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## Remote Chlorophyll-a and SST to Determination of Fish Potential Area in Makassar Strait Waters Using MODIS Satellite Data

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**Abstract.** The objective of this research was to analyze integrated geospatial data using MODIS Satellite data and field data observation to the determination of potential fish area. This study applied in Makassar Strait 118° 0' 0" E-119° 37' 0" E, 3°0'0" S – 4°45'0" S. The methods of this research was conducted using MODIS combine the depth of map waters survey direct interviews and people who participate in fishing activities monthly in January, February, March, April, May, and June. Data were analyzed by using software: Statistics, SeaDas, ENVI, and GIS. The result showed that the horizontal distribution of sea surface temperature (SST) spread evenly or divergent. The distribution of sea temperature in the coastal area was relatively warm in the sea around Barru and Pangkep was ranged 31 to 32 °C. Sea surface temperature dominates in the range of 30 - 31°C. SST correlation coefficient was 0.79 between MODIS and value of observation field data.

### 1. Introduction

The utilization of natural resources in the past sometimes did not pay attention to the balance of the carrying capacity. Behavior that tends to utilize marine biological resources which only prioritize short term profit without paying attention to its sustainability must always be controlled by the government and society. Such continuous fishing activities without any control efforts from all parties will cause fish stocks to be disrupted.

Determination and mapping fisheries fishing ground based on integrated geospatial data analysis is expected to become a reference by local government in determining fishing policy in Makassar Strait. The purpose of this study is to determine the potential fish aggregation area in Makassar Strait based on integrated geospatial data analysis (first year).

### 2. Material and Method

This study conducted at Makassar straits of Barru Majene waters in South Sulawesi from February 2017 June 2017.

### 2.1. Material and tools

The material and tools were used in the study described are: Eart map, satellite image data and questionnaire, and research tools are Boat carrier, *Global Positioning System* (GPS), *Fish Finder/Echosounder*, Computer hardware, Software SPSS 16, SeaDas, Microsoft Excel, ArcGIS 10.3, a digital scale and stationery.

### 2.2. Population and sample

Based on the targets to be achieved; this research carried out with survey method to fishing gears and fishing ground. The population of the study all fishing gears in Makassar Strait (Barru up to Majene waters). Primary data was the result of direct observation where the observer was directly involved in fishing operations. The coordinate point was retrieved (latitude and longitude) in the area where fishing operations are conducted by using GPS (Global Positioning System).

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### 2.3. Data Analysis

The estimation of the distribution of the fishing ground was based on the distribution of fishing points recorded on GPS combined with the fishing ground data based on the information from fishermen and survey results. The fishing ground plot will be made based on the dynamics of the fishing area conducted by local fishermen throughout the year.

Data of the catching area on each fishing gear will be captured in the GPS and transferred to the computer to be mapped.

### 2.4. Determination of Potential Areas of Fishing Ground at Makassar Strait

#### The First Stage

Incorporated digital maps of South Sulawesi and West Sulawesi were to get an overview of the research sites, as well as the determination of boundaries of research areas.

#### The Second Stage

Conducted a topology that was the compilation or input of all data attributes/ databases in the format of the database file (\*.dbf) which consisted of population biological parameters and catch data. This step was conducted to establish the relationship between the spatial data with the attribute data of each parameter used. This process used ArcGIS software.

#### The Third Stage

Interpolated to the field catches and predictive catches (analysis results) obtain thematic maps in the form of spatial data. The method used for interpolation is Inverse Distance Weightness (IDW), which assumed that each input point has a reduced local effect on distance. This method gives higher weight to further cells. Points on a certain radius can be used in determining the output value of each location. After the interpolation is done, it will automatically show the zoning division. This process also uses ArcView GIS software.

#### The Fourth Stage

The presentation of the results of the analysis in the form of graphs of tables and pictures in the form of potential fishing zones and accompanied by a descriptive explanation. Displayed a map of analysis results using ArcGIS 10.3 and created its layout. The criteria for determining that potential fishing zones were determined automatically by ArcGIS 10.3 with the quantile system.

### 2.5. Image Processing Process (SeaDAS)

MODIS Level 2 image processing is done by using SeaDAS software.

