VARIABILITY OF CHLOROPHYLL-A DISTRIBUTION AROUND BELITUNG ISLAND WATERS OBSERVED BY AQUA-MODIS SATELLITE DATA

(Variabilitas Distribusi Klorofil-a di Sekitar Perairan Pulau Belitung Diamati Menggunakan Data Satelit Aqua-Modis)

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ABSTRACT

Belitung Island has a strategic geographical location, which is directly bordered with Sumatera and Kalimantan also Karimata and Malacca Straits. Those conditions make the waters productivity being high due to the support from the biogeochemical cycle, nutrient runoff, and upwelling. This study aims to determine the seasonal variability of chlorophyll-a (Chl-a) around Belitung waters. The method used in this study was spatial analysis with IDW (*inverse distance weighted)* to interpolate the Chl-a surface distribution. Sea Surface Temperature (SST) acquired from Aqua-MODIS were retrieved from NASA (*National Aeronautics and Space Administration*) and wind data were obtained from ECMWF (*European Centre for Medium-Range Weather Forecasts*), data were analyzed statistically and spatially. The Chl-a concentration in the northeast monsoon ranged 0.38-3.5 mg.m^{-3}, in the southwest monsoon ranged 0.15-18.7 mg.m^{-3}, and in the transitional season ranged 0.29-9.04 mg.m^{-3}. The Chl-a concentration during southwest and 1st transitional monsoons were higher due to the maximum sunlight intensity stimulating photosynthesis of autotroph biota. The condition of SST is indicating the upwelling event that involves wind-driven motion of dense, cooler, and usually nutrient-rich water towards the ocean surface. Seasonal SST variability ranged 22.6-28.3^{o}C, 27.3-32.1^{o}C, 30.7-32.3^{o}C, and 29.1-32.8^{o}C during northeast, 1st transitional, southwest, and 2nd transitional monsoons respectively. The existence of ENSO (*El-Nino Southern Oscillation*) contributes to enhance the Chl-a concentration. During ENSO years, the Chl-a concentration was higher than non-ENSO years due to the great impact of ENSO inducing upwelling and higher nutrient availability. Chl-a and SST conditions can be used to predict fishing ground and upwelling area.

Keywords: Chlorophyll-a variability, monsoon, Aqua-MODIS, Belitung Island

ABSTRAK

Pulau Belitung memiliki posisi geografis yang sangat strategis, yang berbatasan langsung dengan Sumatera dan Kalimantan serta selat Karimata dan Malaka. Kondisi tersebut menyebabkan produktivitas perairan Belitung menjadi meningkat karena dukungan dari daur biogeokimia, runoff nutrient dan upwelling. Tujuan dari penelitian ini adalah untuk mengetahui variasi musiman sebaran klorofil-a (Chl-a) di perairan Belitung. Metode yang digunakan adalah analisis spasial dengan IDW (inverse distance weighted) untuk menginterpolasi sebaran Chl-a. Suhu permukaan laut (SPL) diperoleh melalui NASA (National Aeronautics and Space Administration), dan data angin didapatkan dari ECMWF (European Centre for Medium-Range Weather Forecasts), data dianalisis secara statistik dan spasial. Konsentrasi Chl-a pada musim barat berkisar antara 0,38-3,5 mg.m^{-3}, pada musim timur berkisar antara 0,15-18,7 mg.m^{-3}, pada musim peralihan berkisar antara 0,29-9,04 mg.m^{-3}. Chl-a selama musim timur dan peralihan 1 lebih tinggi karena penyinaran matahari yang maksimal yang mendukung terjadinya fotosintesis oleh biota autotrof. Nilai SPL memiliki peran dalam mengindikasikan kejadian upwelling yang melibatkan gerakan angin dari air yang rapat, lebih dingin, dan biasanya kaya nutrien ke permukaan samudera. Variabilitas musiman SPL berkisar antara masing-masing 22,6-28,3^{o}C, 27,3-32,1^{o}C, 30,7-32,3^{o}C, dan 29,1-32,8^{o}C selama musim barat, peralihan 1, timur, dan peralihan 2. Keberadaan ENSO (El-Nino Southern Oscillation) berkontribusi untuk meningkatkan konsentrasi Chl-a. Selama tahun ENSO, konsentrasi Chl-a lebih tinggi daripada tahun-tahun non-ENSO karena dampak besar dari ENSO yang mendorong upwelling dan ketersediaan nutrien yang lebih tinggi. Kondisi Chl-a dan SST dapat digunakan untuk memprediksi fishing ground dan area upwelling.

***Kata kunci**: Variabilitas klorofil-a, musim, Aqua-MODIS, Pulau Belitung*

INTRODUCTION

Belitung Island is part of Bangka Belitung Province located in the strategic and unique areas between two main islands (Sumatera and Kalimantan), and two straits (Karimata and Malacca). It is also located in the South China Sea. Geographic conditions make Belitung waters to become very productive because of the availability of nutrients supported by the photosynthesis process (Simanjuntak, 2009). Distribution of mass water affects the physical and chemical parameters, which has an impact on the dissolved and suspended compounds in the waters. Nutrient and Chlorophyll-a (Chl-a) availabilities sourcing from disposal waste and biogeochemical cycle transported by hydro-oceanography factors (Putri, Zainuri & Priyono, 2016).

