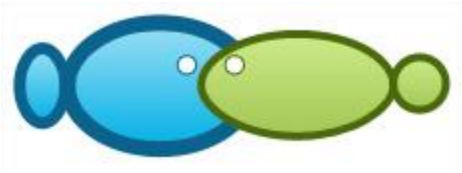

Range of sea surface temperature and chlorophyll-α values based on mackerel catches in the northern waters of West Java, Indonesia

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Abstract. The dynamics of oceanography affect the existence and distribution of fishes. Fishes will look for suitable water conditions for their living habitat. Changes in oceanographic parameters such as temperature, salinity, water fertility, weather, and other parameters are factors associated with it. The SST and Chl-α were the main indicators in determining the presence of fishes, especially for pelagic fishes. Mackerel is one of the prominent commodities in the northern waters of West Java. Changes in water conditions globally also affect the conditions in the territorial waters. This is of course also affecting the existence of mackerel. Therefore, it is necessary to do a study to find out the range of SST and Chl-α values to estimate of mackerel seasonal abundance and distribution in the northern waters of West Java. This research uses an observation method with a combination of remote sensing approaches and filed data. The data used to result from the acquisition of Aqua MODIS satellite data and mackerel fishing activities in the northern waters of West Java. The SST and Chl-α fluctuations were varying seasonally. Based on mackerel catches the range value of SST was 29-31°C and Chl-α concentration 0.28-0.43 mg L^{-1}. Meanwhile, the optimum season for mackerel catch was in the transitional monsoon 1 (March to May).
Key Words: distribution, MODIS, monsoon, oceanography parameters, pelagic fish, remote sensing.

Introduction. The northern waters of West Java has a high fish resource potential of 836,600 tons $year^{-1}$ with a large pelagic fish potential of 55,000 tons $year^{-1}$ (MMAF 2013). According to the head of fisheries office Indramayu District, about a total of 64% of capture fisheries contributions in West Java province come from this district. It is certainly not separated from the infrastructure support of the Karangsong fish landing port. Therefore, recording of the catch is very important for fisheries management in Indramayu, especially in the fishing allocation. The number of fishing boats in the port reached more than 150 units of vessels for the size of 30 gross tons (GT) and 450 units of vessels with size 30 GT downwards, while the number of fisherman reaching 3,600 people. The dominant species caught in the area are the skipjack tuna (*Euthynnus* sp.), followed by mackerel (*Scomberomorus* sp.), giant catfish (*Netuma* sp.) and yellow-pike conger (*Congresox* sp.).

Mackerel fish is one of the big pelagic fish that is popular and being the main catch of fisherman in this region (KPLMS 2013). The fish is the second largest contributor to fish production after skipjack tuna production in West Java Province which landed in Karangsong fish landing port. It contributed about 3,218.49 tons $year^{-1}$ or 15.29% of the total fish (Statistics of West Java Province 2013). Mackerel is included in large pelagic fish category that live at sea level or nearby. It has a characteristic nature to huddle together, thus spreading on uneven waters (Tasya et al 2011). Mackerel spread throughout the waters of South Africa and the Red Sea on the west, to the east include the Indo-Australian archipelago to Australia and Fiji, and the north to Hongkong, Taiwan, and Japan (Collett & Nauen 1983; Widodo 1989). In Indonesia, these fish are spread throughout the coastal areas and islands (Noegroho et al 2018).

The distribution of mackerels is conditioned by cyclical variations of oceanographic conditions so that to find fishing areas can be done through an approach concerning the

oceanographic parameters. Fish life patterns cannot be separated from the existence of various environmental conditions (Setiawan et al 2013). Changes in oceanographic parameters will affect fishes distribution and abundance (Gaol & Sadhotomo 2007). The dynamic of ocean condition also affect life and growth of fish such as: rate of eating, metabolism process, and spawing activities (Henderson 2013). The catch of fishes, however, has decreased gradually since the middle of the 1970s, which gives more attention to the population dynamics studies of the fish (Limbong et al 1991).

The utilization of remote sensing satellite data is essential in solving fisheries problems to determine the relationship between oceanographic environments with the deployment and abundance of fish resources (Harahap & Yanuarsyah 2012). Remote sensing in the field of fisheries and marine allows knowing the factors of the marine environment that affect the distribution, migration, and abundance of fish. Such information can be obtained periodically, quickly, and with wide-area coverage (Safruddin & Zainuddin 2008). This information can be used for prediction of fishing ground. Commonly, physical and biological parameters used in analyzing fishing ground are sea surface temperature (SST) and chlorophyll (Chl)-α concentration (Kusuma et al 2017). In Indonesia, the association of these two parameters toward studies of fish abundance and distribution has been done for over the last decade by Gaol & Sadhotomo (2007), Sambah et al 2012, Hartoko et al (2013), Nurdin et al (2013), Tangke (2014), Soebekti et al (2014), Tangke et al (2015), Mursyidin et al (2015), Apriliani et al (2018), Mulyawan et al (2019).

