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Dynamics of Indian Scad Fish (*Decapterus Spp*) Catching Linked with Temperature Variation Due to Enso Phenomenon (*El-Nino Southern Oscillation*) in Bali Strait

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Abstract : The variation in water temperature is influenced by several factors, one of which is the ENSO (El Nino Southern Oscillation). ENSO is a phenomenon of climate changing which has the impact on the irregularities / anomalies towards the sea surface temperature (SST) significantly (far from normal circumstances). Besides the impact on the STT variation, ENSO also affected the amount of fish catching. The materials of the research are obtained by using the catch per unit effort (CPUE) of Indian Scad Fish from Muncar Fishery Port in every month. The average data of sea surface temperature (SST) is derived from the level 3 Aqua-Modis satellite in order to get the trend and anomalies of monthly temperature. Also, the CPUE of Indian Scad Fish and SST anomaly index in SOI (Southern Oscillation Index) is collected in every month from NOAA Nino 3.4. All data of the research is the monthly average data of Bali Strait condition which is recorded from 2002 up to 2015.The results of the research showed that the temperature variation in Bali Strait had increased in 2005, 2009, 2010, 2013, and 2014, while in 2004, 2006, 2007, 2008, 2011, 2012 and 2015 the temperature tend to be decreased. When an El Niño occurred, the SST in Bali Strait has decreased by about 25.11^{0}C – 25.55^{0}C. Meanwhile, when La-Nina occurred, the SST in Bali Strait has increased about 20.51^{0}C – 31.70^{0}C based on the analysis of standardization. The comparison between surface temperatures with the fishing production of Indian Scad Fish (*Decapterus spp*) in Bali Strait showed a correlation such as the abundant resource of fish and a decent fish catching. However, it is not really suitable to catch the Indian Scad Fish between the period of January and June.
Keywords: Temperature, ENSO, Climate, Indian Scad Fish, Catches, Bali Strait.

Introduction

Sea surface temperature (SST) is needed to be known because it is an important indicator in monitoring the oceanographic conditions and global warming effects. The knowledge of sea surface temperature variability can be used to determine the location of fronts, upwelling, and fish distribution. Water temperature varies greatly, these conditions have an impact on the growth process, swimming speed, reproduction, phenology, distribution, recruitment and organisms mortality that live in it, either the organisms which do migration or not[1].

ENSO and IOD is characterized by the uncommon changes in water temperature, where the increase or decrease is far from normal circumstances. Both of these phenomena have their own characteristics because it is occurred in different places. IOD occurred in Indian Ocean with the temperature differences between western Indian Ocean (region of Africa) and eastern Indian Ocean (region of Indonesia), while ENSO occurred in the eastern Pacific Ocean (region of Peru). Nevertheless, ENSO also has the impact on the climate and weather variations in the southern hemisphere.

Bali Strait also has a quiet high fisheries potential, especially pelagic fish. Indian Scad Fish is one of the small pelagic fish that has an important value in Indonesia. The production of Indian Scad Fish in Bali Strait is in the second position of the most dominant fish in Bali Strait. Muncar is the most important fishery port in Bali Strait[2] because most of the fish that is being catch in Bali Strait is landed at the Muncar Fishery Port.

The information about the temperature variation data is very needed for the study of marine fisheries, especially in the fishing industry. Temperature data can be obtained through a remote sensing method by using Aqua Modis imagery satellite. The regional coverage of this satellite is very wide, and besides that, the remote sensing can be done efficiently because the researchers do not have to take the data directly in the field.

The oceanographic parameters such as the temperature aspect is essential to be analyzed in order to explore the characteristics and to determine the quality of the water. Therefore, in terms of fisheries resource management, the information or data that describes the oceanographic conditions which can affected the fishing results is important to be known.

Materials and Methods

The temperature and chlorophyll data is obtainedmonthly from the temperature recording data of the Aqua MODIS satellite that is downloaded via NASA, namely, www.modis.gsfc.nasa.gov, within the period of 14 years. It includes the territorial waters between 114^0 26’ 00’’ – 115^0 10’ 00’’ BT and 08^0 09’ 00” – 08^0 50’ 00” LS (Figure 1) which consists of 3 stations such as 114^0 26’ 11” BT 08 27’ 14” LS (Station 1), 114^0 34’ 43” BT 08^0 37’ 08” LS (Station 2), 114^0 40’16 BT 08^0 42’ 18” LS (Station 3). Those 3 stations are the territorial area of fishing ground in Bali Strait.The data is then analyzed for its anomalies and times series with Microsoft XL to determine the monthly trend of temperature in Bali Strait.