Belitung waters area is significantly influenced by atmosphere circulations. The rainfall intensity in Belitung waters is affected by 2 seasons in the equator region, those are northeast and southwest monsoons (Supari & Setiawan, 2013). The evaporation directly influences the temperature elevation gradient on the surface, thus it is affecting the Chl-a and the other chemical compound in the waters. Several previous studies have been published. Putri et al (2016) defined the correlation between orthophosphate and Chl-a in the Karimata Strait, the average of orthophosphate is 0.0456 mg/L and the Chl-a value is averagely 0.2225 mg.m^{-3}. The distribution of Chl-a and orthophosphate are concentrated in the near coast and shallow water area. Simanjuntak (2009) studied the influence of chemical and physical factors on plankton distribution in Bangka Timur coast. Phosphate, nitrate, nitrite, and silicate tend to be higher in the shallower area, whilst dissolved oxygen and phytoplankton are greater in the surface. Rustam & Prabawa (2015) focused on monitoring water quality in Belitung Timur. The study shows that the water quality in Belitung Timur is still appropriate for biota and aquaculture.

As the strategic water area, monitoring the productivity level and temperature seasonally is necessary to control the blooming tendency and predict either the fishing ground or upwelling area. Chl-a is very related to the productivity level of the waters, so it is essential to observe the influence of the season changes on the Chl-a variability in Belitung waters. The purpose of this study is to determine the seasonal variability of Chl-a concentration in the Belitung waters.

METHOD

This study conducted in Belitung Island Waters. Geographically, Belitung is positioned between 107°31'5" – 108°18' E and 2°31'5"-3°6'5" S. Belitung Island is bordered by the South China Sea in the north, and Karimata Strait in the east. In the south and west is bordered by Java Sea and Gaspar Strait respectively. There are small islands such as Mendanau and Kalinambang around Belitung island. The chlorophyll-a concentration (Chl-a) and Sea Surface Temperature (SST) data were measured from 5 stations (**Figure 1**). **Figure 1** generated by Indonesia topographic map (RBI Map) and Google Earth Images. All field data collected on June 11th-14th, 2015 (Putri et al., 2016). These field data were used to validate the Aqua-MODIS analysis result. The observation station of Chl-a is shown in **Figure 1**, distributed around of Belitung island consist of 5 stations. Distribution of those stations is considering the representation of the condition of waters, especially in seasonal condition.

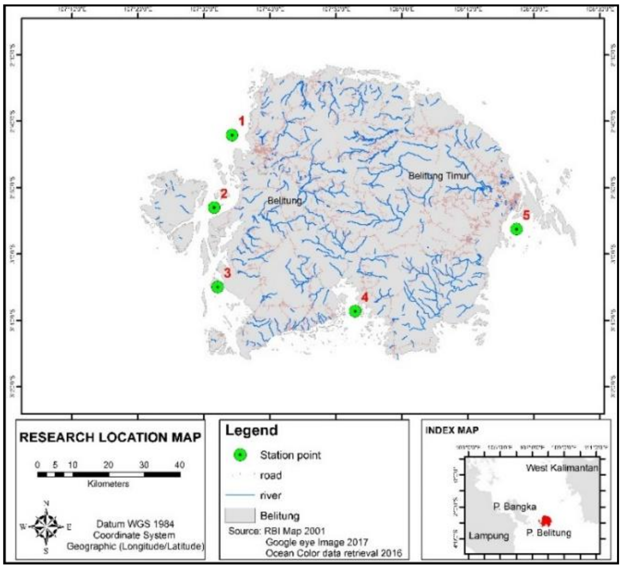


Figure 1. Research location map.

The Chl-a concentration and SST data in this study obtained from Aqua-Modis satellite data that acquired from ocean color web of National Aeronautics Space Agency (NASA) (Fieldman, G., 2017), whilst, seasonal reanalysis data ERA-interim- daily of 0.125° wind data were retrieved from European Centre for Medium-Range Weather Forecasts (ECMWF) (ECMWF, 2017). The monthly SST data during December 2014-November 2015 obtained from NOAA-AVHRR satellite with the resolution of 4x4 km^2 which was retrieved from Physical Oceanography Distributed Active Archive Center (PODAAC) (PODAAC, 2017).

Chl-a concentration estimated using the OC4x4 algorithm. That algorithm shows the Chl-a concentration in the sea surface expressed in mg.m^{-3}. The data processing of Chl-a and SST performed using SeaDAS (SeaWiFS Data Analysis System) version 7.3.2. The first step is cropping the image through the display menu in SeaDAS to extract information according to the observation station. Further, extracted data exported to *mask pixel* and saved in ASCII file that used to obtain information regarding Chl-a concentration and SST fluctuation. Its information visualized temporally and spatially as represent as the study area. Data Chl-a and SST were sorted (Quality control) by deleting the cloud pixel value among <0 mg.m^{-3} and ≤ 20 mg.m^{-3}, for the concentration of Chl-a, and <20°C or > 35°C for the SST data (Nababan & Simamora, 2012).

