ENSO events on Yellowfin Tuna catches.

RESULTS AND DISCUSSION

Results

Features of Oceanographic Conditions

Figure 2 shows the position of fishing ground from troll line and long line who landed their yellowfin tuna catches in Palabuhanratu. Troll line fishing ground is usually close to fish aggregating devices (FADs). Fishing ground pattern is following the monsoon seasons. During the southeast monsoon (Juny-July-August), fishing ground location is shifted a few miles to the east and during the west monsoon (November-December-January) fishing ground location is shifted a few miles to the west. The shifting position is usually not more than 5 miles from the FADs position.

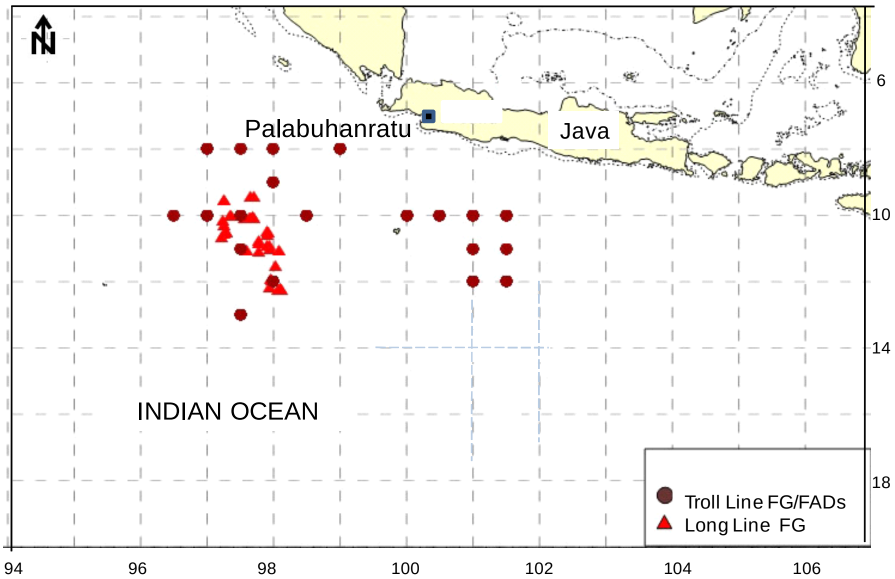


Figure 2. Map of the Fishing Ground Yellowfin Tuna (fishing gear: longline and troll line) in EIO off West Java.

The EIO off west Java has complex dynamic currents and wave systems (Syamsuddin *et al*., 2012). The dominant current and wave features include (Figure 3): 1) the Indonesian Through ûow (ITF), outûow water from the Paciûc to the Indian 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) that ûows 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 these current and wave systems, winds over the Indonesian maritime continent and the position of the Intertropical Convergence Zone 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. These conditions are reversed during the northwest monsoon (November to April) (Gordon, 2005).

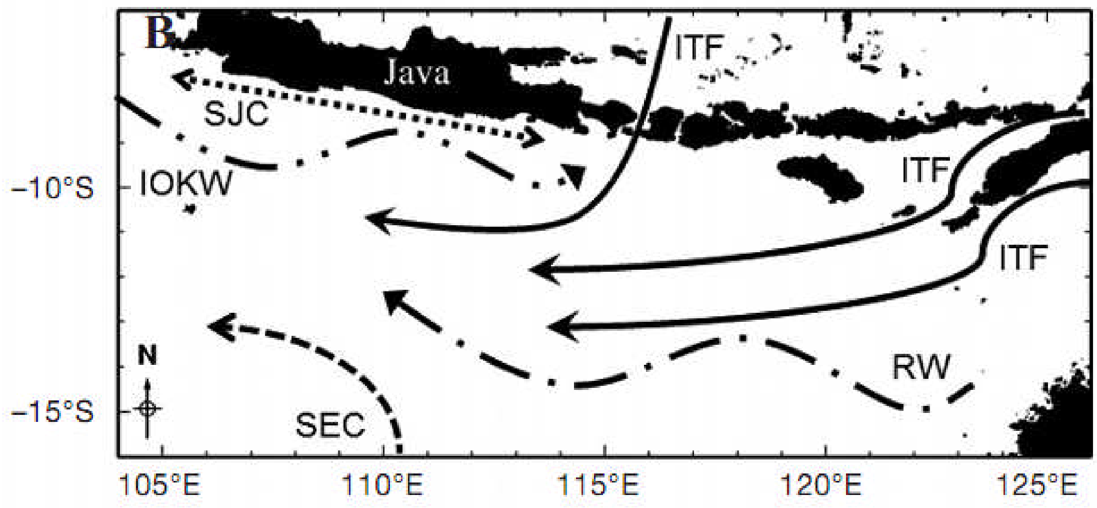


Figure 3. The wave and current systems in the East Indian Ocean off Java are indicated by the dotted line for the South Java Current (SJC), solid lines for the Indonesian Through Flow (ITF), the line with dashes and 2 dots for the Indian Ocean Kelvin Waves (IOKWs), the line with dashes and 1 dot for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

Upwelling in the southern Java - Bali increased in intensity when the climate anomaly and a positive IOD or El - Nino events occured. However, the opposite occurs or negative IOD and La Nina events do not occur in these waters upwelling (Gaol, 2003; Amri *et al*., 2012). In the event of a positive IOD event, the SPL had negative anomalies (lower than normal) (Saji *et al*., 1999; Webster *et al*., 1999) .

