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Research Articles

Relationship between chlorophyll-a and sea surface temperature to tuna catch in the Southern Water of Java

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ABSTRACT: The Southern Waters of Java included in 573 WPP has high fishing activity, which the most important commodity is Tuna. The number of Tuna catch are fluctuated which influenced by oceanography factors in the waters. Some of the factors that affect the catch are sea surface temperature (SST) and chlorophyll-a, so this study aimed to determine the distribution, fluctuations in SST and chlorophyll-a, and its relationship to the Tuna catch. SST and chlorophyll-a data were downloaded from NASA, and Tuna catch data in 2017 was collected from Cilacap Fishing Port. The relationship between SST and chlorophyll-a with the catch was analyzed with cross correlation analysis. Distribution of SST and chlorophyll-a was higher in the east part and coastal areas compared to the western and offshore parts. SST and chlorophyll-a fluctuations are inversely proportional but have a very close relationship. SST in the western season and transition 1 an increase then a decline in the east season and transition II, while chlorophyll-a in the western season and transition I is lower than in the east season and transition II. The highest correlation between SST and catch in the time lag -3, while chlorophyll-a in the lag time -4. @2020 Published by UP2M, Faculty of Mathematics and Natural Sciences, Sriwijaya University

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INTRODUCTION

Indonesia is an archipelagic country that has been recognized by the UNCLOS (United Nations Convention on the Law of the Sea) 1982. Indonesian waters have an area of 5.9 million km^2 consisting of 3.2 million km^2 of territorial and 2.7 million km^2 of ZEE [1]. The water has potential in the fisheries sector with a total fish catch of 6.4 million tons/year. The Southern Waters of Java included in the Regional Fisheries Management (WPP) 573 that has a high potential of fisheries resources. This is in accordance with [2], where the density of marine fish stocks in the southern waters is higher than the waters of western Sumatera. In addition, these waters are also influenced by several oceanographic phenomena and the atmosphere, such as El- Nino Southern Oscillation (ENSO), Indian Oscillation Dipole Mode (IOD), ocean surface current system, Indonesian Through Flow (ITF) and monsoon movement.

Information regarding the oceanographic conditions needs to improve the effectiveness and optimization of fishing activities, especially in determining the time of fishing and fishing ground. These efforts can be through the assessment of several related variables, among them is Sea Surface Temperature (SST) and chlorophyll-a [3].

SST is one of the important parameters that might be known in the sea because it is very important in studying the processes of physics, chemistry and marine biology. Distribution of SST can be used to identify marine parameters such as current, upwelling and fronts [4]. It also affects photosynthesis and metabolic changes in fish, so that the fish will go to the temperature that suits their needs. Chlorophyll-a is also used as information to assess the fish resources because there is a relationship between primary productivity and fisheries resources, so that it can be said that the area has a high concentration of chlorophyll-a where there is a high concentration of fish [5]. Remote sensing is a technique that used to observe the oceanographic parameters such as chlorophyll-a and SST both spatially or temporally. Remote sensing techniques have a high ability to analyze large areas and difficult to be taken manually by a short time so as to save costs in determining oceanographic conditions [6]. The use of survey methods through satellite imagery to facilitate the collection of data, so that it is easier to detect fishing ground of Tuna. In determining the fishing ground, it is necessary to do a survey of the distribution of SST and chlorophyll-a, because the temperature of the distribution of Tuna ranges from 12-31°C. Generally, the high or low SST and chlorophyll-a will affect to tuna catch by fishermen.

The purpose of this study was to determine the distribution of chlorophyll-a and SST (Sea Surface Temperature) as spatially and temporarily, and relationship between chlorophyll-a and SST to Tuna catch 2017 in southern waters of Java.

METHODS

Daily data of SST with 1 km resolution was downloaded from Podacc, Monthly data on chlorophyll-a with 4 km resolution downloaded from Ocean color, and monthly data Tuna catches in 2017 from Cilacap Fishing Port. The method used in this study is survey method and spatial analysis. The stages in this study include data collection, data processing, and data analysis. Imagery data analysis including cropping, extraction and image visualization, while the tuna cath data including the determine CPUE and Fishing Power Index (FPI) by using the formula that developed by [7] and [8].

$$CPUE_t = catch_t / effort_t \quad (1)$$

$$FPI = CPUE_i / CPUE_s \quad (2)$$

$$Effort_s = FPI \times effort \quad (3)$$

$$CPUE_{std} = C_s / Effort_s \quad (4)$$

where,

$CPUE_t$ = catch per fishing effort per month (kg/trip)

$Catch_t$ = catch per month (kg)

$Effort_t$ = fishing effort per month (trip)

FPI = fishing power index

$CPUE_t$ = catch per effort monthly other fishing gear (kg/trip)

$CPUE_s$ = catch per effort monthly standard fishing gear (kg/trip)

$Effort_s$ = effort of fishing gear after standardization

$CPUE_{std}$ = catch per standard effort (kg/trip)

C_s = catch per month (kg)

The spatial distribution of chlorophyll-a and SST is determined by comparing the results of visualization in the form of images per month in 2017, then a descriptive analysis was carried out by analyze at the color gradations in the image. By determining the color gradation, the concentration and distribution of chlorophyll-a and SST will be determined in the study area. Temporal analysis of the concentration of chlorophyll-a and SST was carried out by making a time series graph of monthly data on chlorophyll-a and SST by averaging values in the fishing area. Then the graphs are analyzed descriptive to carry out the differences of the monthly of each parameter in 2009 - 2018. Fluctuation analysis is based on the highest value, lowest value and the average value of each year. The cross-correlation analysis was used to determine the relationship between SST and chlorophyll-a and the relationship between the both parameters to the catch of Tuna.