Chl-a Algorithm

Chl-a algorithm returns the near-surface concentration of Chl-a in mg.m^{-3}, calculated using an empirical relationship derived from *in situ* measurements of Chl-a and remote sensing reflectance (Rrs) in the blue-to-green region of the visible spectrum. The implementation is depended on the availability of three or more sensor bands spanning the 440 - 670 nm spectral regime. The algorithm is applicable to all current ocean color sensors.

The current implementation of the default Chl-a algorithm employed the standard OC3/OC4 (OCx) band ratio algorithm merged with the color index (CI) (Hu, Lee, & Franz, 2012). The refinement is limited to relatively clear water, and the general impact is to reduce artifacts and biases in clear-water chlorophyll retrievals due to residual glint, stray light, atmospheric correction errors, and white or spectrally-linear bias errors in Rrs. As implemented, the algorithm deviates slightly in which the transition between CI and OCx now occurs at 0.15 < CI < 0.2 $mg.m^{-3}$ to ascertain a smooth transition (Belkin & O'Reilly, 2009).

SST Algorithm

The average of monthly SST data was estimated using MCSST algorithm. The wavelengths of the SST algorithm of MODIS band 31 and band 32 used were 11 and 12 µm. The temperature visibilities coming from radiances were observed by inversion from the intensity of blackbody temperature relationship.

That relation was calculated according to each spectral response from MODIS channel. And then the table saved in the HDF file that will be released in the run-time. In the MODSST, the intensity was compared with the relation of blackbody temperature calculated in the run-time. The non-linear SST algorithm set up for 2 different regimes based on the difference in temperature intensity (Kilpatrick et al., 2015).

Lay-Outing the Data

To layout the distribution map of Chl-a seasonally, Inverse Distance Weighted (IDW) spatial analysis techniques were used in this study, it performed to analyze the distribution of Chl-a concentrations in Belitung waters. It helped to lay out the Aqua-MODIS data to be well interpreted the process of distribution, set up for generating IDW is shown in **Table 1.** IDW is a part of spatial analysis from ArcGIS software 10.3. It works to depict the distribution of parameters based on the value obtained. It extends the interpolation value covering the boundary area to get well-interpreted distribution map.

Table 1. Set Up for Generate IDW Processing.

Indicator	Implemented in IDW Processing
Projection Coordinate System	Geographic (Longitude/Latitude) World Geographic System (WGS) 1984
Geoprocessing-Environment Setting	Processing Extend : Top = -2.411348 Bottom = -3.397948 Left = 107.042887 Right = 108.508692
ArcToolbox - Spatial Analyst Tool	IDW Set up : Output Cell Zise = 3.94639717568498E-03 Number of Points = 12 Search Radius = Variable

RESULT AND DISCUSSION

Belitung Island is located in a very strategic position, bordered by several straits and strongly influenced by seasonal winds as well. Wind energy transferred to the surface of the water causes the fluctuation of surface waves eventually forming currents. Ocean current plays a role in distributing the chemical compounds and phytoplankton in the waters. During the southwest monsoon, Chl-a concentrations are quite high in some areas in Belitung waters, shown by the brown color (**Figure 2**). In addition, chlorophyll concentration is quite high in the southern and eastern reached 18.7 $mg.m^{-3}$. In generally, the average of Chl-a concentration during northwest monsoon is 0.65 $mg.m^{-3}$ and the concentration ranged 0.15-18.7 ± 0.66 $mg.m^{-3}$. The high Chl-a concentration is found near the mainland where there are many estuaries in the surrounding, so that the intake of nutrients from land and the river has become a major factor influencing this condition. A nutrient is the basic element in the process of photosynthesis, the higher presence of nutrient, the higher productivity of autotroph biota population (Wisha & Maslukah, 2017).

In the Eastern and the Southern of Belitung waters, due to the semi-enclosed formation, the nutrients from the rivers and land are relatively trapped and settled in that region. Eventually, the accumulation of Chl-a takes place. The transport mechanism of the semi-enclosed area is very low, the distribution of chemical compounds in the surface is not optimal. While, in the other region, such as the Karimata Strait and the Belitung Strait, the condition of Chl-a is fairly low because of the transport potential of open water. Based on previous research (Putri et al., 2016) the concentration of Chl-a in Belitung waters during the southwest monsoon ranged between 0.05 up to 0.42 $mg.m^{-3}$. The spread of Chl-a in Karimata Strait is concentrated in the Belitung Island.

Several supporting data such as temperature, salinity, dissolved oxygen, pH, and turbidity were used to monitor the water condition of Belitung in correlation with Chl-a condition, shown in **Table 2**. Temperature ranged from 29.37-30.02°C, it is still within the safe limits of standard temperature for ocean waters, the value of dissolved oxygen (DO) ranged 4.08-4.20 $mg.L^{-1}$, these values are slighly low for aquatic biota (Wisha et al., 2016). Salinity value ranged from 31.32-33.00 Psu, tend to be normal for aquatic biota. Turbidity value ranged from 1.79-2.00 NTU. It indicates that the value tends to clear waters, the low of turbidity is caused by low particulate solids suspended in water, it is extremely beneficial in supporting the process of photosynthesis by autotroph organism (Wisha et al., 2016).