Upwelling that occurs when positive IOD events is triggered by the strengthening wind anomalies along the southern coast of Sumatra and Java as well as east winds along the equator. The strengthening winds push water away from the coast or the equator, so that the water masses along the south west coast of Sumatra and Java are vacant. Mass of the surface layer water fills the vacant layer, and the mass of the bottom layer water rises to the surface inducing the occorrence of upwelling. Upwelling brings nutrient - rich water mass to the surface, thus increasing the primary productivity, marked by the increase in the distribution of chlorophyll-a (phytoplankton). Generally waters in upwelling sites are abundant fish resources.

Figure 4 shows the Sea Surface Temperature (SST) images EIO waters off west Java. Upwelling with high intensity as indicated by the decrease in SST 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). In 2011 and 2012 upwelling also occurs with high intensity at which time the El - Nino events occur. Highest upwelling intensity as indicated by the low SST area with the most extensive water mass occurred in 2006, during the strong positive IOD by mid-year, followed by a weak El - Nino events at the end of the year. In contrast, during the negative IOD/La - Nina events do not occur in these waters upwelling: 2005 (weak La - Nina) and 2010 (strong La - Nina). In a normal year (2004) upwelling occurs with normal intensity (low).

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

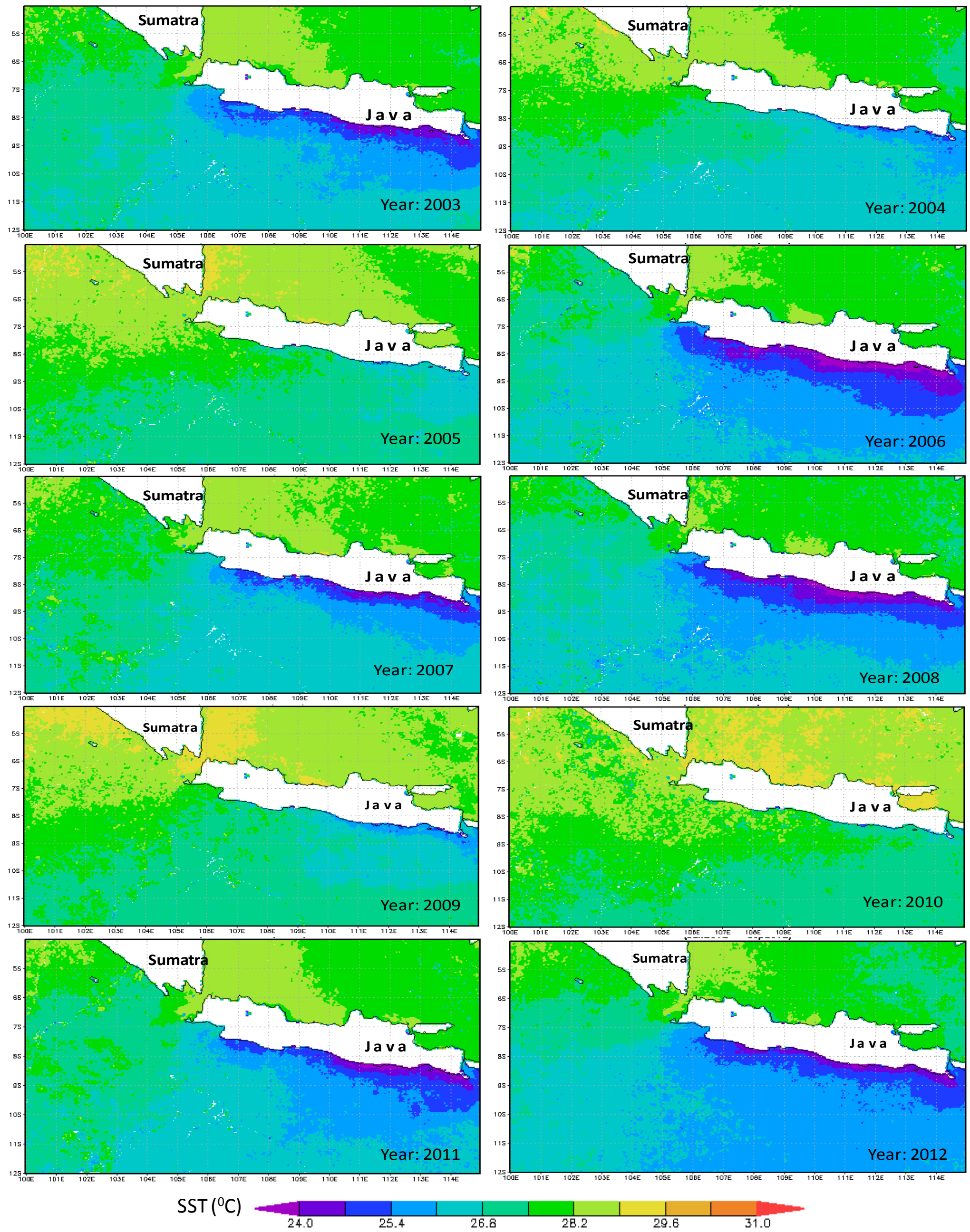


Figure 4. Sea Surface Temperature (SST) images (blue color indicated that upwelling water mass with lower SST on Positive IOD/El-Nino events)in EIO off West Java.