### 2.6. Map Processing Process (ArcGIS)

### 2.7. Map Layout Process

Map layout is the last part in making this PPDPI, where this activity aimed to represent the data that was already processed into a map that can be seen by people as PPDPI information

### 3. Results and discussion

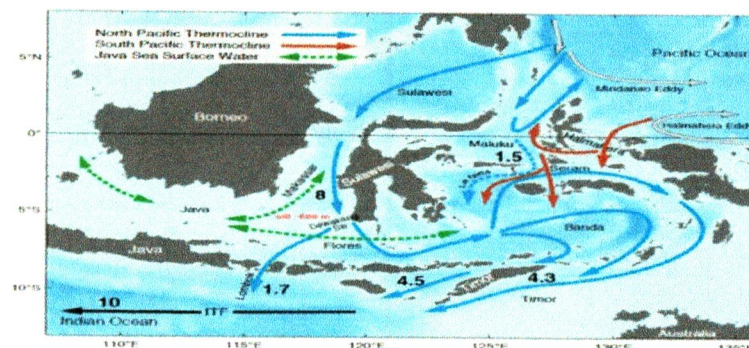
#### 3.1. Oceanographic Conditions in Indonesian Waters

The Utilization of marine fish resources in various areas of Indonesian waters is uneven. In some waters areas, great opportunities for the development of utilization were still open, while some other areas have reached the condition of excessive catching or overfishing [1]. It possibly happened because of no integration in managing potential fishery resource. One of the reasons was the unavailability of data and information about the potential of fishery resources in Indonesia as a whole. Lack of data and information causes fishery potential cannot be utilized optimally and sustainably.

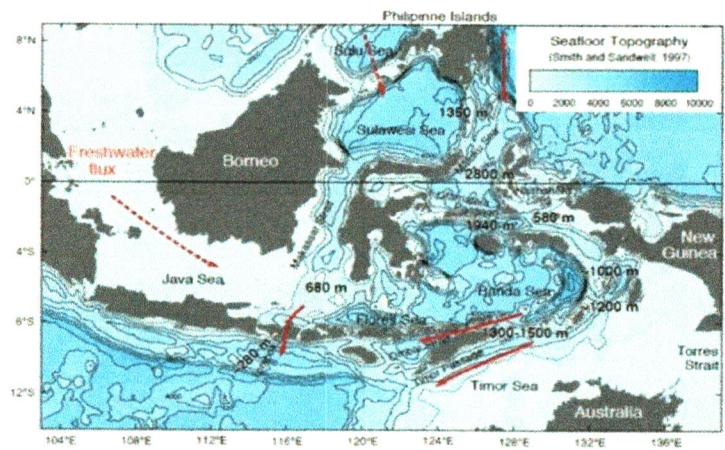
In the perspective of the geographical position, the waters of Indonesia lied in a strategic location based on its potential fishery resources. The location, which lies between two oceans, the Indian and Pacific Ocean, is a boundary as well as a connection of biodiversity against both glasses of water of these oceans. The existence of Banda Sea, Flores Sea, Makassar Strait, and Sulawesi Sea that connecting the Indian Ocean and the Pacific Ocean with seasonal and annual water mass movement pattern had revealed the fact that this mass movement of water influences migratory pattern high migratory species as shown in Figure 2 and 3

Indonesia waters are influenced by monsoon pattern system which has different water mass circulation patterns and varies between seasons, besides it is also influenced by Pacific Ocean waters mass that passes Indonesian waters to the Indian Ocean through (Alindo) The water circulation of Indonesian waters differ between the West and East seasons. On West Season, water masses generally flowed towards the East of Indonesian waters, and on East Season supply of water, masses develop perfectly which was derived from upwelling areas in the Arafura and the Banda Sea. This water masses will flow towards the waters of Western Indonesia [2,3] as seen in Figure 4 between the West and East seasons.

Several research has been revealed that migratory large pelagic fishes, such as Tuna, Skipjack and Tonggol group moved from the northern waters (Sulawesi Sea) to the southern waters (Flores Sea) through Makassar Strait. The geographical location of Sulawesi Island flanked by several glasses of water such as Banda Sea, Flores Sea, Makassar Strait, and Sulawesi Sea are potential of fishery resources rich with biodiversity, especially big pelagic fish inside. The potential abundant of fishery resources around of the territorial waters of the island of Sulawesi is an enormous wealth of nature with some coastal ecosystems in shallow sea waters and deep water ecosystems it has. In addition to the potential of biodiversity with large carrying capacity, it is also naturally defined by various biodiversity and other migratory fishes as a path of permanent movement pattern based on seasonal differences from year to year.