Table 2. Water quality around Belitung Island in the east season.

Parameter	Mean	Max	Min	St. Dev
Temperature (ºC)	29.62	30.02	29.37	0.18
Dissolved oxygen (mg/L)	4.13	4.20	4.08	0.03
Salinity (PSU)	32.48	33.00	31.32	0.52
pH	8.57	8.6	8.54	0.02
Turbidity (NTU)	1.86	2.00	1.79	0.07

Source: Putri et al., 2016

We concluded the value of water quality during Southwest monsoon indicates that the water condition strongly supports the enhancement of Chl-a concentration and primary productivity. It is proved by the low turbidity, optimal salinity and temperature. The low of DO value indicates that autotroph biota uses the dissolved oxygen to process the photosynthesis mechanism. It is clear, that some areas in Belitung waters have a very high chlorophyll-a concentration reached 18.7 mg.m^{-3}. During Northeast monsoon, a higher rainfall and lower solar radiation occurred, resulting in an increased value of chlorophyll-a ranged 0.38-3.5 mg.m^{-3}, shown in **Figure 3**. The highest concentrations were observed in the West, North and South part of Belitung Waters. High concentration of Chl-a was found around estuaries, the higher intensity of rain in this season increases the runoff from the river so that the nutrients from the land and rivers carry away and accumulate in the estuary. Phytoplankton can perform well-photosynthesis with the support of nutrient sufficient which eventually make Chl-a concentration increases. On the northeast monsoon, maximum chlorophyll found in the lining of *euphotic zone* (<20 m). Therefore, the chlorophyll condition on the surface was not abundant (Westphal et al., 2014). Rainwater was predominated in the estuary during the northeast monsoon which caused the mixing and degradation of water salinity. These conditions may directly impact the reduced of Chl-a condition in the water.

The low Chl-a was observed during Northwest monsoon and this was attributed to negative wind stress curl and downwelling (Radiarta & Saitoh, 2008); (Wiggert, Vialard, & Behrenfeld, 2009) (**Figure 10**). Therefore, the Chl-a concentration was decreased. In the 1st transitional season, chlorophyll-a concentration ranged from 0.29-8.07 mg.m^{-3}, in which the highest concentration is located along the West, South and Southeast coasts, shown in **Figure 4**. While, in the 2nd transitional season, chlorophyll-a concentration ranged from 0.03-9.04 mg.m^{-3}, in which the largest concentration is located in the western waters of Belitung Island (**Figure 5).**

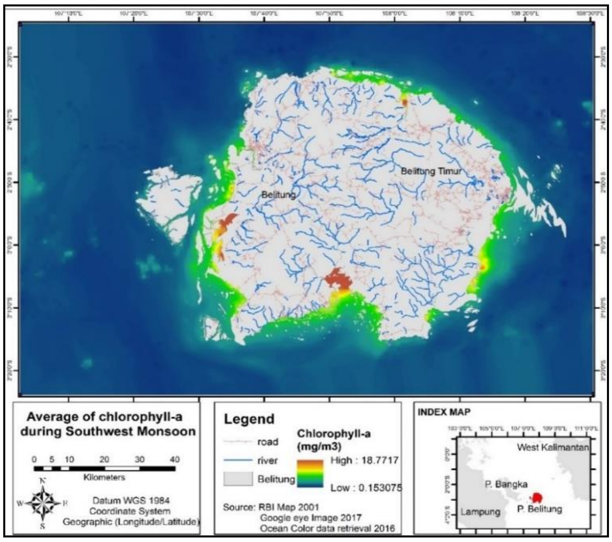


Figure 2. Variability of Chl-a during southwest monsoon (June-August 2015) in Belitung Island derived using Aqua-MODIS data by applying OC3 algorithm.

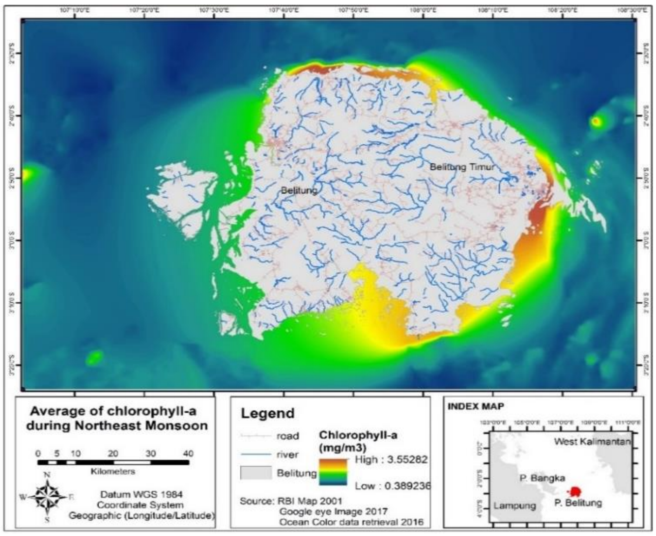


Figure 3. Variability of Chl-a during northeast monsoon (December 2014-February 2015) in Belitung Island derived using Aqua-MODIS data by applying OC3 algorithm.