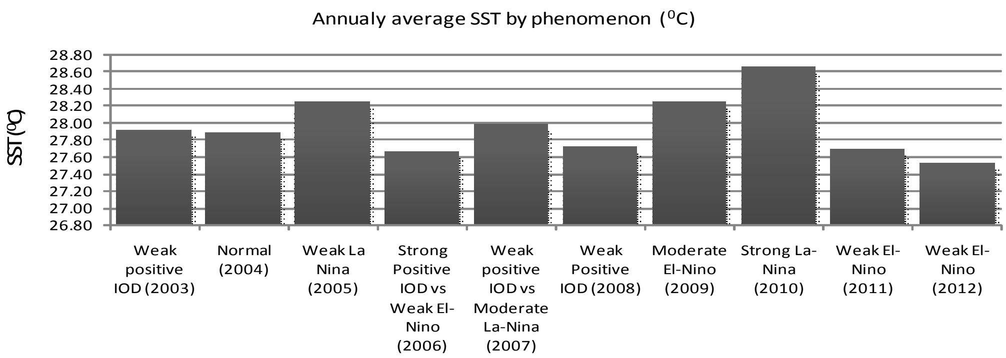


Figure 5. Annualy average of SST by phenomenon in EIO off west Java 2003-2012.

Figure 6 displays the image of the surface distribution of chlorophyll-a (Sea Surface Chlorophyll / SSC images) EIO waters off west Java. Increase in the value of the distribution of chlorophyll-a with high spread value and distribution of a wide area occurred in the years of intensive upwelling, i.e. 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 was found in the La-Nina events (2005 and 2010). Value distribution of chlorophyll-a in the La-Nina events was lower than the normal phase (2004). The location of the increased value of the distribution of chlorophyll-a was identical to the location of the SPL reduction proving that enrichment of chlorophyll-a occurred due to upwelling events.

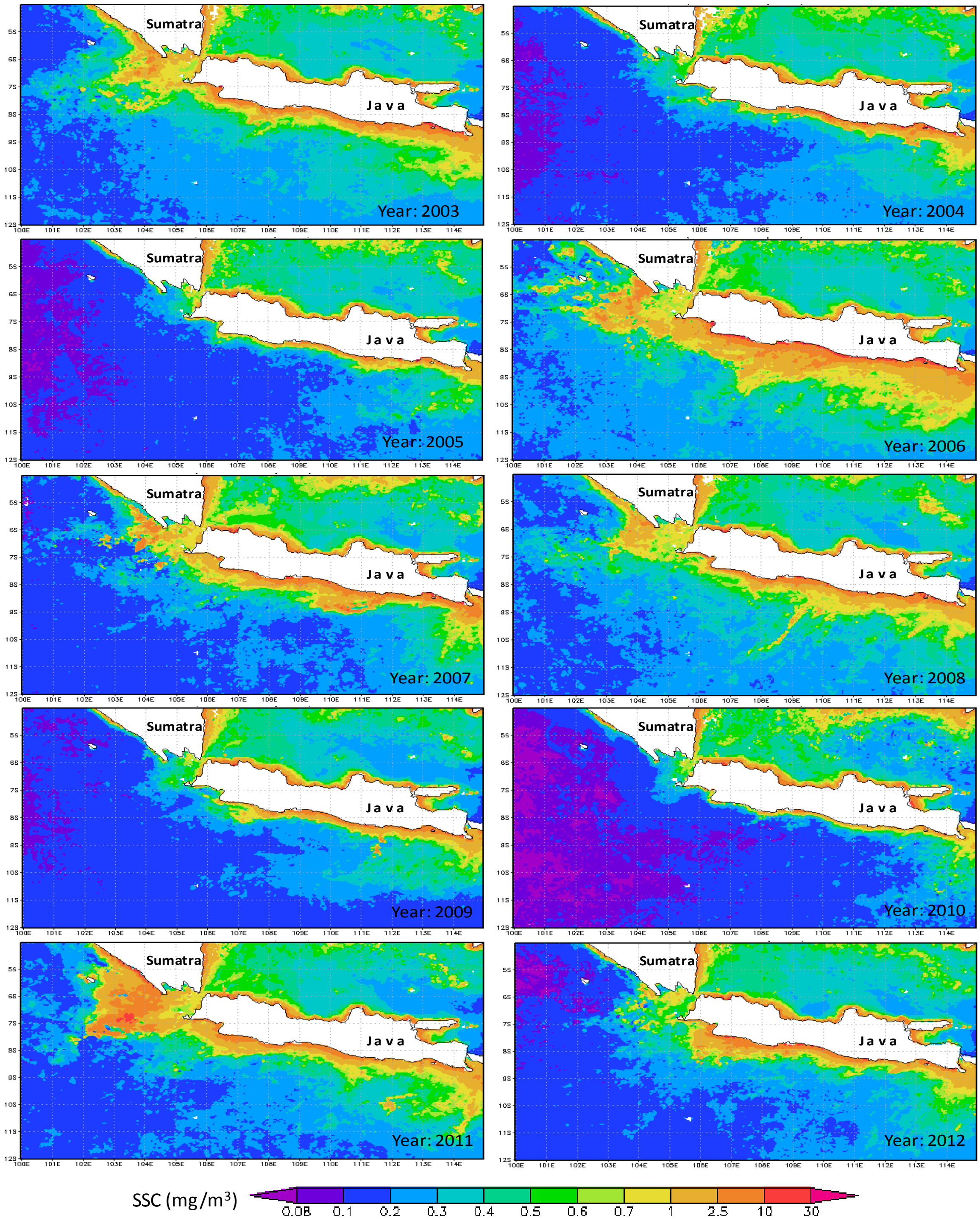


Figure 6. Sea Surface Chlorophyll-a images (yellow and red color indicated that higher chlorophyll-a concentration as effect of upwelling process) in EIO off west Java.