RESULTS AND DISCUSSION

Spatial Distribution of Sea Surface Temperature and Chlorophyll-a

Sea Surface Temperature

Distribution of SST in the southern waters of Java was differences and changes horizontally, where changes in SST will affect the lives of existing organisms. This distribution is caused by the influence of the height of the sea surface, the intensity of light and land which is easier to absorb the heat [9]. Organisms will adjust the place of life in accordance with the normal limits of temperature that can be tolerated. Temperature changes are very visible in the southern part of eastern Java. Changes that occurred began from the east to the west which were carried by the wind (Figure 1).

As Spatially, the water temperature varies by region and month (Figure 1). It is seen that the temperature in the coastal area is higher compared to the offshore area and occurs every year. It is caused by the land is easier to absorb the heat while in the high seas it is not easy to change temperature when the ambient temperature does not change. SST in the southern part of eastern Java is higher in the western season compared to the southern part of western Java, and in the eastern season the southern part of eastern Java is lower than the western part. So that it can be justified that the SST movement occurs from the east to the west caused by wind movements.

Distribution of SST in the east begins to rise in November to April with the increase in March, and decreased in May to October with the lowest SST in August. Generally, it can be stated that in the shouter waters of Java on average high temperatures occur in the west seasons (rainy) and lower temperatures in the east season (dry season). The spread of SST affects fish living in the area, especially in tuna. [10] studied the temperature for optimum catch of Tuna ranges from 17 – 24°C, so optimum capture can be conducted in the eastern season until transition II. The distribution of SST was also conveyed by [11] which states that in July the southern waters have decreased SST lower than the northern waters. While in August to September, the SST in the south is getting lower and evenly distributed from the coast to the sea, because there is increasing upwelling. Whereas in the north of Java SST tends to be constant there is no significant decrease in temperature compared to the Indian ocean which occurs evenly with a decrease in temperature.

The phenomenon of this distribution is influenced by the regions at latitude 10° NL – 10° SL are the regions that receive the most radiation from sunlight and temperature is a measure of the kinetic energy of molecular motion contained in an object, then the sea water temperature in the equatorial area trends to be high and constant [12]. The temperature difference between the coast and the sea can also be caused by season, weather, depth of sea, air circulation, and closure of clouds that can block sunlight into the waters [9].