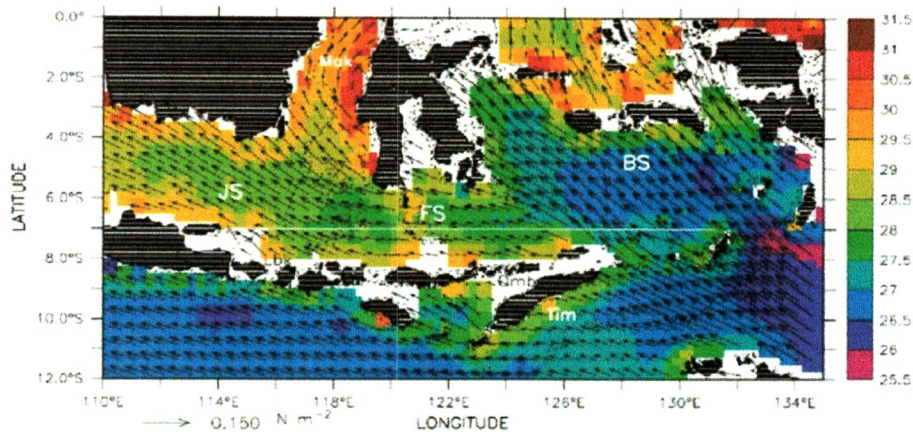


**Figure 1.** Cross Water Flow of Indonesia and Estimated Total Volume Of Water Transported In  $10^3\text{m}^3/\text{Second}$ [2]



**Figure 2.** The Oceans Of Indonesia Overlaid Above The Depth (m). Crossflow Indonesia is indicated by a red arrow [2].

Fishing ground defined as waters area where targeted fish is expected to be catch optimally but still under the limit of sustainability of the resources. Good fishing ground waters with the environment, food content, and breeding or spawning ground that are suitable for the life of targeted fish. Identification of potential fishing ground using remote sensing technology is an indirect method of identification. From remote sensing data, observation of sea surface temperature (SPL), upwelling or frontal zone and estimate the content of chlorophyll-a in waters were conducted. The results of these observations are presented in the form of contour maps, so as to estimate the fertility level waters conditions with habitat favored by schooling fish based on latitude coordinates and for tuna and skipjack [4, 5].



**Figure 3.** Average sea surface temperature and wind patterns on February (above) and July (below) in Indonesian waters [3].

One of the most reliable methods used for the determination of fishing ground is through analysis of satellite image data and verification or support of field data and existing data. Satellite observations later on mapped with GIS techniques. This GIS technique combines the various fisheries and marine information necessary to create distribution maps and fish abundance [6].

### 3.2. Sea Surface Temperature (SST) Distribution of Makassar Strait

The environment in which fish live depends heavily on oceanographic conditions in these waters. Therefore, knowledge of conditions and changes in oceanographic factors is needed to determine the exact fishing areas. One of the oceanographic factors that greatly affect the distribution and abundance of fish is the temperature of the waters.

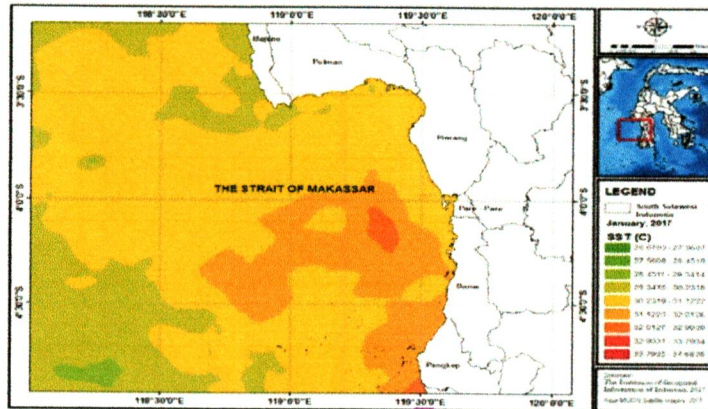


Figure 4. The Horizontal Profile of the Sea Surface Temperature in Makassar Strait waters on January 2017