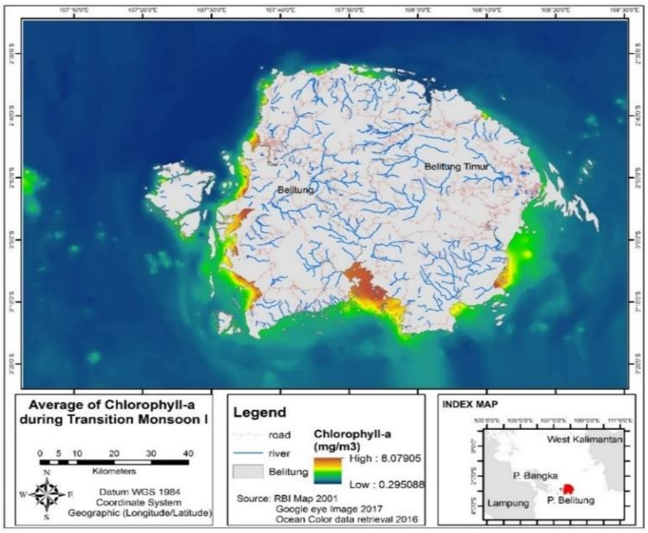


Figure 4. Variability of Chl-a during the 1st Transitional Monsoon (March-May 2015) in Belitung Island derived using Aqua-MODIS by applying OC3 algorithm.

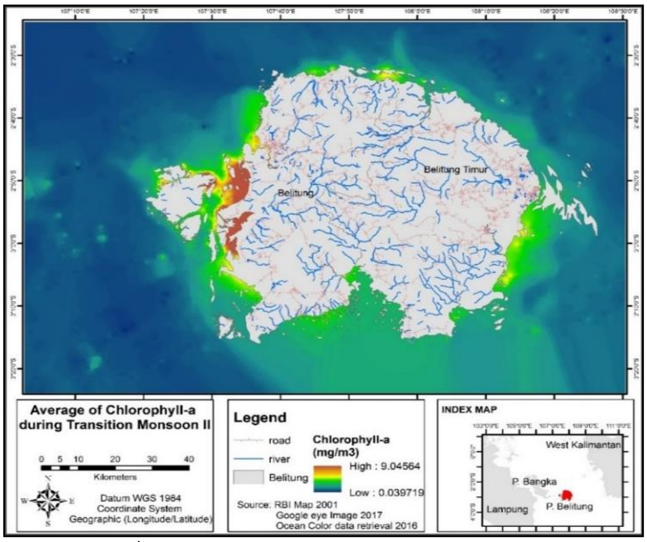


Figure 5. Variability of Chl-a during the 2nd Transitional Monsoon (September-November 2015) in Belitung Island derived using Aqua-MODIS by applying OC3 algorithm.

In the 1st and 2nd transitional seasons, Chl-a concentration is slightly different which the average of Chl-a during 1st transitional season reaches 0.65 ± 0.49 $mg.m^{-3}$ and during 2nd transitional season reaches 0.46 ± 0.51 $mg.m^{-3}$ respectively. The highest concentration of Chl-a is observed in the southern during the 1st transitional season and in the eastern during the 2nd transitional season (**Figure 4 and 5**). These conditions mainly influenced by the wind direction predomination during the northeast and the southwest monsoon (**Figure 10 and 11**). During the transitional seasons occurred the extreme weather conditions, switching between high and low temperatures in the waters happened so fast (Nababan & Simamora, 2012).

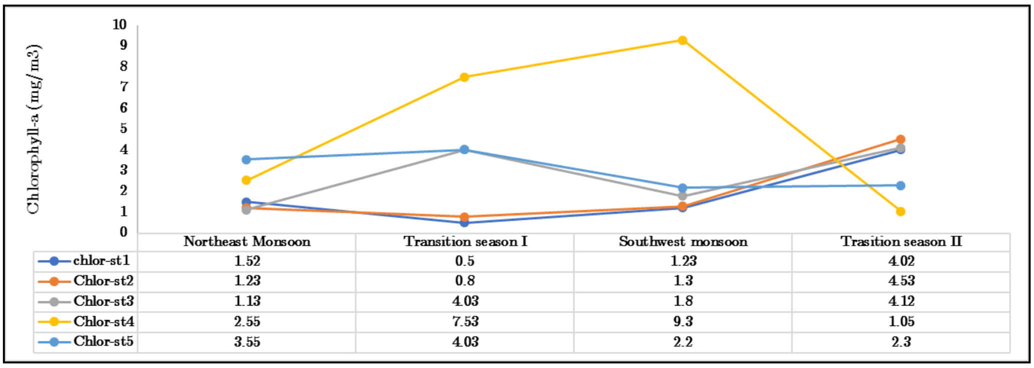
The concentration of Chl-a is unstable in each season. The extreme condition occurs during northeast monsoon in which the concentration of Chl-a becomes low. During the southwest monsoon, Chl-a rises tremendously high. That condition is severely controlled by SST in each season that is warmer in the southwest monsoon (ranging from 30.7-32.3°C) and cooler in the northeast monsoon (ranging from 22.6-28.3 °C) (**Figure 7**). According to Chow et al. (2013), the increase and decrease in surface and integral euphotic zone Chl-a abundance is correlated with sea surface temperature conditions, suggesting that Chl-a abundance is proportional to the strength of upwelling and vertical mixing (biogeochemical cycle).