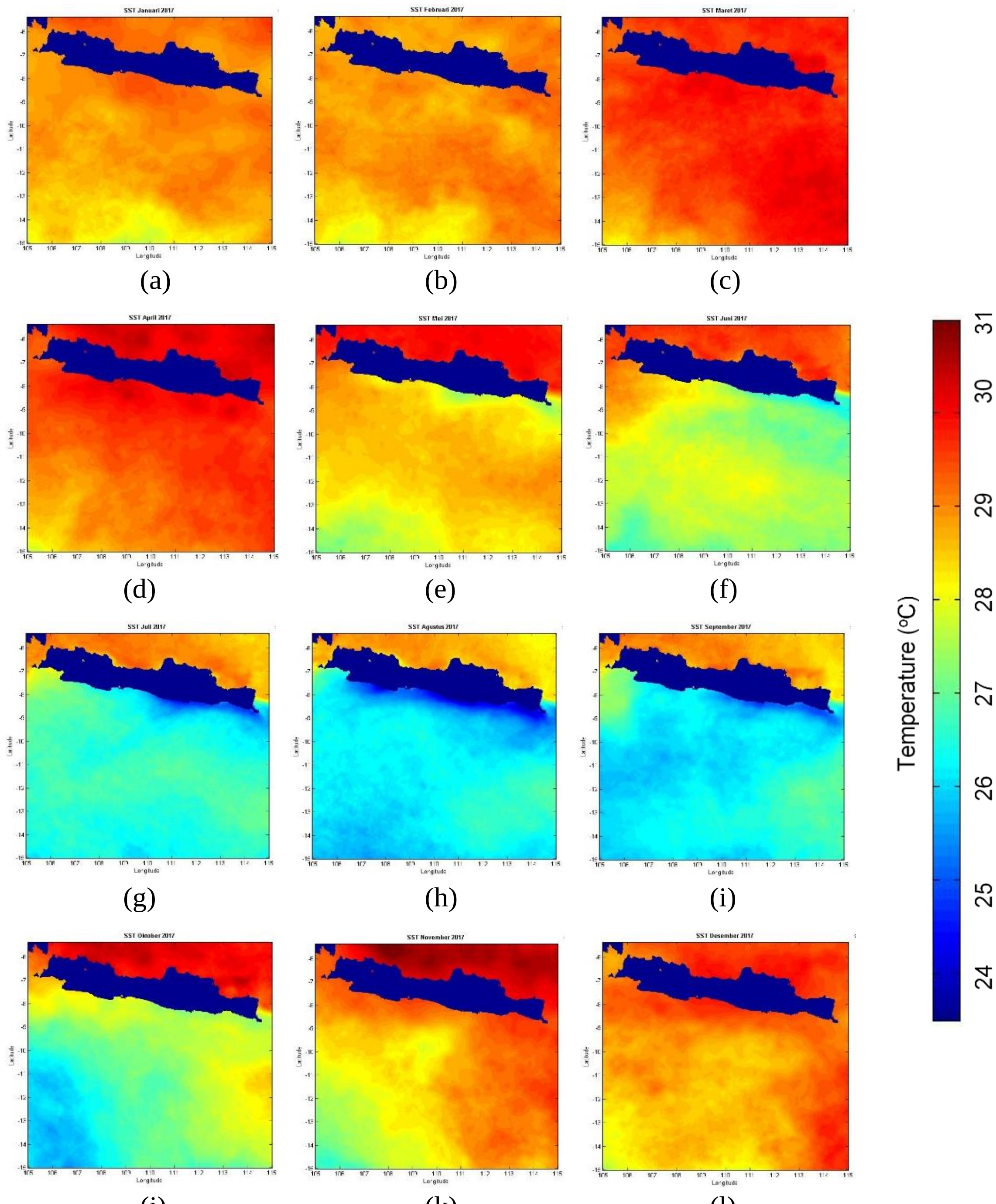

Figure 1. Distribution of SST in southern waters of Java in 2017; (a) January (b) February (c) March (d) April (e) May (f) June (g) July (h) August (i) September (j) October (k) November (l) December

Chlorophyll-a

Distribution on the SST will affect the organisms in the waters including phytoplankton. Where phytoplankton will survive at a temperature that suits their needs. The indicator used to determine the abundance of phytoplankton is chlorophyll-a. Distribution of chlorophyll-a concentrations in the southern waters of Java is very low compared to the waters of northern Java. Distribution of chlorophyll-a is also higher in the southern sea of eastern Java compared to the western part; the phenomenon is the same as SST (Figure 2).