Figure 4 shows that the horizontal distribution of sea surface temperature is uneven or different. The distribution of water temperature in the coastal area is relatively warm especially in the area around Barru and Pangkep waters (31 to 32 °C). Unlike the sea surface temperature waters of Mamuju regency that was relatively cold (about 26 – 28 °C). Sea surface temperature in January 2017 ranged 26 to 34 °C and dominated as the range of 26 to 31 °C. The dynamics of this temperature will affect the pattern of movement and distribution of pelagic fish in the waters.

In February 2017, the range of sea surface temperature remained constant in the range of 26 – 34 °C, but the water temperature in February tended to be cooler compared to January, especially around the waters of Majene regency which was ranged 26 to 29 °C. The surface temperature was also found relatively warm in coastal areas, especially around the waters of Pinrang and Barru District and relatively hot in the waters of Pangkep District (Figure 5).

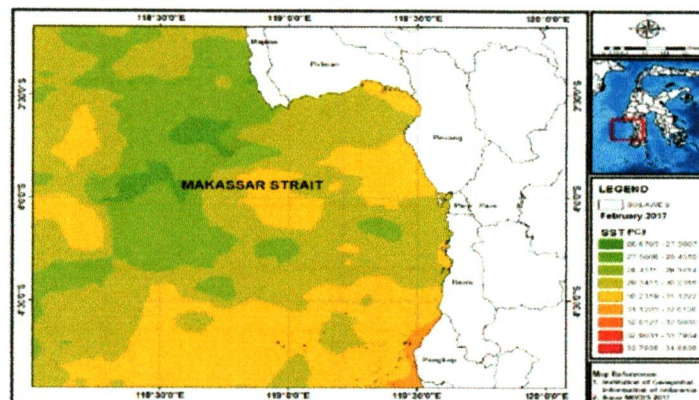


Figure 5. The Horizontal Profile of the Sea Surface Temperature in Makassar Strait Waters on February 2017

Figure 5 also shows that temperatures in the offshore area were colder compared with coastal area, as well as the surface temperature in the Northern part of Makassar Strait compared with the Southern Part that was relatively warm. The condition of dynamic oceanographic in the Makassar Strait waters was also demonstrated in March 2017 compared to January and February 2017. In general, the temperature of the waters was relatively warm in the coastal area that was about 30 to 32°C in the coastal around of the district of Polewali Mandar, Pinrang, part of Parepare Municipality beach, and Barru and Pangkep Districts. Further, about 25 miles towards the offshore, the sea surface temperature was relatively cold (28 to 30°C) and gradually colder at the offshore area (Figure 7). Furthermore, the oceanographic dynamic condition in April to June 2017 as shown in Figure 7 to Figure 10.

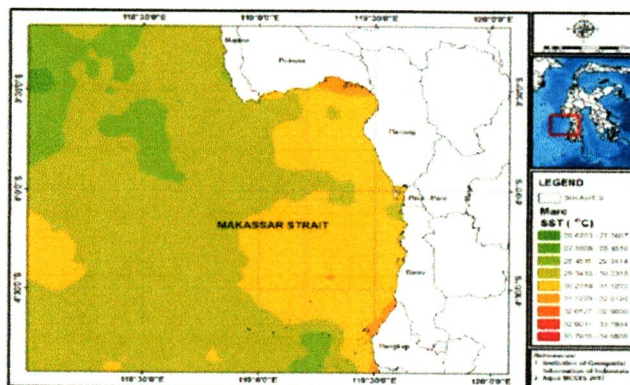


Figure 6. The Horizontal Profile of the Sea Surface Temperature in Makassar Strait Waters in March 2017