Figure 1. Research Location

Besides the data of the temperature, the data per trip fishing effort was used in this research. The data is compiled from Muncar Fishery Port. The data per trip fishing effort is obtained from the monthly statistical data which then is used to determine the relationship between the temperature and chlorophyll with the catch per unit effort.

The analysis of Indian Scad Fish production is performed by using time series graph and interpreted in accordance with the highest and lowest number of monthly CPUE production in Muncar Fishery Port. The calculation of CPUE (catch per unit effort) aims to determine the rate value of the fishing effort based on the division of the total catch towards the fishing effort. The formula which is used for the CPUE calculation is as follows:

$$\text{CPUE}i = \frac{Ci}{fi} \quad \text{...(1)}$$

Ci = the *i*-th catching results (ton)
Fi = the *i*-th catching efforts (trip)
CPUEi = the *i*-th total catch per unit effort (kg/trip)

Data standardization analysis is used to standardize all existing data and to obtain its standard value, so that it would be easier to make a graph from all the existing data[3]. The formulation used are as follows:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} \quad \text{..(2)}$$

$$z = \frac{xi - \bar{x}}{s} \quad \text{...(3)}$$

z = standardization value
xi = the *i*-th xvalue
● = average value
s = deviation standard
n = total number of data

The analysis of time series and anomalies of the sea surface temperature as well as the analysis of the catch per unit effort is done by using Microsoft Excel 2013.

Results and Discussion

The Temperature Trend in Bali Strait

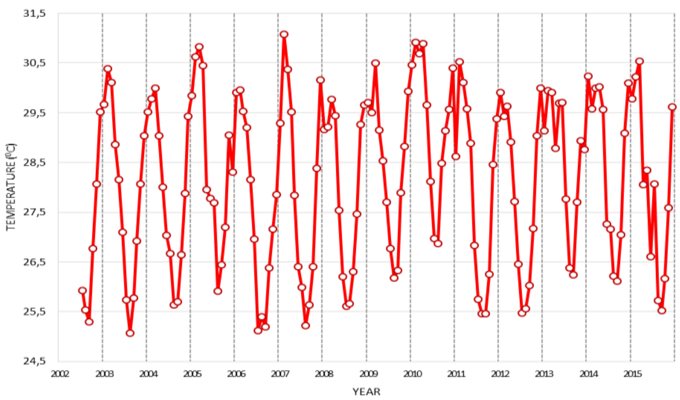

Figure 2. The time series temperature in Bali Strait

Time series graphic is conducted to determine the variations of the sea surface temperature monthly for 14 years, so we could know when high temperature or low temperature is occurred in Bali Strait research area. As seen on Figure 2, the value of SPL in Bali Strait is fluctuated in every month. Generally, the phase of high temperature occurs in December to May, while it starts to decline in the beginning of June and peaked in August.

If it is seen from time series point of view, the SPL value fluctuations in Bali Strait is ranging between 25.100C - 31.11^{0}C. The lowest SPL value is occurred in December 2006, while the highest SPL value is occurred in September 2010 each year. In 2006 the El-Nino phenomenon had occurred in Indonesian territory, which have an impact on the sea surface temperature declining and chlorophyll-a rising concentration as a result of the strong upwelling intensity[4].

The calculation of the SPL anomaly value is conducted to determine the data deviations that occurs within the normal state for 14 years. The calculation is done by reducing the SPL value each month in a certain year with the entire month average value.