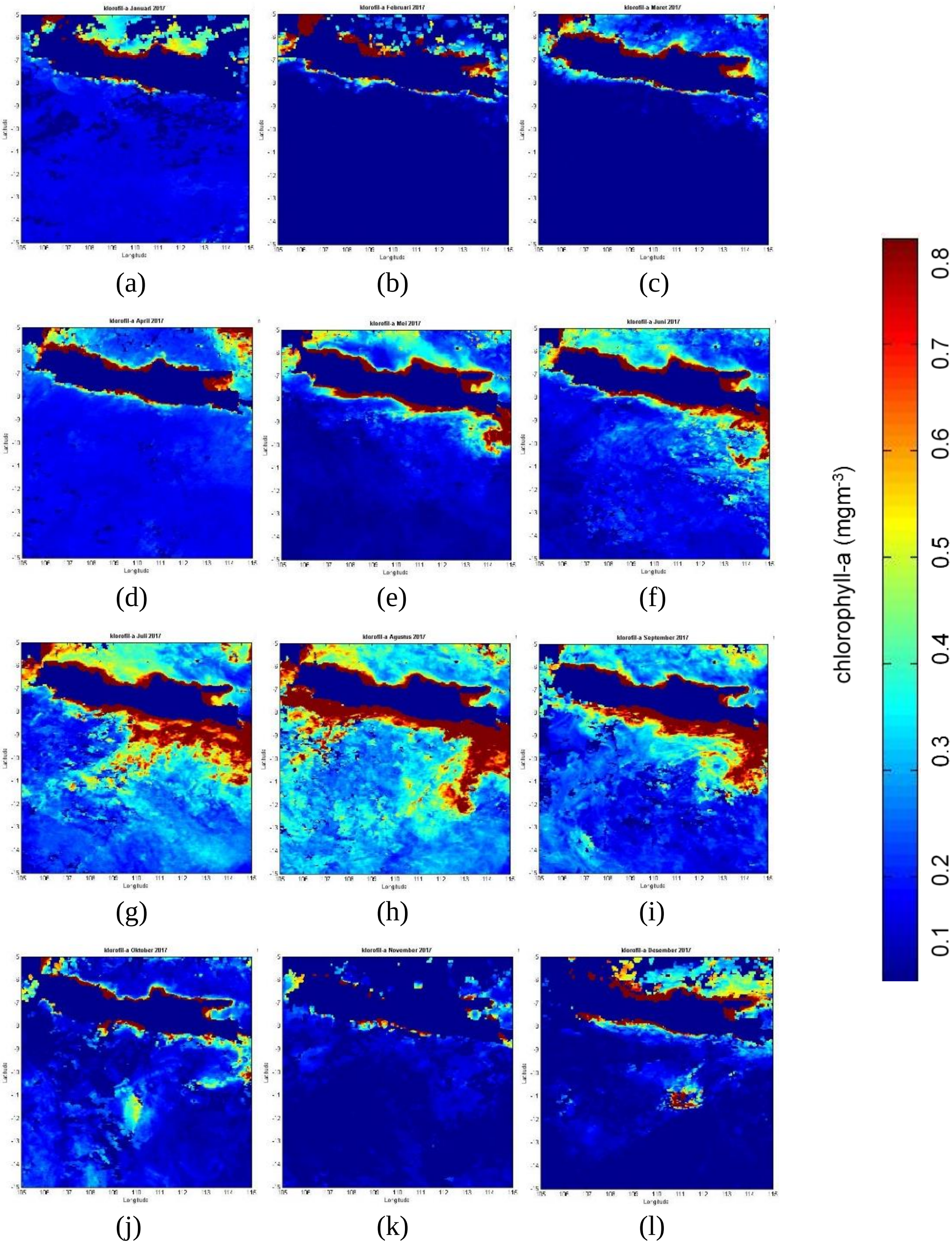

Figure 2. Distribution of Chlorophyll-a in southern waters of Java in 2017 (a) January (b) February (c) March (d) April (e) May (f) June (g) July (h) August (i) September (j) October (k) November (l) December

The distribution of chlorophyll-a in the southern sea of Java looks lower compared to higher northern Java and the concentration in the offshore area is lower and evenly distributed from the coastal area or close to the mainland. Distribution in eastern waters is also higher than the western part, it can be seen from June to September which tends to be high in concentration compared to the month before and after (Figure 2). In generally, it can be said that the chlorophyll-a concentration is low in the western season and begins to increase in the transition season I, the highest concentration in the east season then a decline in the transition season II.

That is inversely proportional to SST, which in the western season and transition I is higher than the east and transition II. The varying chlorophyll-a concentration can be caused by the intensity of the light entering the waters and nutrient content in the waters. The coastal area of higher concentration than the offshore waters. The high concentration in the coast is caused by the supply of large amounts of nutrients from the land and then into the waters of the sea. Low concentrations offshore are caused by no direct supply of nutrients from the land, but in certain regions the concentration of chlorophyll-a offshore is higher due to the high concentration of nutrients produced through the physical process of water mass, where the mass of water remove nutrients from the deep layer to the surface layer caused by the upwelling process [13]. The high concentration of chlorophyll-a on the beach is also influenced by aquaculture activity, depth, direction and velocity of the current [14].

Based on Figure 2 the highest chlorophyll-a concentration in July to September which is in the eastern part of South Java, while in Figure 1 the lowest temperature value is from July to September located in the south of East Java. If observed from July to September, it can be seen that the movement of SST and chlorophyll-a from east to west is from east Java to West Java. This shows that the highest chlorophyll-a concentration often occurs not at the lowest SST, this phenomenon indicates that there are factors other than upwelling that supply nutrients. This factor causes high chlorophyll-a concentrations in the south of Bali and East Java. According to [15] in the South Sea of East Java to Bali, especially in the eastern season, there is often an eddy current. This current effect from a meeting of the Java coastal currents with the southern equatorial currents.

The distribution of low SST and high chlorophyll-a can be wider to West Java can be influenced by the IOD value. The greater the value of IOD (Indian Ocean Dipole), the farther the lowest SST center and the highest chlorophyll-a. The higher of IOD value causes lower air pressure in the western Indian Ocean and increased air pressure in the eastern Indian Ocean. This will cause the wind speed to increase westward [3].

Temporal Fluctuation Of Sea Surface Temperature And Chlorophyll-A

Sea Surface Temperature

SST in the waters will experience an increase and decrease in accordance with the ongoing season, Figure 3 is a graph of the high and low monthly SST values in the southern Java sea in the catching area of Tuna taken from MODIS for 10 years. In general, SST have one-time maximum temperature and one-time minimum temperature in one year. The amount of temperature each year varies depending on the climate and anomalies in these waters so that it can affect the high and low SST.

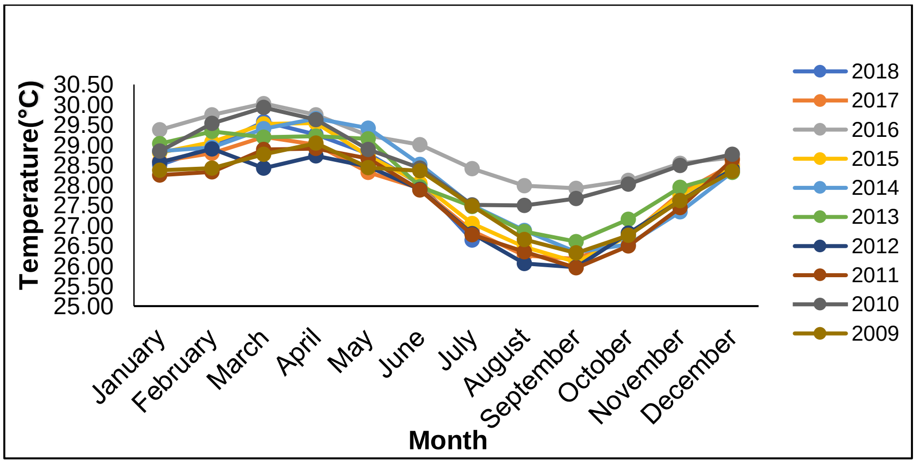

Figure 3. Monthly fluctuations of Sea Surface Temperature (SST) in 2009-2018

The graph above shows that in each month, the temperature trends to have the same fluctuations. SST in January began to increase to the maximum in March, then in the next month it declined to the lowest in September and in the next month it increased. During these 10 years, the highest average temperature occurred in 2016 and the lowest temperature in 2011. The lowest sea surface temperature on average in September, which indicated in the month there was an upwelling phenomenon with the elevation of low temperatures from the waters. This is consistent with research [16], which states in the second transition season there were many indications of upwelling around the South of Java, because the temperature in the area is low and there are many fronts. Generally, the highest value of SST in the west season and transition I while the low temperature in the east season and transition II.