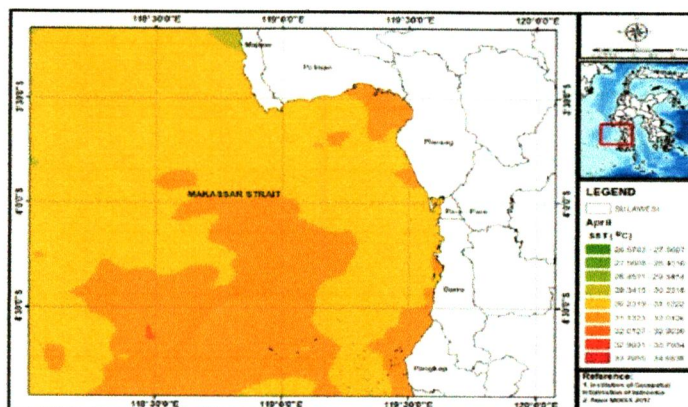
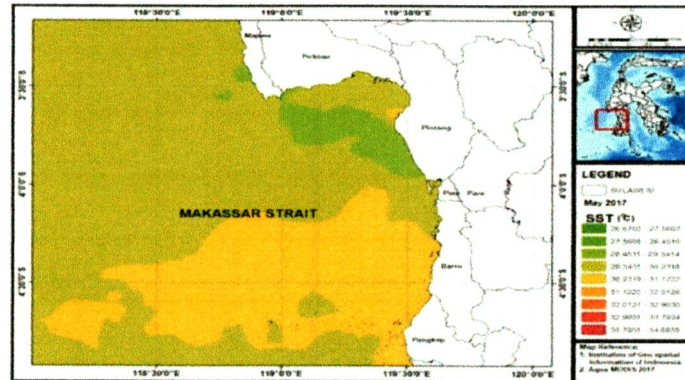
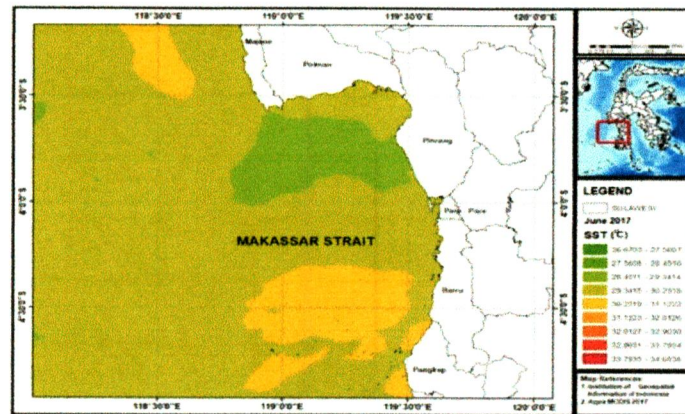


Figure 7. The Horizontal Profile of the Sea Surface Temperature in Makassar Strait Waters in April 2017

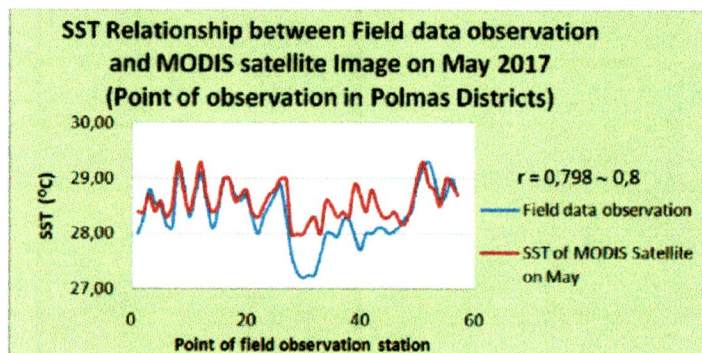


**Figure 8.** The Horizontal Profile of the Sea Surface Temperature in Makassar Strait Waters in May 2017



**Figure 9.** The Horizontal Profile of the Sea Surface Temperature in Makassar Strait Waters in June 2017

Figure 9 shows that sea surface temperature (SST) in Makassar on April Strait waters reached the highest heat from January to June 2017. Sea surface temperature was generally in the range 30 to 32°C which was almost homogenous in every part of the waters of the Makassar Strait. The high sea surface temperature condition then looked declining in May 2017 (28 °C, 31 °C) and dominant at 29°C, 30°C.



**Figure 10.** SST between MODIS image data processing to field observation data (Source, 2018 primary data processing)

Figure 10 explained the value of correlation coefficient 0.789 or equal to 0.80 between field data observation in Polman waters and MODIS satellite images recorded in May 2017. This can be interpreted the significant relationship of two data. Field data is control data so that the deviation of MODIS Satellite image data can be known, and used to calibrate the data.