More applicative and specific studies need to be done to be used further for the management of fisheries activities, especially capture fisheries. Therefore, it is necessary to understand the pattern and trend of SST and Chl-α toward the mackerel catches. From the background that has been conveyed, the study aims to determine the range of SST and Chl-α values to estimate the mackerel seasonal abundance and distribution in the northern waters of West Java.

Material and Method

Geographic location. The northern waters of West Java are categorized into the Fisheries Management Area 712 (WPP-712). The oceanographic conditions in Java Seas are affected by tide and monsoon situation (Siregar et al 2017). There are three islands located in the north of Indramayu which are Marine Protected Areas (Purba et al 2018).

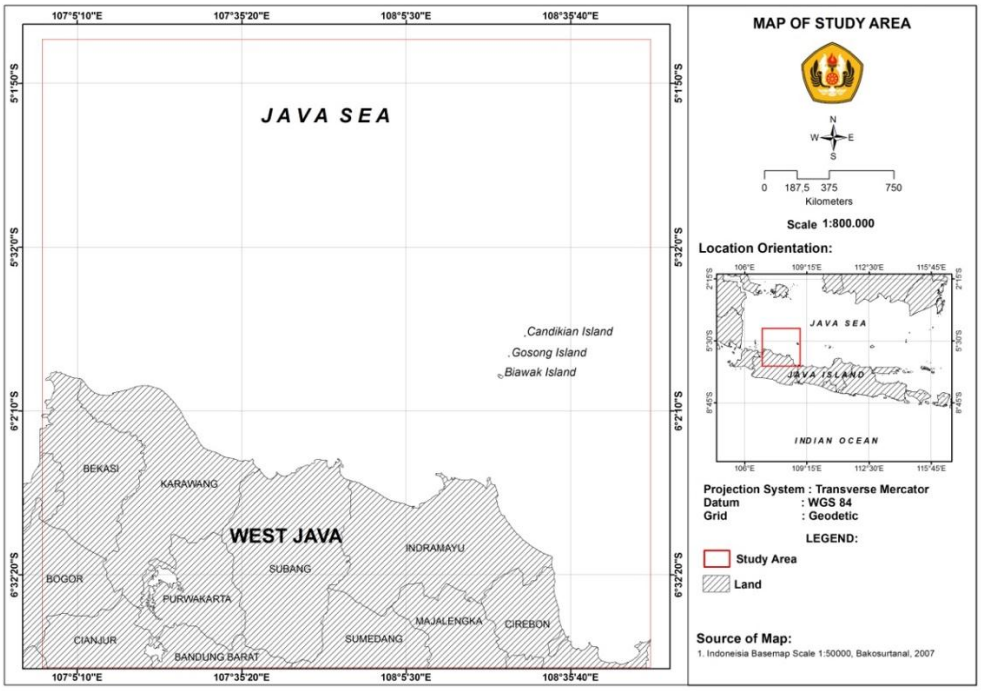

Figure 1. Study area with three islands overlaid and five districts facing the Java Sea.

Data and method. The present research was designed using the observation method with a combination of the Remote Sensing Technology approach with field data. With this approach is very possible to obtain spatial data widely and quickly. The accuracy of the data has been tested and coupled with data validation by doing field data retrieval (ground check). Data used in this research are SST, Chl-a, and yield of mackerel fishing activity (location coordinates and fish catch production). The scheme of the research stages can be seen in Figure 2.