Based on Figure 3, the minimum temperature in 2015 is lower than in 2016 and 2014 because there is the influence of El Nino causes the temperature in the waters south of Java to be low. In the figure, it can be seen that there are significant differences in 2010 and 2016 in the eastern season and transition II where the temperature is higher than in other years. The difference is due to the negative phase IOD (Indian Ocean Dipole) occurring in June to November. This causes a weakening of the intensity of upwelling in these waters. As a result, SST this year will be higher than in other years [17].

SST in the catch area in 2017 shows the same pattern as the previous year, where the highest temperature occurs in the west season and transition I while the temperature is low in the east season and transition II. The highest average temperature in 2017 reaches 29.20°C and the lowest reached 26.17°C. Based on the research of [18] in 2017 there are natural phenomena, namely tropical cyclones that occur on November 27-29 2017. This phenomenon raises an SST anomaly in the waters south of Java to reach more than +0.2°C, this gives rise to warm sea conditions. The warmth of SST in the sea generates energy in the interaction of the ocean and atmosphere. But the phenomenon that occurs does not change the pattern of SST fluctuations in the waters south of Java.

The decrease in temperature in the eastern season was caused by the increasing intensity of the southeast monsoon. The strong southeast monsoon will cause upwelling phenomena so that the sea surface temperature will decrease by raising the temperature at the bottom of the water which tends to be low. Transition season 1 sea surface temperature has increased optimally because the sun at the equator so that the SST is high [19].

Chlorophyll-a

The high and low sea surface temperature can affect the concentration of chlorophyll-a in the waters. The monthly fluctuations in the concentration of chlorophyll-a from 2009 to July 2018 in the waters of southern Java in the Tuna catchment area taken from MODIS are made in graphical form (Figure 4). The chlorophyll-a concentration in the catchment area is low compared to the coastal area. During the year chlorophyll-a in the waters of southern Java have an increase and decrease. In the western season chlorophyll-a tends to be low, whereas in the east season chlorophyll-a will be higher. The high and low concentrations of chlorophyll-a in the waters in each year will always be different, this is due to climate factors and disturbances in these waters.

Every year chlorophyll-a concentrations in the waters fluctuate, the highest average chlorophyll-a concentration in 2017 and the lowest average in 2016. Chlorophyll-a in January is low, where in that month was the lowest concentration of chlorophyll-a. The next month began the highest increase in August and there were also those that occurred in September, then in October the concentration has decreased (Figure 4). In 2017 the catchment area the pattern of chlorophyll-a fluctuations is the same as the previous year with the highest concentration of 0.3 mgm^{-3} in August and the lowest in February of 0.08 mg^{-3}. The year is included in the highest average concentration of the previous year, so the phenomenon of upwelling was indicated in August. In that year the cempaka tropical cyclone phenomenon did not directly influence the concentration of chlorophyll-a when viewed from the results of the analysis, direct influence seen in SST in the ocean.