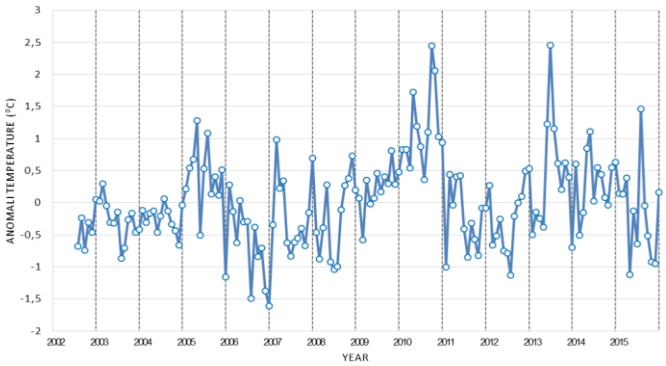

Figure 3. Temperature Anomalies in Bali Strait

The highest sea surface temperature anomalies occurred in June 2013 (2.46^{0}C) and the lowest sea surface temperature anomalies occurred in June 2006 (1.61^{0}C).In 2006 the El-Nino phenomenon had occurred in Indonesian territory, which have an impact on the sea surface temperature declining and chlorophyll-a rising concentration as a result of the strong upwelling intensity[4].

The seasonal variation in Indonesia is divided into four, namely west season (December, January, February), transitional season I (March, April, May), east season (June, July, August), and transitional season II (September, October, November). Every season has its characteristics of different sea surface temperature due to the variations in the atmospheric pressure and wind speed which always fluctuating.The SPL seasonal variations data in Bali Strait is in the period of 2002-2015.

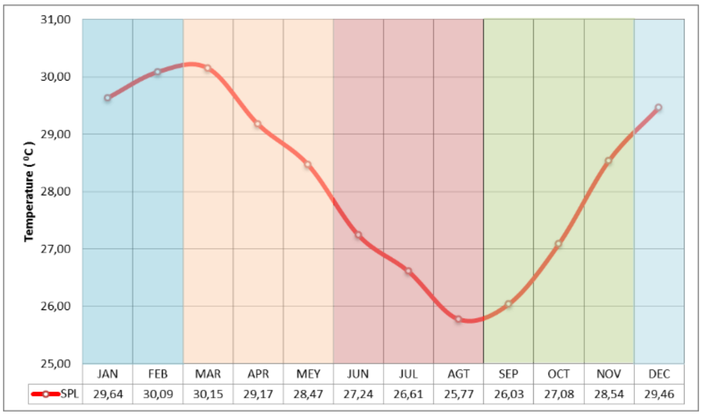

Figure 4. The Seasonal Temperature Average Trend

The average value of the highest average temperature occurred in February until March (west season - transitional season I) with the temperature ranging between 30.15^{0}C – 30.09^{0}C and the lowest average temperature occurred Agustus until September (east season - transitional season II) with the temperature ranging between 25.77^{0}C – 26.03^{0}C.In accordance with Gaol[5]which stated that during the west season, the air pressure in Indonesian waters is weakened, so the wind would make a water flow that will carry warm water of high pressure water toward the Indonesian waters (lower air pressure). Otherwise, during the east season, in the southern of Indonesia, an upwelling will have occurred and caused the temperature to be colder.

The Relationship Between the SPL and the Phenomenon of Climate Change

El-Nino Southern Oscillation (ENSO)

ENSO is a phenomenon of sea surface temperature deviations that occurred around Peru and eastern Pacific, which influenced the climate and weather conditions in the western Pacific to the Indian Ocean and the area around the equator. ENSO is divided into two phenomena, El-Nino that is characterized by the warming of SPL in eastern Pacific and La-Nina that is characterized by the decreased of SPL in eastern Pacific. The parameters used to determine the ENSO phenomenon among others are SOI (Southern Oscillation Index) and Nino 3.4.

Southern Oscillation Index (SOI)

SOI is based on the atmospheric pressure differences between Eastern Indian Ocean (Darwin Region) and South Pacific (Tahiti Region). In the El-Nino and La-Nina, both of these areas will experience the atmospheric pressure value differences that is quite extreme, whereby when the SOI is negative (-) exceeding normal (less than -0.5) then it indicates El-Nino, but when the SOI is positive (+) exceeding normal (more than +0,5) it indicates La-Nina. El-Nino is characterized by the value of the atmospheric pressure that is less than -0.5, while La Nina is characterized by the atmospheric pressure value that is more than 0.5. SOI is displayed in time series from the 2004 up to 2015 as shown in Figure 5.