At station 1, the highest Chl-a value is observed in the 2nd transition season, reached 4.04 $mg.m^{-3}$ and the lowest is identified in the 1st transitional seasons reached 0.5 $mg.m^{-3}$. At station 2, the highest Chl-a is observed in the 2nd transitional season and the lowest is found in the 1st transitional season, ranged 0.8-4.53 $mg.m^{-3}$. At station 3, the highest Chl-a value is found in the 2nd transitional season and the lowest is found in the northeast monsoon, ranged 1.13-4.14 $mg.m^{-3}$. At station 4 and 5 there is a different trend of Chl-a concentration. At station 4, Chl-a is highest on the southwest monsoon and lowest on the 2nd transitional season, ranged 1.05-7.53 $mg.m^{-3}$. At station 5, the highest concentration is found on the 1st transitional season and the lowest is found on southwest monsoon, ranged 2.2-4.03 mg.m^{-3} (**Figure 6)**. The fluctuation of Chl-a concentration in each observation station is influenced by several conditions which are wind, hidro-ocenography, water quality, and nutrient availability (Sediadi, 2004).

Seasonal variability of Chl-a in each station is influenced by the location which bordered by many estuary zones, especially for station 2 and 4. It can be the main source of nutrient from the river and land that has been supplying the nutrient compound. These conditions will enhance the abundance of phytoplankton and the other autotroph biota (**Figure 6)**. The Chl-a concentration at station 2 is the highest for 2nd transitional monsoon and at station 4 is the highest concentration for the 1st transitional monsoon as well as for the southwest monsoon. During northeast monsoon, the Chl-a relatively high supported by the low of temperature (**Figure 7**) showing the upwelling tendency possibly takes place, whilst, during the southwest monsoon, the Chl-a concentration becomes lower and the SST is quite high, resulting in downwelling tendency. SST trend is proportional to station 1, 2 and 3, but different in station 4, shown in **Figure 7**. The highest and the lowest temperature range is found on the 2nd transitional season at station 2 and 4 ranged 20.5-32.8ºC.

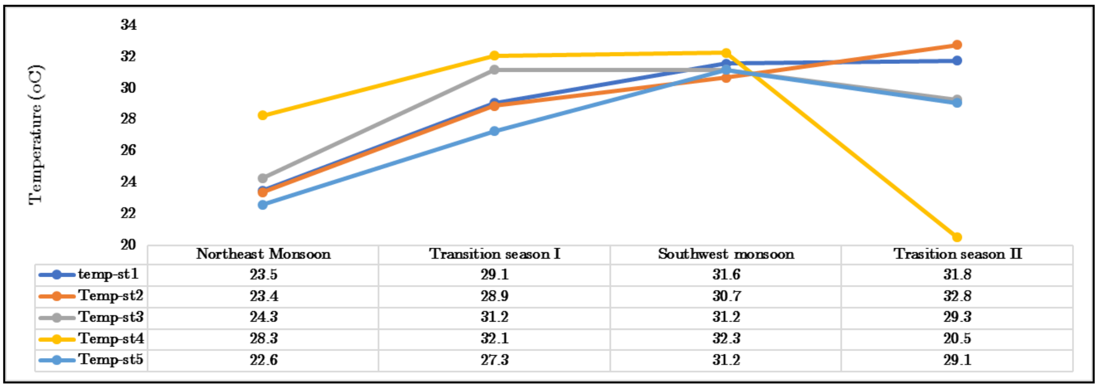
The lowest average of SST observes in the northeast monsoon, in which the highest rainfall intensity happened along the season. The highest average of SST is found in the southwest monsoon (dry season), it is automatically related to the higher intensity of sunlight. Based on the Ocean Color data (NASA, 2015), Chl-a concentration is higher in the southwest monsoon, due to upwelling and mixing from the biogeochemical cycle. Chl-a concentration is lower in the northeast monsoon, due to the decreasing of photosynthesis mechanism. The relation between Chl-a and SST conditions are the best way to predict the fishing ground area, which the area is cooler with higher Chl-a abundance, classified into the area of fishing ground.

SST value around Belitung waters ranged from 20.5-32.8ºC during the 2nd transitional season, 27.3-32.1ºC during the 1st transitional season, 22.6-28.3ºC during the northeast monsoon, and 30.7-32.3ºC during the southwest monsoon respectively. Based on the data, the SST will be optimal for biota in the range of 20-30ºC, indicating upwelling event (Grémillet et al., 2008). The average of SST from January 1998 until December 2009 in the Karimata Strait ranged from 27.91-31.95ºC, it shows that the temperature is rising around 1ºC for 4 years (Nababan & Simamora, 2012).