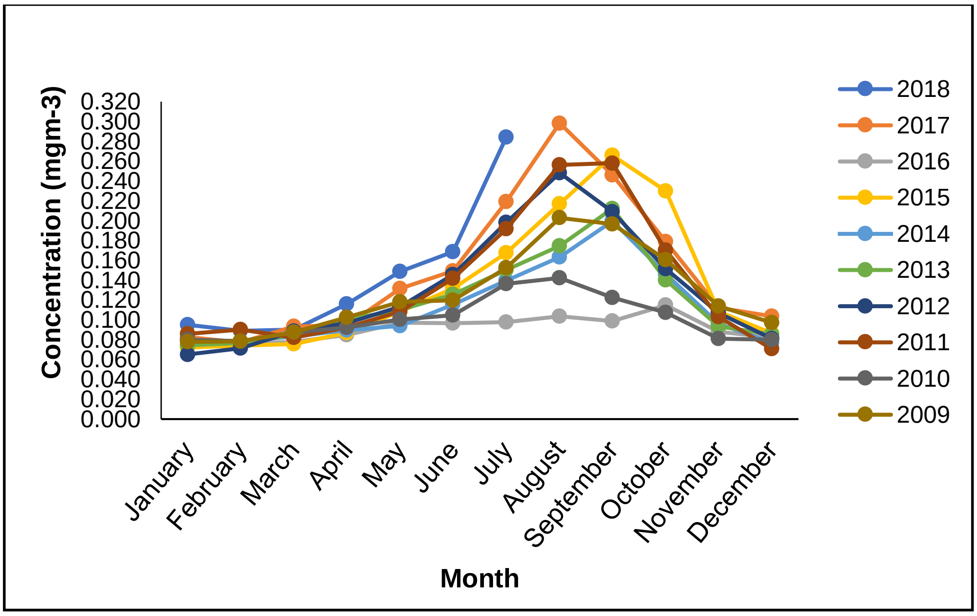

Figure 4. Monthly fluctuations of chlorophyll-a concentration in 2009-2018

Generally, high chlorophyll-a concentrations are found in the eastern season and transition II while chlorophyll-a is low in the western season and transition I. This is inversely proportional to sea surface temperature, when the SST rises there will be a decrease in the concentration of chlorophyll-a and vice versa if the temperature of chlorophyll-a will rise. The high SST and low chlorophyll-a in the western season indicate that there is a downwelling in that season. otherwise, in the low SST east season and high chlorophyll-a, it shows that the area is upwelling. This is in accordance with the statement Sha [16], that is the phenomenon of downwelling in the waters of southern Java appearing in the western season and partly in the transition season I. This downwelling occurs in South Bali and South East Java is marked by the presence of fronts in these waters, the front shows the difference in temperature in these waters. Generally, the highest SST and lowest chlorophyll-a occur in the same month but the location is different, it is caused by the increased speed of the Southeast Monsoon which encourages low-temperature water below to rise to the surface [20].

Fluctuations in chlorophyll-a of each year have similarities, but in 2010 and 2016 there was a decrease in concentration different from the previous year. The decrease concentration in that year in the eastern season was due to the occurrence of negative phase IOD. This incident resulted in an increase in the average sea level in South Java, Bali, Lombok-Sumbawa waters from June to November. based on research from [21], decreasing concentrations in the period from June to November in the lowest waters of South Java occurred in September while in South Bali in October.

The Catch Per Unit Effort (CPUE) Of Tuna In Southern Waters Of Jawa

The types of tuna catch are landed at the Cilacap Ocean fishing Port including Tuna Albacore (*Thunnus alalunga*), Big Eyes (*Thunnus obesus*), and Madidihang (*Thunnus albacares*). Based on the data obtained, tuna fish landed at the port were captured in the waters of South Java using long line and gill net fishing gear. The catch of Tuna varies in each month. The amount of CPUE results presented in Figure 5.

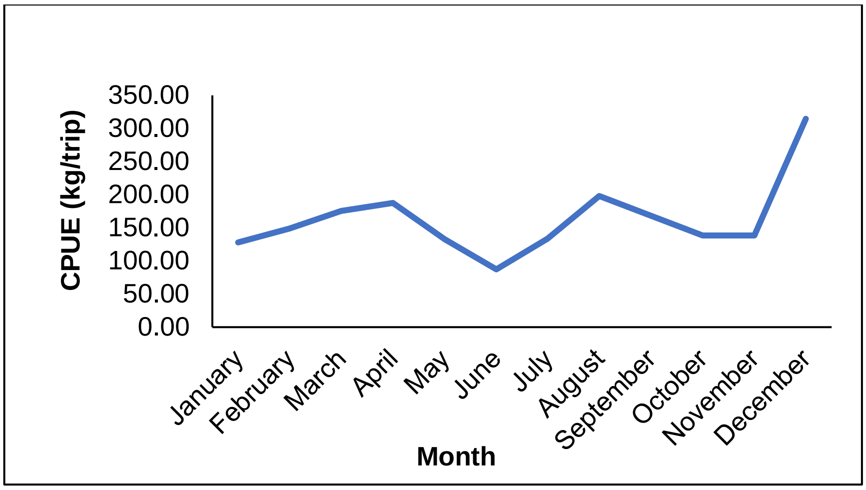

Figure 5. Catch of tuna in 2017

The catch of Tuna per effort in Figure 5 looks to have variations each month due to the changing seasons effect from the monsoons. The lowest CPUE value is in June and the highest in December, so that it can be said that the lowest CPUE value is found in the east season and high in the western season. This is in accordance with the statement of [22]. that is, the catch of tuna in December is higher compared to January and February. December is the early of the month in the western season so that conditions in the waters have not changed much compared to the transition season II. Whereas according to [23], the high value of CPUE in December was due to bad weather occurring in that season so that few ships competed in the capture. It is known that the CPUE values are inversely proportional to the effort of catching. so, the CPUE value is inversely proportional to the capture effort. When the CPUE value is high, the number of efforts is low, otherwise if CPUE is low then the number of efforts is high. But according to [24], tuna fishing season occurs in June or east season. Shifts in height capture can occur because there are changes in oceanographic conditions in these waters so that it will result in changes in patterns of fishing over time.

The high CPUE value in the waters of southern Java coincides with increase SST in the waters and decreases concentration of chlorophyll-a, while the lower CPUE occurs in the decrease in SST and an increase in the concentration of chlorophyll-a. According to [25] oceanographic parameters can affect the distribution of large pelagic fish. Water temperature is an oceanographic parameter that affects directly while phytoplankton is a parameter that does not directly affect to fish. Pelagic fish will move to avoid higher temperatures or look for lower temperatures suitable for their bodies. The difference in water temperature will also affect migration and the size of school fish [26]. But in [25], in June and December there was a low correlation. Because besides oceanographic factors, CPUE value is influenced by fishing efforts carried out by fishermen.