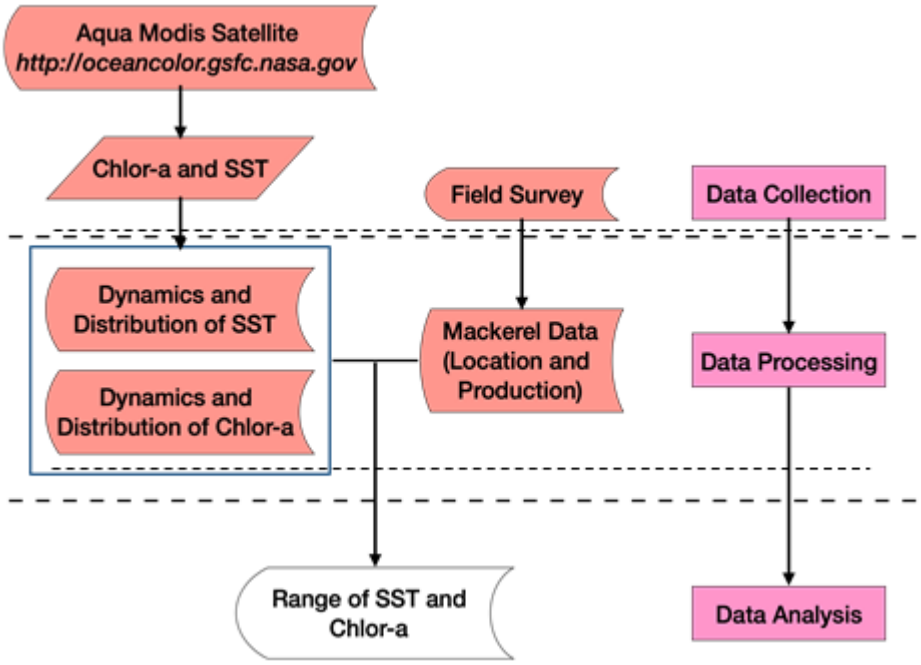

Figure 2. Research scheme and process.

SST and Chl-a data were obtained from Aqua/Terra MODIS satellite image recordings and can be downloaded from http://oceancolor.gsfc.nasa.gov (NASA 2014). The satellite data were collected and taken from daily recording. SST and Chl-a data from the satellite recording will be validated with data of mackerel fishing activity. The information on fishing activity was obtained by interviewing local fishermen at the fish landing port in Karangsong, Indramayu. A survey of mackerel fishing on the fishing boats had been done to validate the data. The validation was carried out by directly measuring the parameters in several locations and also on the catch of mackerel fish (fishing location and fish catch production).

Results and Discussion

SST and Chl-a condition. The condition of SST and Chl-a in the north of West Java in the 2014-2015 period has dynamical average values each month. The fluctuation is shown in Figure 3. The two graphs also illustrate the relationship of these parameters with the mackerel catch pattern. Monthly, temperature condition had the average ranges between 28.5-30.5^{o}C. In the annual cycle, it is seen that low temperatures occur in January and August. Meanwhile, high temperatures were recorded in April and November. The pattern of fluctuation changes are according to the monsoon. A more detailed explanation related to Asian monsoon can be found in Siregar et al (2017). The average chlorophyll concentration ranged between 0.3 and 1 mg L^{-1}. The lowest concentration was recorded in March and November, meanwhile, the highest Chl-a concentration was obtained in January and July.

The fluctuation pattern of SST shows the opposite pattern with Chl-a, where the low chlorophyll is at high SST and vice versa. Figure 3 shows the changes in SST

correlated within mackerel catches. The mackerel catch follows the pattern of SST change. Mackerel production will increase if the temperature has increased and contrary if the temperature decreases the catch is also reduced. However, the pattern seen in Figure 4 is still less apparent in changes of chlorophyll concentration.

The next analysis results are an overlay of data between SST, Chl-a, and mackerel fishing activities. The data were analyzed by making scatter diagrams as seen in Figure . The graph illustrates that mackerel catches are more stable at SPL of 29–31°C. Meanwhile, mackerel catches have the optimum Chl-a concentration with a range of 0.28-0.43 mg L^{-1}.