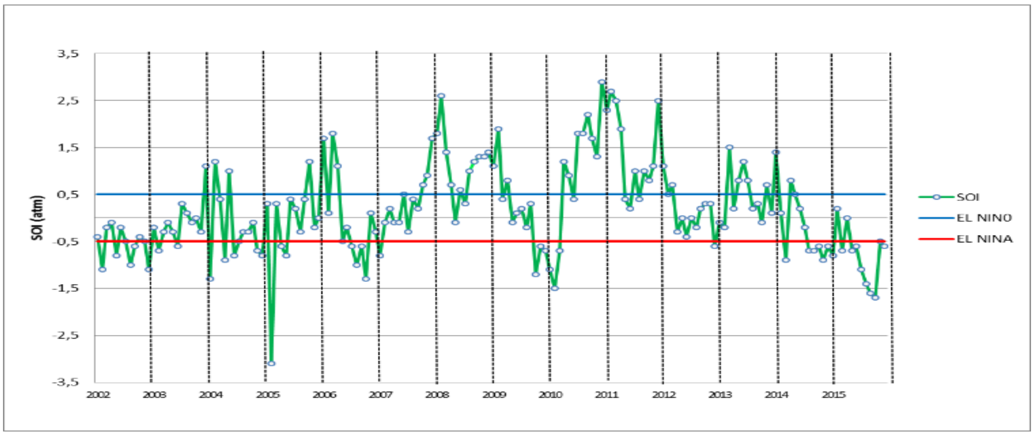

Figure 5. Southern Oscillation Index (2002-2015)

Based on the SOI graphic, we could see the low SOI for 3 months continuously in 2006, while the high SOI is occurred in 2010 and 2011. As also seen in Figure 5, there is a significant change in the atmospheric pressure in a certain year that is indicating ENSO phenomenon. The phenomenon is characterized by the occurrence of anomalous value that is exceeding the normal deviation for 3 months or more in a row. From the graph above, we could know the irregularities anomalous values for 3 months or more in a row - in 2006, late 2009 and early 2010, as well as at the end of 2015 the decline in the atmospheric pressure value which is exceeding the normal line is indicating the occurrence of El Nino, while in the late of 2007, 2008, 2010, 2011, and 2013 an increase in the atmospheric pressure value that is exceeding the normal line is indicating the occurrence of La Nina. SOI lowest value occurred in February 2005 with a value of -2 atm, while the highest SOI value occurred in December 2010 with a value of 2.5 atm.

Nino 3.4

Nino 3.4 is a SST anomaly value deviation that occurred in the Niño 3 and Niño 4 of the Central Pacific. Inversely proportional to SOI, El-Nino phenomenon is characterized by a positive (+) index that is exceeding the normal value (+0.5), while La Nina phenomenon is characterized by a negative (-) index that is exceeding the normal value (-0.5). Nino 3.4 graph is shown in Figure 6.

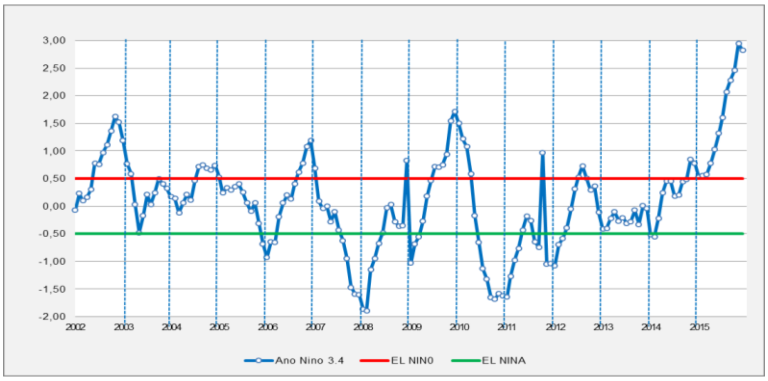

Figure 6. Nino 3.4 index (2002-2015)

As seen on Figure 6, there is a particular changes of the SPL anomalies in a certain year which indicates the occurrence of ENSO phenomenon. From the Nino 3.4 graph, we could know the SST anomaly value deviation that is occurred in late 2004, late 2006, early 2007, late 2009, early 2010 and late 2015 has increased more than the normal value which is indicating the occurrence of El Nino, while in late 2007 until early 2008, late 2010 until early 2011, and late 2011 the Nino 3.4 index has declined more than the normal value which is then indicating the occurrence of La Nina. The highest Nino 3.4 index is occurred in November 2015 (2,95^{0}C), while the lowest Nino 3.4 index is occurred in January up to February 2008 (-1,86 ^{0}C)and 1,89^{0}C in Octoberas well as in December 2006 up to January 2007 (-1,62 ^{0}C and -1,64^{0}C). In 2006/2007, the increase in ONI (Oceanic Nino Index) indicates the occurrence of El Nino in Pacific, and causes a decrease in Indonesia sea surface temperature as a result of the increased upwelling waters[4].