The spatial and temporal changes of oceanographic conditions (January to June 2017) will affect the distribution and abundance of pelagic fish in the waters. In general, fishing ground is not permanent, constantly changes and shifting according to the changes in environmental conditions, the fish naturally will choose more suitable habitats while that habitat is strongly influenced by oceanographic conditions or parameters of such as sea surface temperature, chlorophyll-a, depth and so on [7,8]. This affects the dynamics of movement of seawater both horizontally and vertically which in turn affects the distribution and abundance of fish.

Furthermore, reported that from the distribution pattern of sea surface temperature image we could view oceanography phenomenon such as upwelling, frontal zone, and surface current pattern. Areas that have such phenomenon as mentioned above are generally fertile. With the knowledge of the fertile territorial waters, the potential fishing ground can be predicted since fish migration tend to move to rich water.

Big pelagic fish are a group of fish located on the surface layer up to the water column with main characteristics always in schooling form and migrate for the various need of their life [1]. This group of fish is widespread throughout tropical waters even to subtropical waters areas such as tuna and skipjack [4,5]. Big pelagic fish in the Eastern part of Indonesia located in the Banda Sea, Halmahera, Maluku, Sulawesi, the Pacific waters the north of Papua, Flores Sea, Makassar Strait and Bone Bay. The range of distribution value of some key economic large pelagic fish for an aquatic condition such as sea surface temperatures and water depths as is shown in table 3.

**Table 3.** The Range of Sea Surface Temperature and Depth of Waters which Suitable for Some Species of Pelagic Fish.

No.	Jenis Ikan	Suhu (°C)	Kedalaman (m)
1.	Cakalang ( <i>Katsuwonus pelamis</i> )	15 – 30°C	Max. 260 m
2.	Tuna sirip panjang ( <i>Thunnus alalunga</i> )	10 – 25°C	Max 600 m
3.	Article I. Yellowfin tuna ( <i>Thunnus albacares</i> )	15 – 31°C	Max. 250 m
4.	Article II. Tuna Mata Besar ( <i>Thunnus obesus</i> )	13 – 29°C	Max. 150 m
5.	Article III. Bluefin tuna ( <i>Thunnus Thunnus</i> )	3 – 30°C	Max. 985 m
6.	Tongkol ( <i>Euthynnus</i> sp)	18 – 29°C	Max. 200 m
7.	Article IV. Tenggiri ( <i>Scomberomorus</i> sp)	24 – 30°C	10 – 70 m

Sources: [9]

The changes and variations of oceanographic factors indicated the pattern of distribution of fish resources was uneven and also caused the number of catches to be uncertain. To increase the number of catches by taking into account the sustainability of fish resources, it is very important to know the exact location of fish and its fishing grounds [10].

### 3.3. Chlorophyll-a density in Makassar strait Waters

The distribution of chlorophyll-a density at the sea varied geographically as well as by the depth of the water. That variation was caused by the difference of sunlight intensity, and the concentration of nutrients within the waters. At sea, distribution chlorophyll-a density had a higher concentration at the beach and coastal areas and lowered at the offshore. The high distribution of chlorophyll-a concentrations in coastal waters is due to the supply of nutrients in large quantities through runoff from the mainland, whereas the low concentration of chlorophyll-a in the offshore area was because of the absence of direct supply of nutrients from the land. However, in certain of offshore areas there was a considerable amount of chlorophyll-a concentration. The situation is caused by the high concentration of nutrients produced through the physical process of water mass, where the water mass in lifting nutrients from the inner layer to the surface layer [3]. Research is not always possible to determine chlorophyll content without using any correction any dependency is obtained from laboratory measurement data. In plants, the role of chlorophyll is also very important too [11].

Distribution of chlorophyll-a density in Makassar Strait waters based on satellite image data analysis from January to March 2017 then visualized by geographic information system (GIS). Generally, from January to March 2017, the range of chlorophyll-a density was found to be in the range of 0.0771 – 2.9574 mg m<sup>-3</sup>. The chlorophyll-a density was generally at a relatively low value in the range of 0.0771 – 0.399 mg m<sup>-3</sup>, which was commonly found in high seas. The high density of chlorophyll-a was found around the beaches along District of Polewali Mandar, Pinrang, Parepare Municipality and Barru and Pangkep District coast (Figure 5.10 and 5.12).