SSC spread value ranges in the location of fishing ground troll line and longline the waters off southern west Java (Appendix 2) were in 2003: 0.0874-0.2421 mg/m^3 (average 0.1434 mg/m^3); 2004: 0.0913-0.2155 mg/m^3 (average 0.131817 mg/m^3); 2005:0.0846 - 0.1955 mg/m^3 (average 0.1282 mg/m^3); 2006:t 0.0956 - 0.2909 mg/m^3 (average 0.1949 mg/m^3); 2007: 0.1050 - 0.2314 mg/m^3 (average 0.1594 mg/m^3); 2008: 0.0911 - 0.2577 mg/m^3(average 0.1538 mg/m^3); 2009: 0.0799-0.1955mg/m^3 (average 0.1266 mg/m^3); 2010: 0.0890 - 0.1318 mg/m^3 (average 0.1045 mg/m^3); 2011: 0.1000 - 0.2310 mg/m^3 (average 0.1526 mg/m^3), and 2012: 0.0890-0.1818 mg/m^3(average 0.1253 mg/m^3).

The average value of the distribution of SSC on positive IOD events (2003, 2006, 2007 dan 2008) is simirality with the El-Nino events (2011 and 2012). Average spread value was lowest in the weak SSC 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 .

Catch Rates of Yellowfin Tuna

Of the total fish landed by fishers in Palabuhanratu, around 22% were other types of tuna (Yellowfin, Bigeye and Albacora). Skipjact tuna occupied portions 8% and neritic tuna (Kawakawa, bullet tuna,longtail tuna and frigate tuna) reached 7%. The largest catch proportion of 64% was mostly small demersal fish and some small pelagic fish (Figure 8).

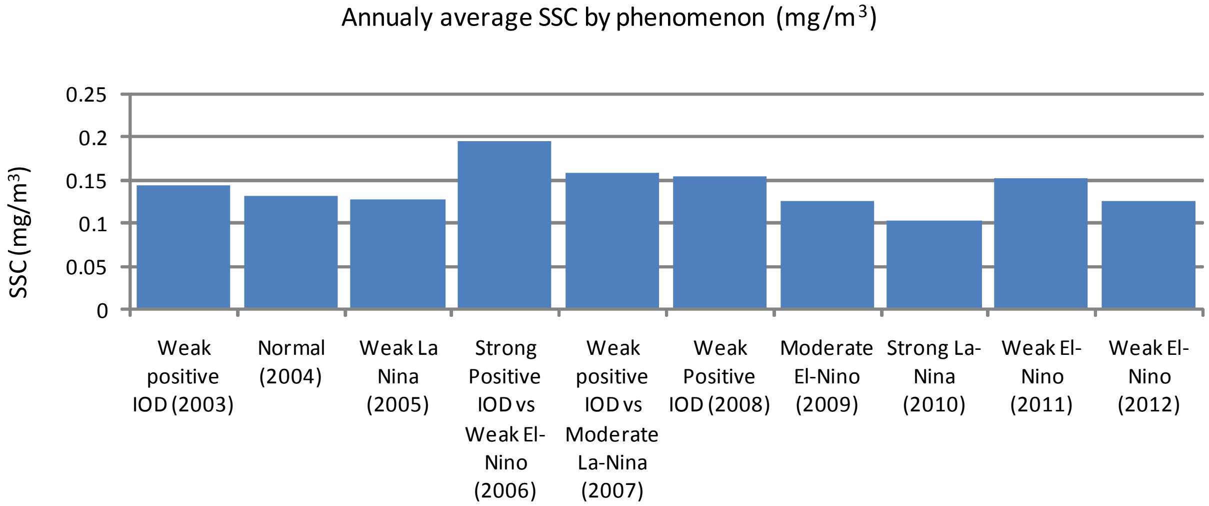


Figure 7. Annualy average of SSC in EIO off west Java by phenomenon 2003-2012.

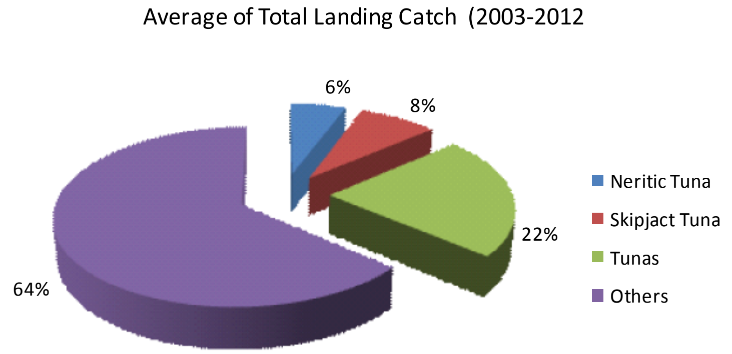


Figure 8. Catch composition (all speciess) were landed Palabuhanratu 2003-2012.

Since 2003, data recording tuna catches are separated into species, i.e.Yellowfin tuna (*Thunnus albacares*), Bigeye tuna (*Thunnus obesus*) and Albacora (*Thunnus alalunga*). Bigeye tuna is the largest catch which is approximately 50% of the total tuna catch. Yellowfin tuna and Albacore catches occupyf 39% and 11% respectively (Figure 9).