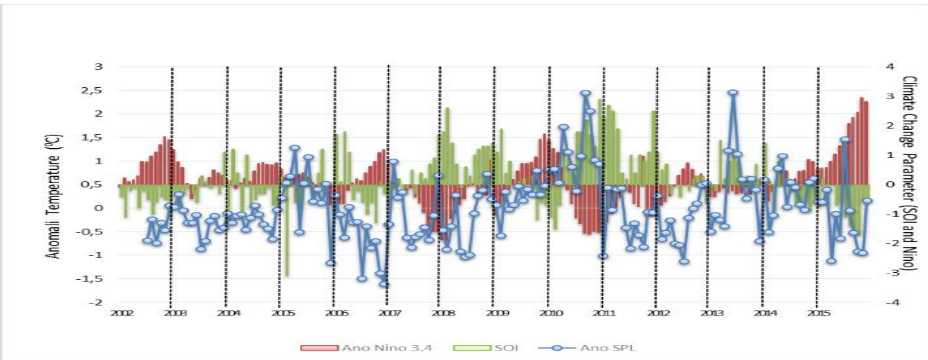

Figure 7. The relationship between ENSO phenomenon and SPL variation in Bali Strait (2002-2015)

El-Nino phenomenon occurs in 2006-2007, so it was influenced the SPL anomaly with a negative value (very cold) which is 25.10^{0}C, colder than the previous years. It was happened because during the strong El Nino, the value of SPL in Bali Strait sufficiently cool. Likewise, the phenomenon of La Nina in 2010 was influenced the SPL anomaly with a positive value (very hot) which is 30.92 ^{0} C. It also happened because La-Nina SPL value is already quite warm. Whereas the phenomenon of El Nino and La-Nina was occurred in 2011 and 2014 but there was not such serious effect towards the SPL value in Bali Strait. There was a time when in 2014, when the SPL value was cool enough due to the phenomenon of El Nino, IOD- events made the temperature to be warm again, so the SPL value tends to be more stable (normal) with a value of 25.55^{0}C. However, in 2010, when the SPL value was already quite warm due to the phenomenon of La Nina, strong IOD+ events came and made the SPL value cool again, consequently the water temperature becomes normal and tend to be stable again with a value of 29.86^{0}C.

The Trend of Catching Indian Scad Fish (Decapterus spp) in the Bali Strait

Time series graphic is conducted to determine the variations of the sea surface temperature monthly for 14 years, so we could know about the highest and the lowest Indian Scad Fish CPUE in Muncar Fishery Port. The Indian Scad Fish CPUE anomaly is shown in Figure 8 below.

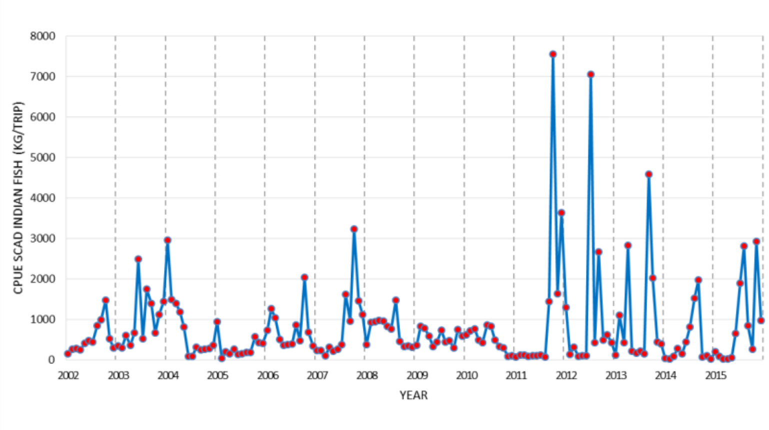

Figure 8. Indian Scad Fish Timeseries CPUE (2002 – 2015)

Indian Scad Fish production(*Decapterus spp*) in Bali Straittend to be very fluctuated from year to year. The anomalies of the Indian Scad Fish (*Decapterus spp*) production had reached the highest point in October 2011 (7547.02 tons/trip) and in July 2012 (7059.58 tons/trip) while the lowest point of the Indian Scad Fish production is in January 2011 (69,77 kg/trip)andin August 2011 (58,66 kg/trip).