In January 2017, the highest density of chlorophyll-a was found a small portion of the waters area covering Mandar Bay (Polewali Mandar District), Barru District and the highest four the waters of Spermonde of Pangkep District. While in other territorial waters tend to be low in the range of 0.0771 – 0.399 mg / m<sup>-3</sup> (Figure 5.10). The differences of the masses water supply was due to the effect of seasonal changes result in changes in water conditions that affect its variation of water productivity. Changes in of the condition of water mass can be determined by looking at the properties of water masses including temperature, salinity, dissolved oxygen, and nutrient content [2].

The aquatic environmental was a high concentration of chlorophyll-a within very prospective and supportive the life and development of fish in the region especially small pelagic fish group which the main prey is plankton [12]. Coastal areas usually had high primary and secondary productivity resulting in an abundance of fish at low tropical levels to middle tropical levels [13].

In Indonesian waters, there are differences in wind patterns that directly affect the pattern of the surface current of Indonesian waters and changes in mass characteristics are thought could lead to the changes in water productivity level. This situation depends on various things like how the chemical-physical distribution of aquatic factors. Therefore, it is necessary to analyze and study the effect of oceanographic factors on the physical distribution of aquatic chemical and its relation to the concentration level of chlorophyll-a.

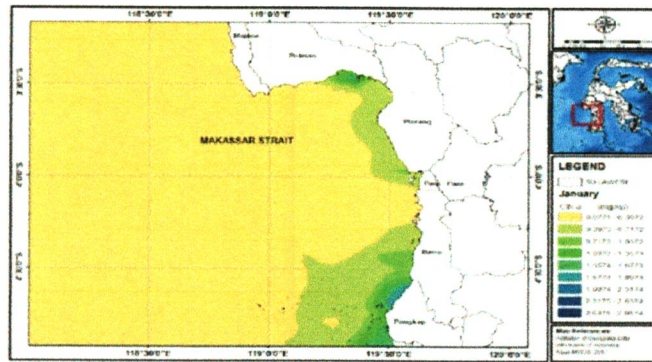


Figure 11. The Distribution of Chlorophyll-a Concentration in Makassar Strait Waters in January 2017

Figure 11 showed the distribution of Chlorophyll-a Concentration in January 2017 in Waters of Makassar Strait. Chlorophyll-a density tends to be constant from January 2017. The chlorophyll-a density tends to develop around Mandar Bay and the waters of Pinrang District (Figure 12). The content of chlorophyll-a can be used as a measure of the number of phytoplankton in particular water and can be used as guidance of aquatic productivity. Areas with high chlorophyll values have a close relationship with the upwelling process.

The distribution of chlorophyll-a in the waters column was highly depended to the concentration of nutrients. The nutrient concentrations in the surface layer were very small and will increase in the thermocline layer and its underlying layer. That nutrients had low concentrations and changes at sea level and their concentration will increase with increasing depth and will reach maximum concentration at the depths between 500 -1,500 m.

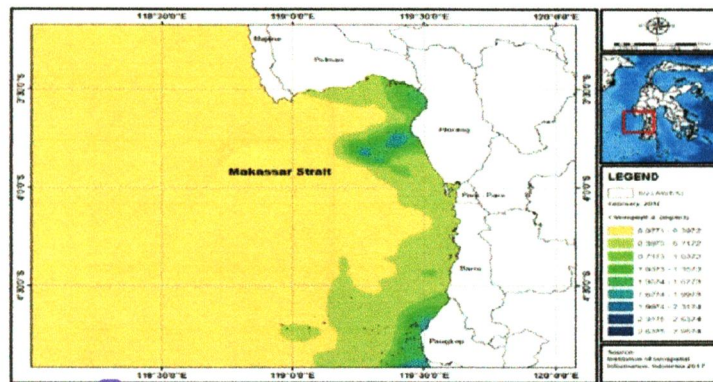


Figure 12. The Distribution of Chlorophyll-a Concentration On February 2017 in Makassar Strait waters.