Yellowfin tuna landed in Palabuhanratu was generally caught using longline, troll line, gillnet, seine and pelagic danish. Dominant fishing gear for yellowfin tuna is a long line approaching 70% of total yellowfin tuna catch, followed by troll line (22%) and gill net 8% (Figure 10). Payang catch is relatively small, because the operational areas were close to the coast.

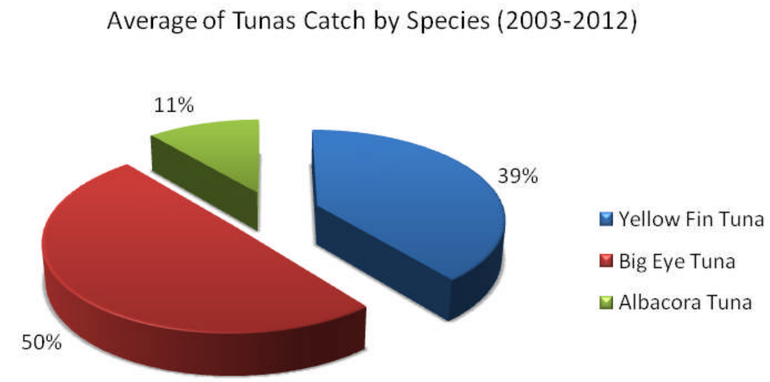


Figure 9. Catch composition of tunas landed in Palabuhanratu 2003-2012.

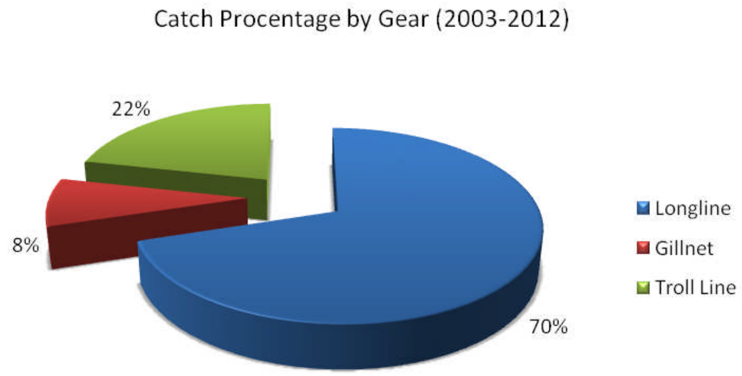


Figure 10. Catch Composition of Yellowfin tuna by Gears.

Total annual yellowfin tuna catch during the period of 2003-2012 is shown in Figure 11. High catches were noted in 2005 (1,495 tons), 2010 (1,718 tonnes) and 2012 (1,675 tons). The lowest catch was occurred in 2003 (178 tons).

Number of trip per month with most observation in Palabuhanratu, particularly for: longline, gillnet and troll lineis shown in Figure 12 (A and B). The highest total trip took place in 2007 and 2010, i.e. 2,789 trips and 3,056 trips respectively. The lowest trip was noted in 2004, i.e. 956 trips (APPENDIX 3). The highest and the lowest longline trips were identifiedin 2007 (1,611 trips) 2003 (164 trips) respectively. The highest and the lowest gillnet trips were occurred in 2005 (1,082 trips) and in 2010 (52 trips) respectively. Trips troll line was The highest troll line trip was in 2010 (1,927 trips) and the lowest was in 2005 (188 trips). As seen in Figure 12, the trips of troll show an increasing trend from 2009.

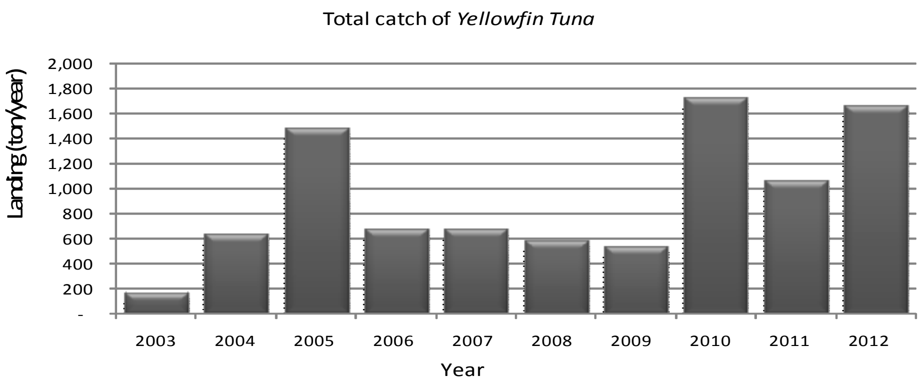
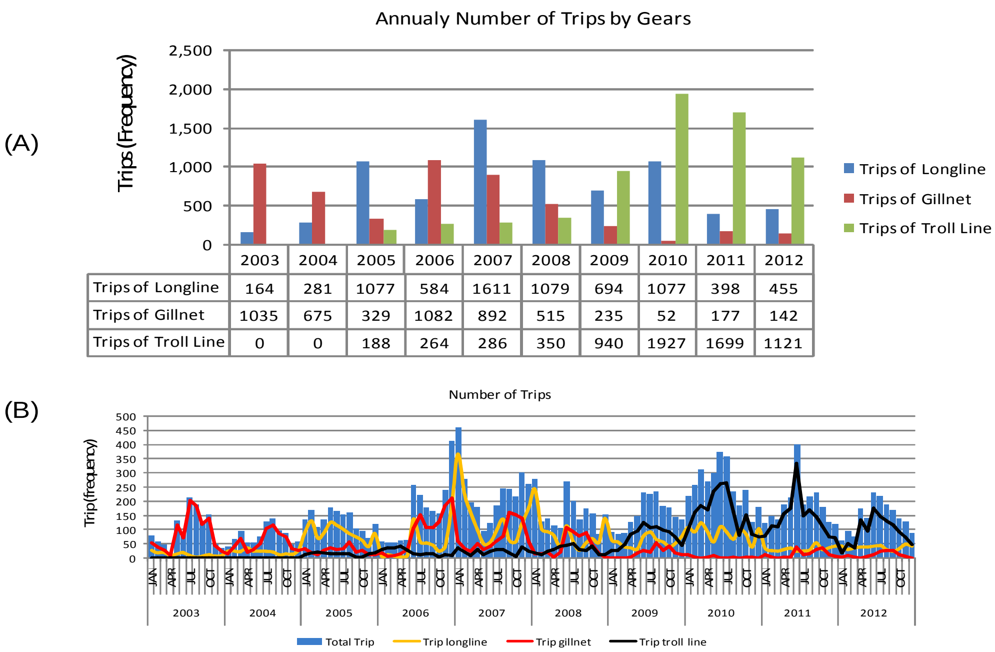