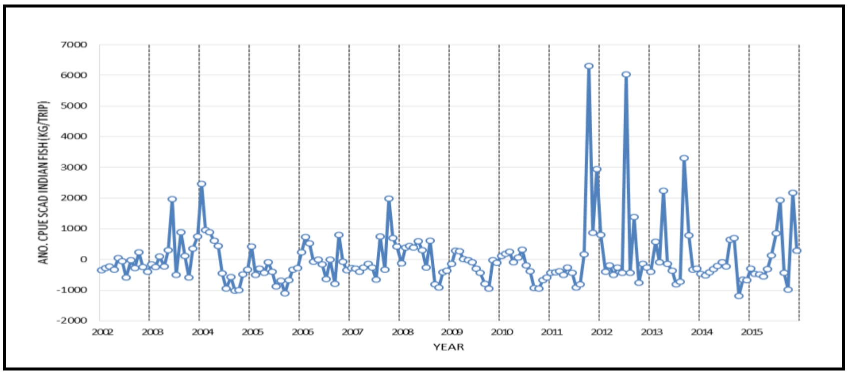

Figure 9. Indian Scad Fish CPUE (2002-2015)

Based on Figure 9, the production value of the Indian Scad Fish in Bali Strait is fluctuated each month. In general, the highestCPUE anomaly of the Indian Scad Fish (*Decapterus spp*) is occurred in October 2011(6,304.2 kg/trip)andin July 2012 (6,037.9kg/trip), while the lowestCPUE anomaly is in September 2006 (-789.208) andin December 2014(– 671.039).

The ability of the fishermen to predict the presence of fish in its season could determine the success of the fishing. Indian Scad Fish fishing season can be seen in Figure 10. It can be seen that January is the month with the lowest fishing results (160 kg/trip) while there is an increase in February and will reach the highest peak of fishing season in March (1,091 kg/trip). However, there will be a decrease in the following month until mid-year until it increases in September (663 kg/trip) then decreased again until the beginning of the year.

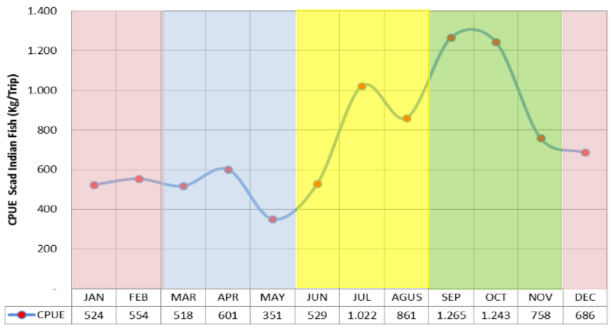

Figure 10. Seasonal Indian Scad Fish CPUE Trend

Parameters Standardization

Before conducting the parameters grouping, it is necessary to do a standardization analysis that is used to standardize all the existing data and to obtain the standard value so that it will be easy to create the data graphs[1].