Relation Between SST And Chlorophyll-A To Tuna Catches

Analysis of the relationship SST and chlorophyll-a was carried out using the correlation equation. This analysis is to look at the relationship SST and chlorophyll-a in the research area. The magnitude of the relationship between the two parameters is illustrated through the graph in Figure 6, where in the figure the dots are getting closer and closer to the linear line, the higher the correlation between the parameters. Conversely, if the points stay away from the linear line, the lower the correlation. The points on the graph are obtained through a correlation analysis between monthly SST and chlorophyll-a data on the average fishing area from 2009 to 2018.

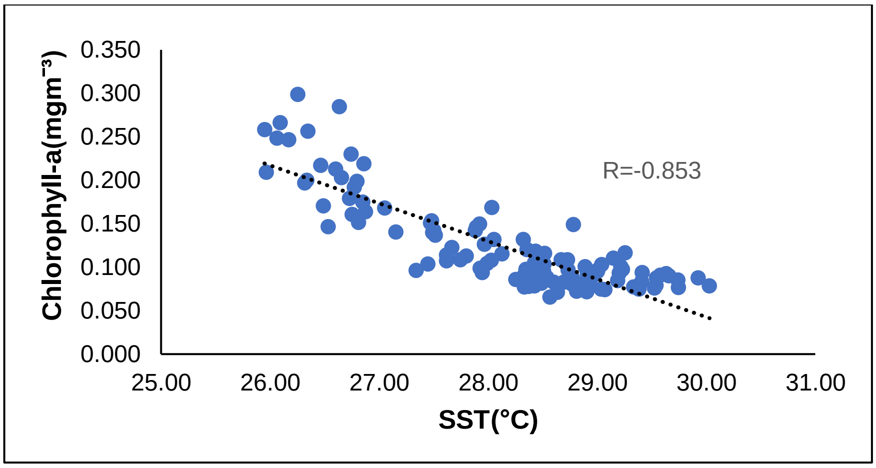

Figure 6. Relationship between SST and Chlorophyll-a

In theory SST and chlorophyll-a have the opposite relationship, where the SST is high, the chlorophyll-a concentration will be low, because at high temperatures it will disrupt the metabolic process. Correlation tests conducted between SST and chlorophyll-a get the value R = -0.85, where the value of the correlation coefficient with intervals of 0.80 - 1 has a very high level of relationship. The correlation value that is negative which means the relationship between two variables is opposite direction, the higher SST then chlorophyll-a concentration would be lower.

The scatterplot graph in Figure 8 shows that the point most approaching the line ranges from 28.25°C – 29.25°C which means that the temperature affects chlorophyll-a in that temperature range. The negative relationship between SST and chlorophyll-a due to high light intensity will damage chlorophyll-a so that it will disrupt the photosynthesis process and not run well. Conversely, if low SST causes chlorophyll-a also cannot photosynthesize with optimum. The lack of photosynthetic activity is due to the amount of light received is not enough to carry out photosynthesis. The maximum temperature used for phytoplankton photosynthesis is 30°C [27].

Analysis of the relationship of SST and chlorophyll-a to the catch of tuna using the cross-correlation statistic test. The use of this test because Tuna has an active moving nature and not as a phytoplankton predator directly which will cause time delay, so that when the area has a high chlorophyll-a concentration, not necessarily many caught fish. Calculation of time delay needs to be done so that the capture can be optimal. The time delay between SST and catches is illustrated in graphical form so that there are times when there are many and few fishes.

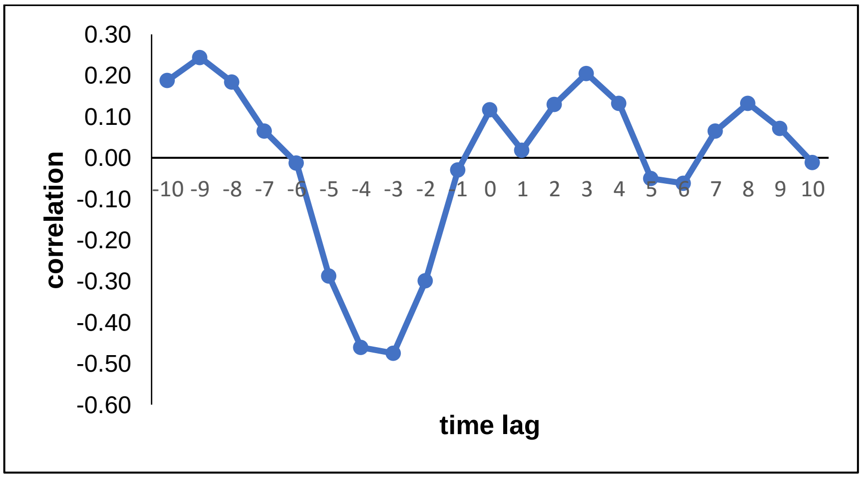

Figure 7. Relationship of SST to Tuna Catch

SST has a negative relationship to the catch, where when the temperature is high the catch will be low. The highest correlation value is -0.47 which indicates that the resulting correlation is negative (Figure 7). Based on the graph, the highest correlation is found in the -3 in lag time which indicates that tuna fishing can be maximal 3 months after the lowest SST, but in the second to fifth months there was still a correlation but lower. A high SST will cause fish to move adjust to the optimum temperature of the fish. Generally, the distribution of tuna occurs at 11-28 °C and the optimum catch at a temperature of 17-24 °C.