Figure 11. Annualy total catch of Yellowfin Tuna in the period of 2003-2012.



	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

Figure 12. Annualy total trips (above) and monthly trips (below) by fishing gears in the period of 2003-2012.

Catch Per Unit Effort (CPUE) of Yellowfin Tuna

Catch per Unit Effort (CPUE) of Yellowfin Tuna from 2003 to 2012 is shown in Figure 13. The highest CPUE for yellowfin tuna was occurred in 2006 when the strong positive IOD event in 2011 and 2012 as well as a weak El-Nino events took place. The lowest CPUE was occurred in 2005 in accordance with weak La-Nina event.

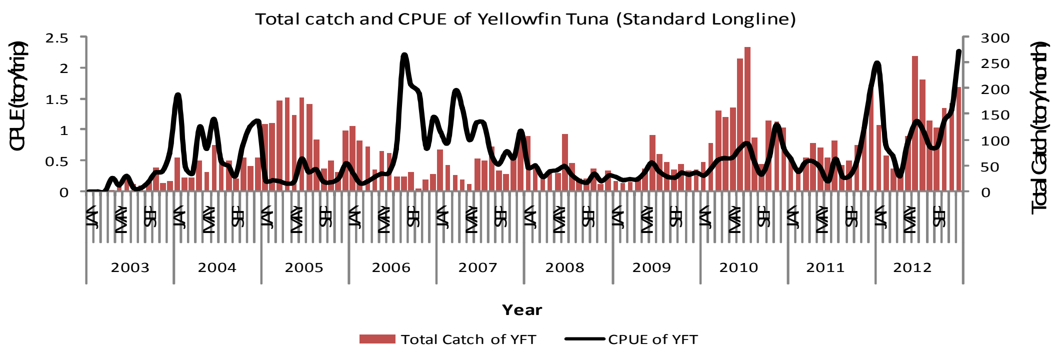


Figure 13. Monthly CPUE of Yellowfin Tuna (standard effort using long line) overlain with total catch 2003-2012.

Discussion

Figure 14 displays the temporal variability of SST and SSC/Chlorophyll-a in the EIO off west Java overlain with inter-annual indices (DMI index and NINO 3.4 index). At the time when a strong positive IOD associated with weak El-Nino event in 2006 has caused a decline in the average value of the distribution of SST (around 25 ^{0}C), this indicates a highly intensity of upwelling. 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) was observed, which indicates an increase in marine primary productivity. The same phenomena with a lower intensity also occurred in 2011 and 2012 during a weak El-Nino event. Conversely, during weak La-Nina event in2005 and the strong La-Nina event in 2010) the average value of the distribution of SST was much higher than normal (> 29 ^{0}C) and in the same period the average value of the distribution of chlorophyll-a was very low (<0.1 mg/m^3).

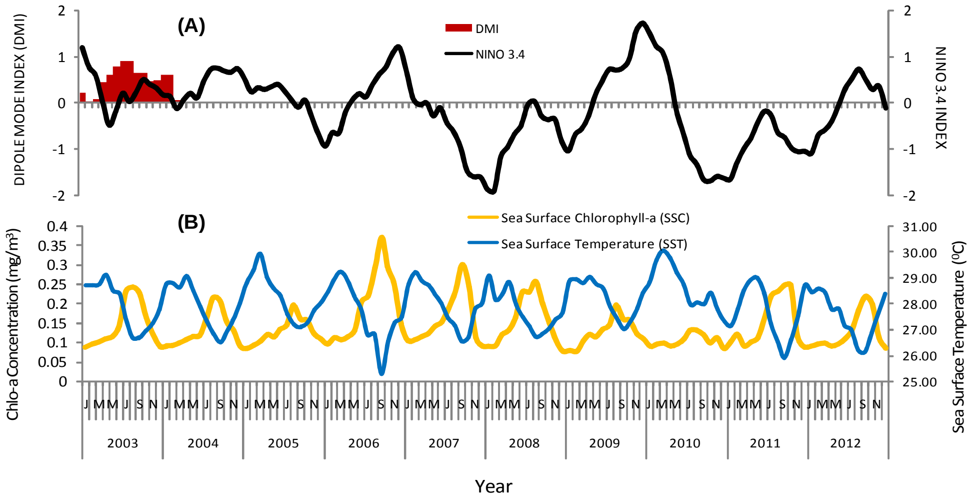


Figure 14. Temporal variability of SST (blue line) and SSC/chlorophyll-a (yellow line) in the Eastern Indian Ocean off West Java), overlain with inter-annual indices, DMI index (shaded in magenta) and NINO 3.4 index (black line).