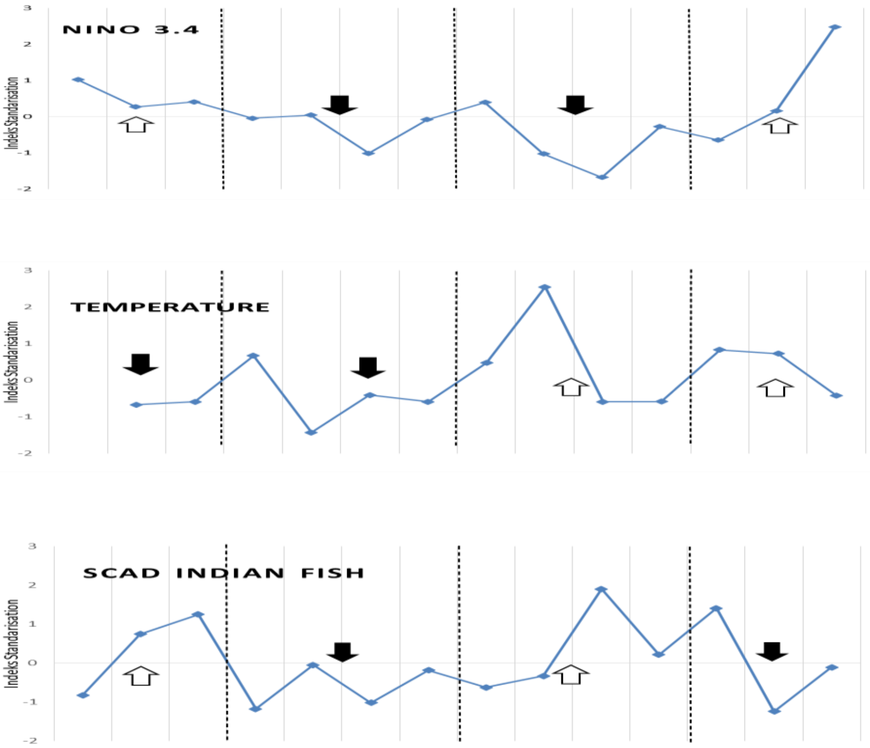

Figure 11. Parameters Standardization

Based on Figure 11, the relationship between Nino 3.4, temperature and Indian Scad Fish fishing results is mutually correlated when the Nino 3.4 is increased and the temperature is decreased then it shows a positive correlation with the fishing results declining. This is in contrast with the condition that when Nino 3.4 is decreased and the temperature is about to rise, it will show a positive correlation with the increased fishing results. The relationship between fish and water temperatures are divided into 4 parts.

Indian Scad Fish Catching Season and Its Factors

The seasonal patterns of Indian Scad Fish in Bali Strait are often incompatible with the general pattern of the season. It can be seen from a very close relationship between the sharp fluctuations with its total production, which is mainly due to environmental changes. The pattern similarity between the season in a year with the upcoming year is not yet to be known, it depends on the presence or absence of the significant influences in water environment changes.

Southern Oscillation Index (SOI) has a very real impact on the fish landing in Bali Strait. Within the years of an El Nino, it will produce a very high landing, and within the years of anti-El Nino, it will produce a very low landing. Therefore, in determining the fishing season index, it requires a long enough serial data to reduce data fluctuations. In east season, high nitrate concentrations occur in Bali Exposure. Nutrients such as nitrate and phosphate is essential for phytoplankton growth. So that, in the east season where upwelling is occurred, it will have resulted an increase in phytoplankton. The concentration of plankton in Bali Exposure is higher than the water in the middle of the strait and Java Exposure[6]. As a result, a food source for fish larvae that was spawned in June-July can be provided adequately. Furthermore, the larvae will keep growing until it reached its adulthood and eventually will be caught in east-west transitional season until west season.

One of the way to optimize the fishing results is by setting a fishing area closure in certain seasons. This is to give the fish a chance to grow bigger so that it has a heavier weight and finally the biomass in the ocean is also increase. The increased biomass may increase the chances of the ship to increase the catches without increasing the fleet. After doing the closure in the north, then it can make another fishing in the south with other targeted.

From the findings above, it can be concluded that the monthly data of temperature variations in Bali Strait over this 14 years (2002-2015) shows the lowest average temperature of 25.10^{0}C (July 2006) and the highest average temperature of 30,92^{0}C (February 2010). The correlation between the temperature and the fishing result indicates that low temperature is followed by low Indian Scad Fish production while intermediate temperature is followed by an increased Indian Scad Fish production.

Furthermore, the dynamics of Indian Scad Fish CPUE (catch per unit effort) that is landed at Muncar Fishery Port in the period of 2002-2015 has the highest average CPUE of 7547.02 kg/trip (October 2011) at a temperature of 26.26^{0}C and the lowest average CPUE of 14.69 kg/trip (December 2014) at a temperature of 30.10^{0}C.

Dealing with the conclusion, some suggestions are made. First, the government should have made a conservation policy by setting fishing time period in order to preserve the fish resources sustainability in Bali Strait. Second, there should have a further research with an assessment of other aspects such as the socio-economic aspect to make it easier to be applied in the community.

Acknowledgement

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