The high concentration of chlorophyll-a also does not directly affect the catch, because Tuna is not a direct phytoplankton eater. Tuna is a small fish eater, so there is a delay between chlorophyll-a to the optimal catch. Optimal fishing of tuna can be carried out several months after increase in chlorophyll-a concentration. In accordance with the cross-correlation graph (Figure 8) shown in the highest correlation value.

The catch also has a relationship with chlorophyll-a concentration but the relationship is relatively small as found in Figure 8, where the highest correlation value of 0.62 is positive. The second month of correlation begins to rise until the highest correlation occurs in -4 time lag, which means that the optimal catch of tuna in the fourth month after the occurrence of high chlorophyll-a concentrations in the area, then there was a decrease in the fifth month to the lowest in the sixth month. But in the second and fifth month there are still correlations between chlorophyll-a and catch.

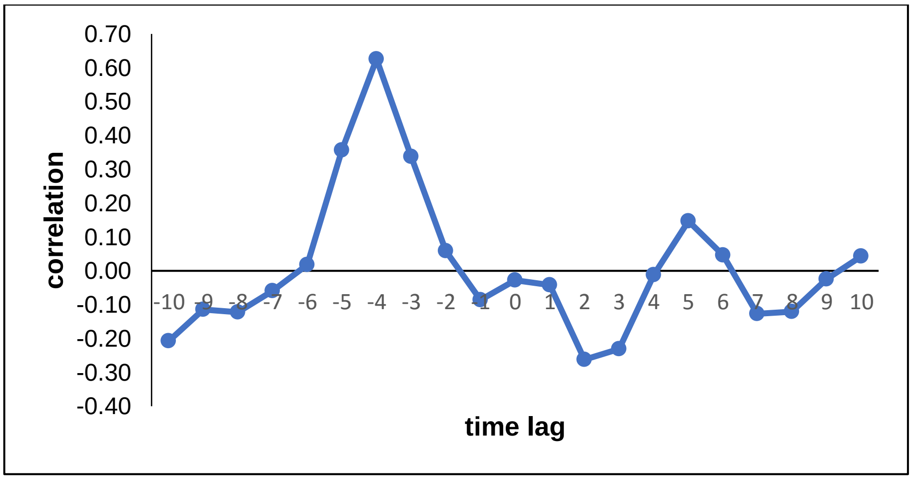

Figure 8. Relationship of Chlorophyll-a to Tuna Catches

The length of time lag in this study is in accordance with [28], which states that the increase in the catch number of Cakalang in Halmahera waters at lag time 5-6 months after upwelling, where Cakalang is still a family with Tuna, namely the Scombridae family. Based on research from [29], through gastric surgery shows that the second food composition of large pelagic fish changes and one fish as the main food is the same namely layang fish. Another study said that there was a lag time of approximately 3 months between upwelling and lemuru catches, where the lemuru fish is the same as the layang fish that eat zooplankton. The higher fish tropic level will be the longer the time between upwelling and the amount of fish catch, where in this study the time lag between upwelling and maximum catch of tuna is 3-4 months. [30] also states that the time lag between chlorophyll-a and catch of Tuna species is 4 months.

Distribution Tuna that there is not only influenced by one oceanographic factor, but also influenced by currents in the area [31]. Whereas according to [32], the influence of SST on the distribution of tuna in the tropics is only a little because the temperature is relatively the same each year. Many fish are caught at low temperatures, because at high temperatures fish will migrate to deeper waters beyond the reach of fishing gear. So that the chances of fish being caught will be smaller and result in decreased catches.

Chlorophyll-a and tuna catches have a relationship that is low in this study, this is in accordance with the statement of Umar [33], chlorophyll-a does not directly affect tuna fishing, because tuna is not included in the fish that consumes the first phytoplankton in the food chain. Phytoplankton in the food chain are eaten by herbivores belonging to small fish, then eaten by larger carnivorous fish, then at a higher level. So that phytoplankton is considered as primary producers that have fundamental functions in the food chain in supporting the life of marine biota. The existence of a time lag between chlorophyll-a and the catch of tuna shows that there is a process of increasing nutrients, phytoplankton, small fish, and increasing large fish such as tuna [35].

CONCLUSIONS

The spatial distribution of SST and chlorophyll-a in the southern waters of Java in each year is similar where high temperatures tend to be found in coastal areas while offshore temperatures are getting lower. Likewise, in chlorophyll-a, where concentrations on the coast are higher than offshore. The average high temperature and high chlorophyll-a are found in the eastern part of southern waters of Java while the western part is lower. SST and chlorophyll-a concentration in the southern waters of Java was fluctuate every month. SST have an increase in the western season and transition I while have a decline in the east season and transition II was influenced by the southeast monsoon. whereas in chlorophyll-a increase in concentration occurs in the eastern season and transition II while in the western season and transition I there is a decrease in concentration. SST has a relationship with chlorophyll-a in waters. The magnitude of relationship seen from the statistical analysis of the correlation of -0.85 which means that both parameters have a very high and negative relationship. Whereas SST with catches are negatively correlated with -3 in time lag while chlorophyll-a with the catch is positive with -4 in time lag.

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