The average value of the very low SST distribution in 2006 was happened becauseit took place in the middle of strong positive IOD years and at the end of the year followed by weak El-Nino event. Of SST and SSC imagery visible upwelling water masses were characterized by low SST and high spread quite widely chlorophyll-a. Indication of intense upwelling at that time can be seen from the thermocline profile measurements EIO buoy in the waters off the west Java as shown in Figure 15. As seen on the chart of the vertically sea temperature distribution,thermocline layer depletion occurs from June until the end of the year (November), which indicates that the thermocline layer water masses were in the EIO and then pushed to the surface layer, due to the upwelling of water masses encouragement.

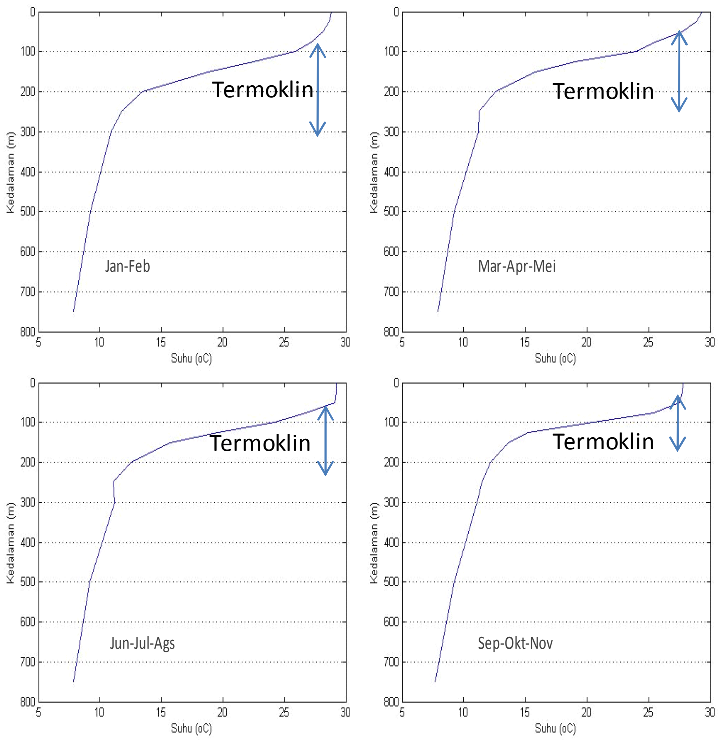


Figure 15. The vertically distribution of sea temperature according to the monsoon in Eastern Indian Ocean taken from buoys instrument data at the strong positive IODM event associated with a low El Niño event 2006).

CPUE of yellowfin tuna suggests that the positive IOD events (2003 , 2006, 2007, 2008) and El - Nino events (2011, 2012) shows that the increase in CPUE lasts from mid -year until the end of the year (Figure 16). Such pattern is identical to the weakening pattern indicating the ongoing SST upwelling followed by an increase in the value of the distribution of chlorophyll-a. The linkage pattern between distribution of tuna and oceanographic conditions as described Laevastu and Rosa (1963), Squire (1982) suggest sthat variations in water temperature has an important role in determining the spatial distribution of tuna.

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 reflecting an increase in the abundance of phytoplankton (primary productivity). That condition will encourage yellowfin tuna to migrate to the site associated with the availability of food. Further more, depletion of the thermocline layer pushed to the surface layer, closer to yellowfin tuna as a species living in between the epipelagis – mesopelagis layers, where the fishing gears such as longline, troll line and gillnet operate. Therefore, according to that phenomena the fish abundance is characterized by increasing CPUE. This condition is consistent with Longhurst and Pauly (1987) informing that the type of yellowfin tuna has spread vertically limited by the depth of thermocline layer.