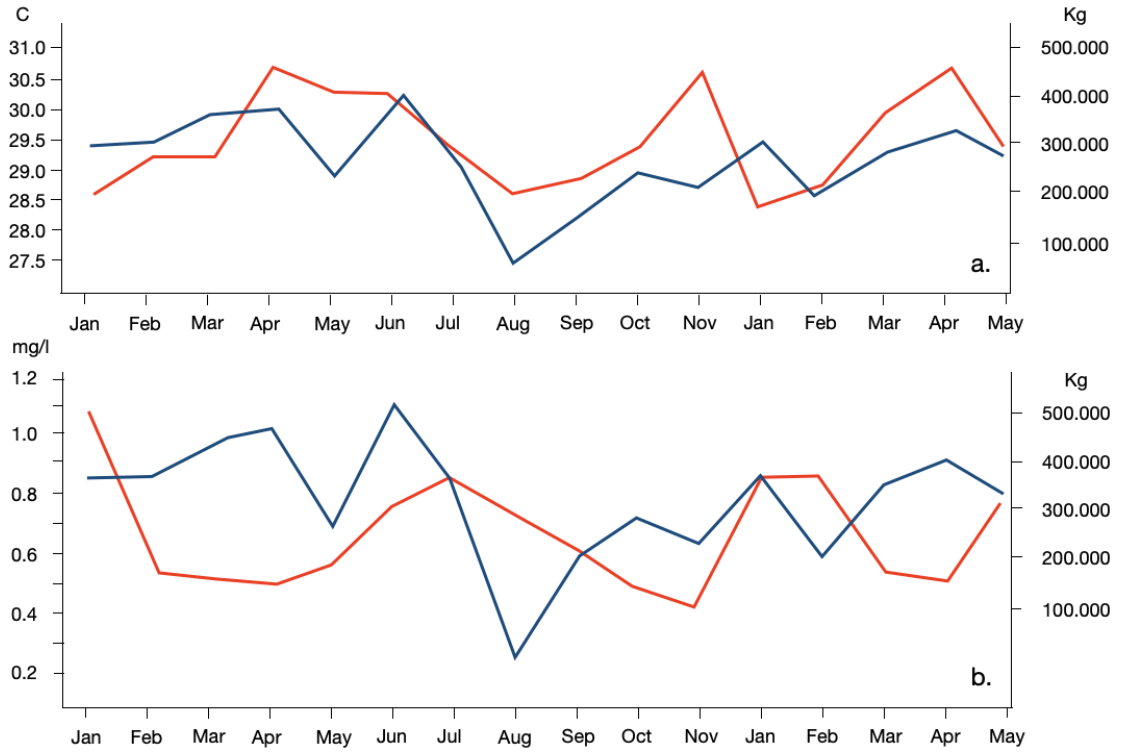

Figure 3. Monthly average of a) SST value and b) Chl-a concentration associated with mackerel catch from 2014-2015. (Red line - SST and blue line – production).

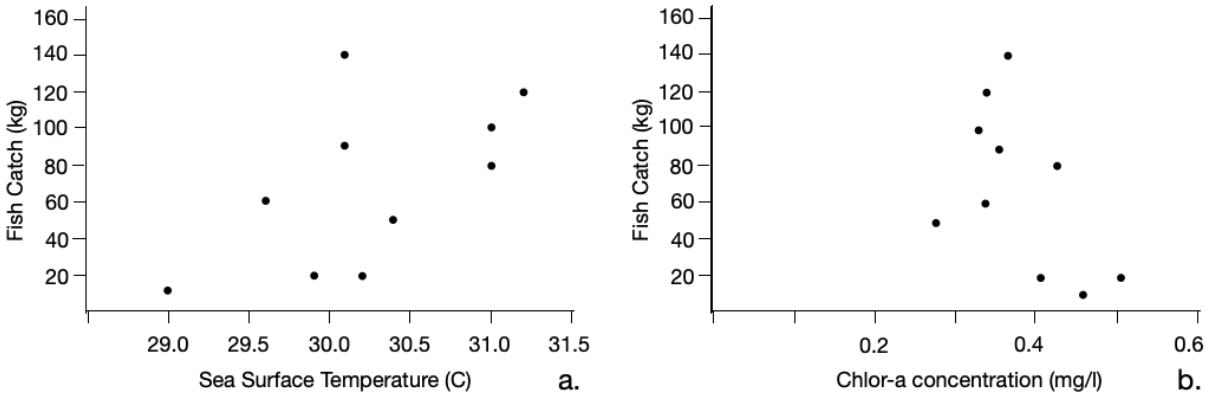

Figure 4. (a) Range of SST values based on mackerel catches and (b) Range of Chl-a concentration values based on the mackerel catches.

The results of the present study shows that SST and Chl-a influence the distribution of mackerels. This evidence can be seen clearly from the patterns and trends that occur when compared to the results of mackerel catch. Temporally, the trend of increasing temperature will indicate the increase in the mackerel abundance. This can be seen from the increase in fish catches. On the other hand, the abundance of Chl-a becomes an

important factor as well which indirectly triggers the presence of mackerels. Although from some study results, statistically, the relationship of both oceanographic factors against the catch has a low to moderate coefficient of correlation (Riyantini et al 2018).