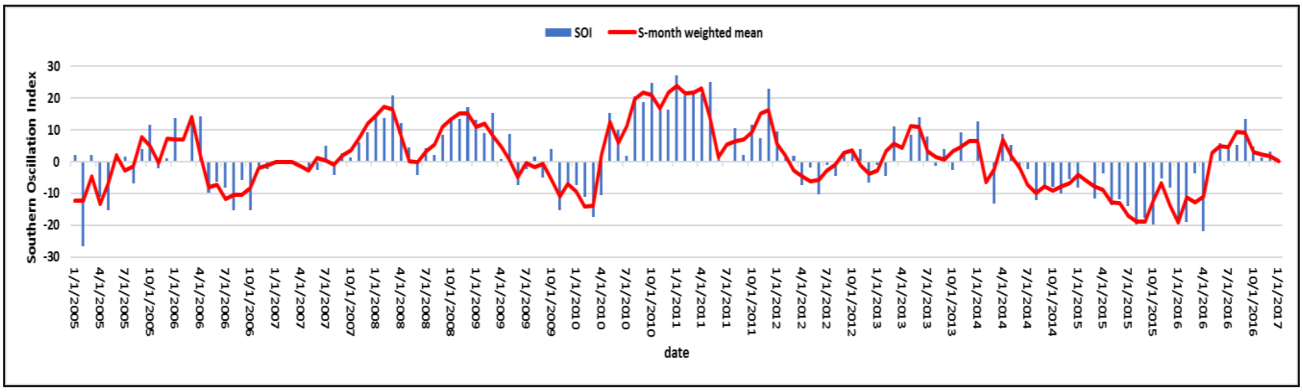
	Northeast Monsoon	Transition season I	Southwest monsoon	Trasition season II
chlor-st1	1.52	0.5	1.23	4.02
Chlor-st2	1.23	0.8	1.3	4.53
Chlor-st3	1.13	4.03	1.8	4.12
Chlor-st4	2.55	7.53	9.3	1.05
Chlor-st5	3.55	4.03	2.2	2.3

Figure 6. Seasonal variability of chlorophyll-a in each station.



	Northeast Monsoon	Transition season I	Southwest monsoon	Trasition season II
temp-st1	23.5	29.1	31.6	31.8
Temp-st2	23.4	28.9	30.7	32.8
Temp-st3	24.3	31.2	31.2	29.3
Temp-st4	28.3	32.1	32.3	20.5
Temp-st5	22.6	27.3	31.2	29.1

Figure 7. Seasonal variability of sea surface temperature in each station



Source: http://www.weatherzone.com, 2017

Figure 8. Graph of Southern Oscillation Index (SOI).

The average of Chl-a is different between El-Nino-Southern Oscillation (ENSO) and non-ENSO years. The annual variability of Chl-a concentration in Belitung waters obtained from the average values comparison of Chl-a concentration every year. Based on the analysis, it was obtained the real annual variability of Chl-a concentration between ENSO and non-ENSO years. To decide the month of ENSO and non-ENSO years, we used the SOI (Southern Oscillation Index) that is the difference in air pressure between Tahiti and Darwin. ENSO's month is defined by SOI <-10 and non-ENSO's month is defined by SOI>10 (**Figure 8)**.

In general, the Chl-a concentration in the northeast until the first transitional monsoons (April - May). ENSO months is relatively higher than non-ENSO months (**Figure 9)**. The most unstable Chl-a concentration is found at station 2 and 4. It changes significantly in every month of ENSO. The other station, such as station 1, 3 and 5 are not significantly different between ENSO and non-ENSO months. Increases in ocean Chl-a was pronounced in the tropical region where ENSO impacts on upwelling and nutrient availability were greatest (Villanoy et al., 2011). Globally, Land source of Chl-a did not exhibit a clear ENSO response, even though regional changes were substantial.

The wind has a major role in the atmosphere and sea interaction. The wind speed enhancement in the coastal area is related to the mixing of water mass increasing vertically. It makes the waters to become fertile due to the vertical water mass movement (from the bottom to the surface). Finally, the Chl-a abundance will enhance. Based on wind data analysis result, in the northeast monsoon (**Figure 10)**, the wind direction is moving towards to Australia. In that monsoon period, rainfall intensity was increased (wet season), it makes the runoff of nutrient from land accumulated in the estuary, but the height of evaporation and the weakness of sun light effect to the phytoplankton abundance in process of photosynthesis, finally the Chl-a during this monsoon becomes low.

On the southwest monsoon (**Figure 11)**, wind direction moves from the southwestward to northeastward, and brings the warm water vapor from Australia Continent (dry season). In this monsoon, upwelling mechanism often occurred in the waters. It makes the waters becoming more unstable than the usual, resulting in enhanced Chl-a concentration and primary production in the Belitung waters. The primary productivity and algal blooms are sustained by eddy/wind interactions, which amplify the eddy-induced upwelling (McGillicuddy et al., 2007).