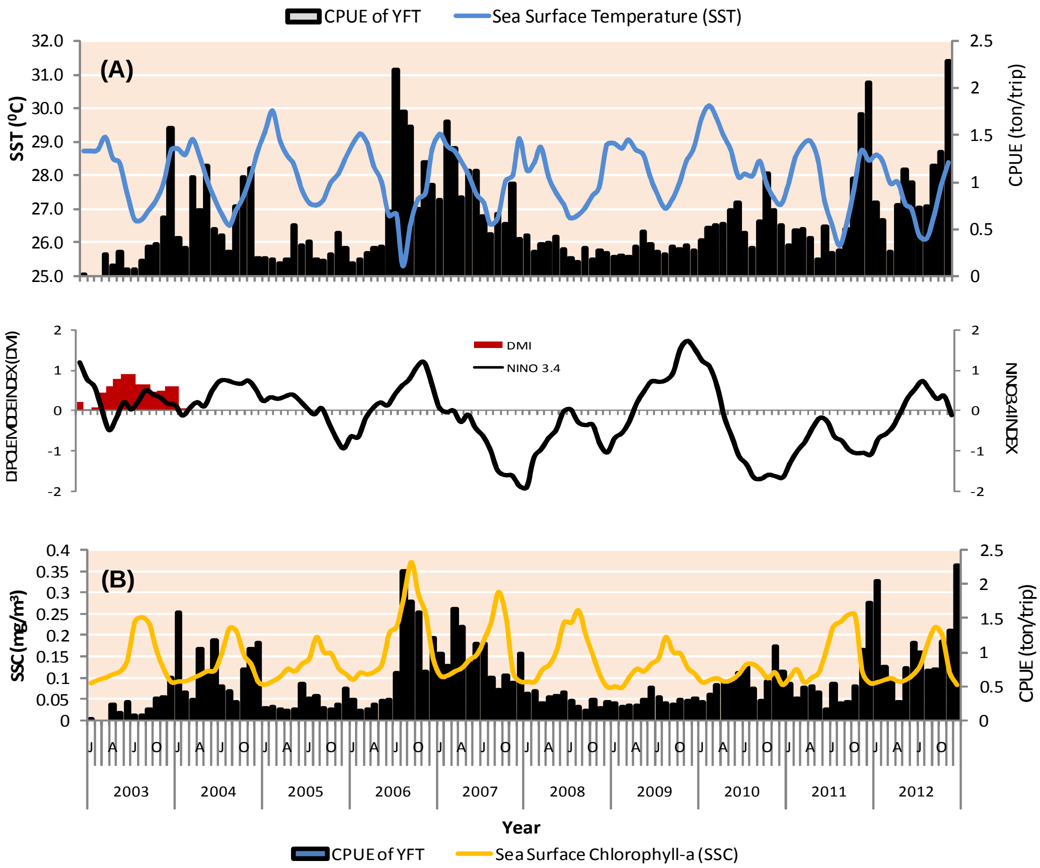


Figure 16. Correlation of SST (above) and SSC (below) with CPUE of Yellowfin Tuna.

Analysis of catch composition per year (Figure 17) revealed that yellowfin tuna caught by fishers in Palabuhanratu was predominant species during normal climatic conditions in 2004 (80.8%) and weak La-Nina event in 2005 (78.2%). The proportion of yellowfin tuna reached up to 48.99% in 2006 when strong positive IOD and weak El-Nino occurred. In the years assoociated with the occurrence of weak positive IOD and El-Nino event, the composition of yellowfin tuna catches was ranging between 29% and 33% , in which the predominant species in this event was bigeye tuna (51-69%). While, according to the observations in Palabuhanratu during 2004-2012, albacora was caught in a small percentage (1-14%).

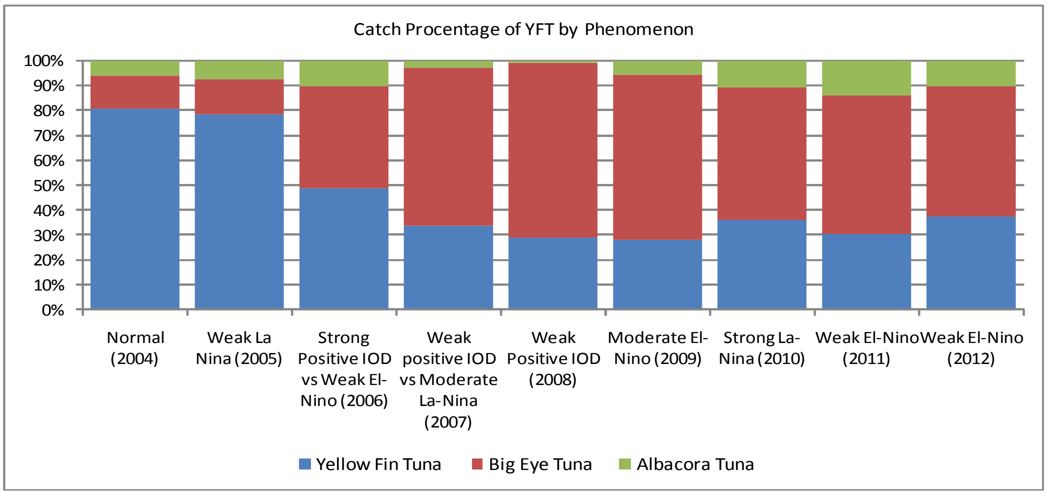


Figure 17. Catch composition (%) of tuna in Palabuhanratu during period of 2003-2012.

CONCLUSION

This study revealed the indication of the influence of regional climate anomalies Indian Ocean Dipole Mode (IOD) and El Niño - Southern Oscillation (ENSO) events on oceanographic conditions (SST and SSC) in the waters of the Eastern Indian Ocean (EIO) off west Java. Changes in oceanographic conditions in the event of climate anomalies influenced the catch of Yellowfin tuna and its composition. The CPUE of Yellowfin tuna in the strong positive dipole mode and a weak El - Nino was higher. The increase of CPUE followed pattern of the upwelling process, started from May - June and get the peak between September and October. Very high increase of in CPUE when strong positive dipole mode and a weak El - Nino was suspected to be related to the increase of the distribution of chlorophyll -a due to upwelling. In contrast, yellowfin tuna CPUE is very low during the La - Nina event eventhough still as predominant catch. Further investigations into the prediction of fishing ground locations of yellowfin tuna through the use of long - term, historical time series of environmental conditions are recommended for better understanding the effects of climate variability.

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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. CACTHES

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 (Standar 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