Fluctuations and range of temperature values that occur still show the same pattern as the previous five years (Syamsuddin et al 2018). Despite fluctuation, qualitatively, the temperature of water in the study area can be classified into moderate to warm conditions (Simanjorang et al 2018). Nevertheless, the trend of SST changes occurring in these waters indicates an increase from year to year (Habibie & Nuraini 2014; Siregar et al 2017). The changes in water column dynamics of water column in Indonesian waters are very fluctuative both temporal and spatial. Moreover, the number of islands scattered in the territory of Indonesia causes spatial variation between waters, so that spatial and temporal analysis is needed in each waters area (Qu et al 2005). The SST variation of northern waters of West Java is part of the Java Sea and is very dependent on the monsoon cycle that passes through Indonesia. The temperature in the sea surface in the transitional monsoon (transitional 1 = March – April - May; transitional 2 = September – October -November) is higher than in the Asian monsoon (December – January - February) and Australian monsoon (June – July - August). In the Asian monsoon period, SST in the northern region is higher. On the contrary, in the Australian monsoon period, is higher in the south region. Meanwhile, around the equator is the highest SST in the transitional period (Habibie & Nuraini 2014). In the transitional period, the high-temperature is influenced by wind speed, sea surface current, rainfall, and the movement of the sun. Besides that, the position of the sun against the earth is in the equator line causing the increase of water temperature at the sea surface.

Mackerel cathes and oceanographic condition. SST and Chl-a concentration have a significant correlation (Zamir et al 2015). Changes in ocean surface temperature are associated with changes in other variables, including biological variables such as Chl-a (Setiawan et al 2013). Productions of mackerel catches and Chl-α concentration have an opposite trend compared to SST. At a Chl-α concentration that tends to have a downward trend, the production of mackerel fish catches increases. When Chl-α concentration increases the production of mackerel tends to decrease. This situation can be seen in Figure 4, wherein the transitional monsoon 1 in 2014, the Chl-α concentration tended to be stable and followed by a stable catch, but when there is an increase in Chl-α concentration the catch tends to decrease. However, the catch is preferable to the suitability of the aquatic environment compared to the availability of Chl-α at the time of catching. Meanwhile, the overall concentration of Chl-α has a value depending on differences in light intensity, precipitation, and nutrient concentration. The Chl-α concentration at the surface of the waters has the highest value during the Asian monsoon when is expected that the rain intensity has the highest value in this season. The concentration of Chl-α is higher in coastal areas and lower in offshore waters, due to the presence of nutrient sources derived from river estuaries found on the coast.

In general, the presence of pelagic fish such as mackerel fish is more dominantly influenced by SST, this is due to its nature that prefers optimum temperature in doing activities such as spawning, eating and other activities, besides fishing in the Java Sea is more affected during the spawning season of fish (Wahyuningrum et al 2011). The increase in catch occurs in transitional monsoon 1 along with the increase of SST. It will decline back in the Australian monsoon by the decrease of SST. This pattern will recur in the transitional monsoon 2. The highest production of mackerel occurred in June 2014 while the lowest catch in August 2014. From the description displayed, it appears that the best time of mackerel catch is from March to May (transitional monsoon 1), which is in accordance with the research results of Zulkarnian et al (2011). The main results obtained from this study are the range of values of SST and Chl-α in determining the abundance and distribution of mackerel. Based on SST, Chl-α condition, the catchment of mackerel in the north waters of West Java was recorded in June, July, and August (Australian monsoon). The range of SST was of 29-31^{o}C, while the concentration of Chl-α value had a range of 0.28-0.43 mg L^{-1}. In the Australian monsoon period the mackerel was still found even in the lowest quantities, and it is assumed that the Asian monsoon

will provide optimum catches. The results of the present study can be used as a reference for comparation with other seasons as well as for different study areas as indicator of fishing ground.

Conclusions. The SST in the northern waters of West Java in 2014 - 2015 had a range value of 28.3-31.4°C. In the transitional monsoon 1 and 2, the SST tended to increase compared to the SST in the Asian and Australian monsoon. Meanwhile, the range value of Chl-α concentration was 0.3-1 mg L^{-1}. The concentration of Chl-α in the coastal area has a high enough value due to the presence of nutrients carried by the river to the estuary. The influence of season influences the fluctuation of Chl-α concentration. The highest concentration occurs in the Asian monsoon while the lowest concentration occurs in the transitional monsoon 1 and 2. If the oceanographic condition is associated with mackerel distribution, then it can be concluded that SST and chlorophyll- α dynamics has a positive effect on the mackerel abundance and distribution. The increase in catch production occurs in the transitional monsoon 1 along with the increasing of SST. Furthmore SST value in the range of 29–31°C, and the range of Chl-α value 0.28-0.43 mg L^{-1} can be used as indicator of fishing ground.

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