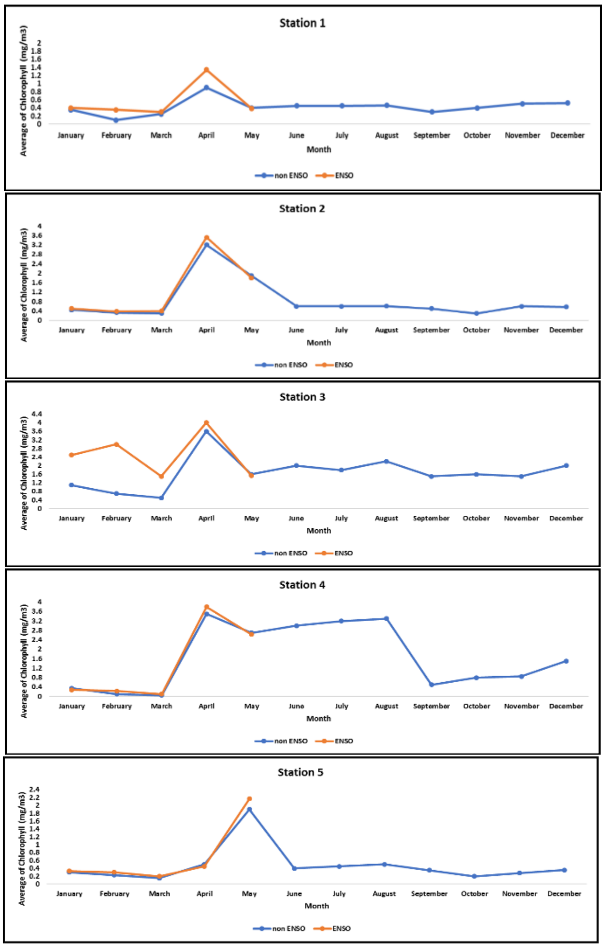


Figure 9. Chl-a concentration plot between year ENSO vs. Non-ENSO.

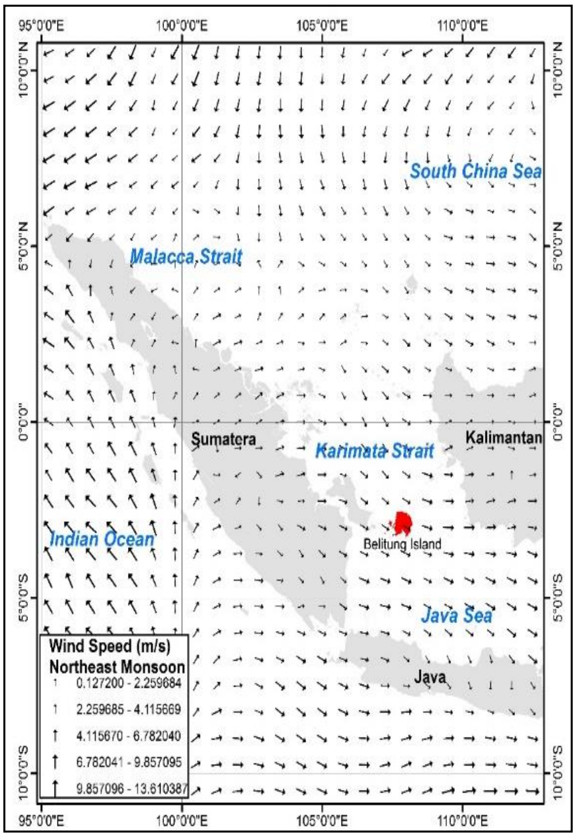


Figure 10. Wind Speed and Direction During northeast monsoon.

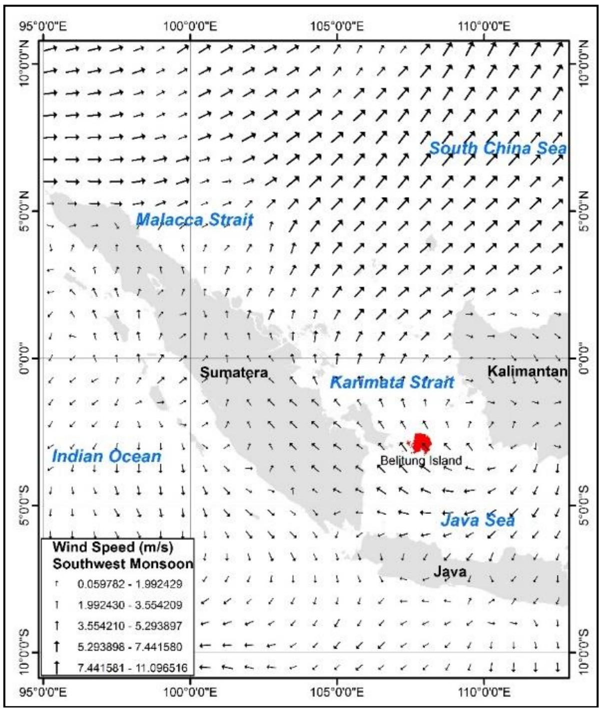


Figure 11. Wind speed and direction during southwest monsoon.

CONCLUSION

The Chl-a concentration is high during the southwest monsoon. It becomes low in the northeast monsoon due to the influence of upwelling, nutrient availability, wind movement, and sunlight intensity as well. The Chl-a concentrations are relatively higher in the months of ENSO than non-ENSO months because of the mixing and turbulence during the upwelling period. The SST value is more unstable during all season but seasonally the changes are slightly significant ±1-5ºC. The values of SST and Chl-a can predict the fishing ground area. Wind speed and direction is the main factor controlling Chl-a distribution vertically and horizontally. This study is useful to help determining the water condition which it can help the local fishermen to determine fishing ground. Therefore, suggested for further research to examine thoroughly the role of SST and Chl-a for the determination of fishing grounds in Belitung waters.

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