Figure 12 showed the distribution of Chlorophyll-a Concentration On February 2017 in Makassar Strait waters. In March, as in January and February 2017, the relatively high chlorophyll-a density was found along the coast except around the coast of Majene Regency. It was because in this water area the currents were so strong that it was difficult for plankton to thrive in this area at a certain time (Figure 12). The distribution of chlorophyll-a concentration in April - June 2017 can be seen in Figure 14 to 16) below.

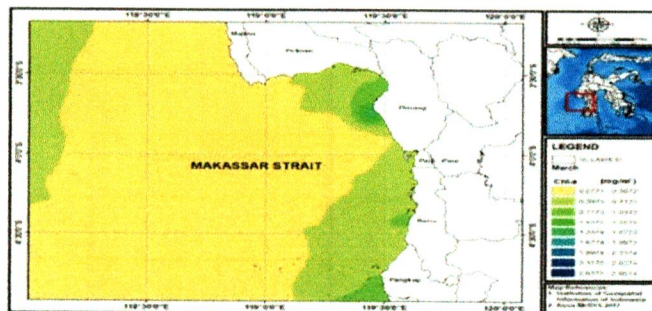


Figure 13. The Distribution of chlorophyll-a concentration on March 2017 in waters of Makassar Strait.

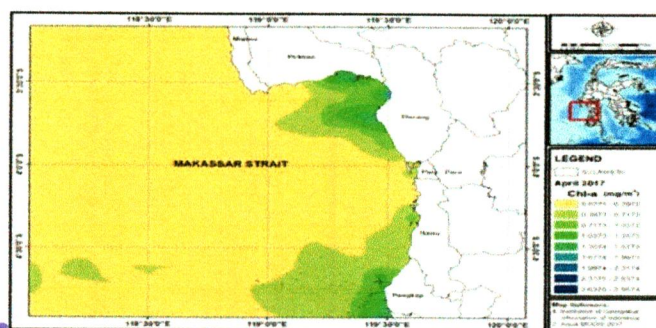


Figure 14. The Distribution of chlorophyll-a concentration in waters of Makassar Strait in April 2017

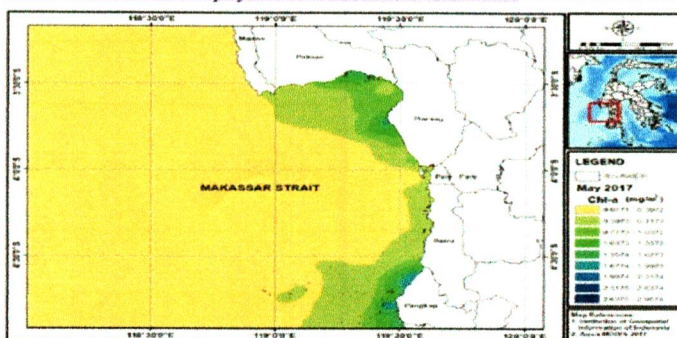
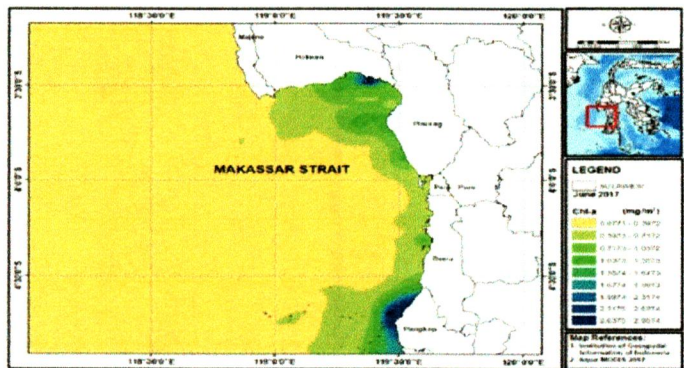


Figure 15. The Distribution of chlorophyll-a concentration in water of Makassar Strait in May 2017

An interesting fact in March 2017 was the presence of chlorophyll-a density around Kalimantan coastal waters, which were different from January and February. April, May and June 2017. This may be due to changes in the current pattern that cause stirring of water masses that

allowed phytoplankton utilizes existing nutrients in the water for growth and development. However, the concentration of chlorophyll-a in the western coastal area of South Sulawesi Province (Makassar strait) continues to grow from April to June 2017 (Figure 11 to 15).

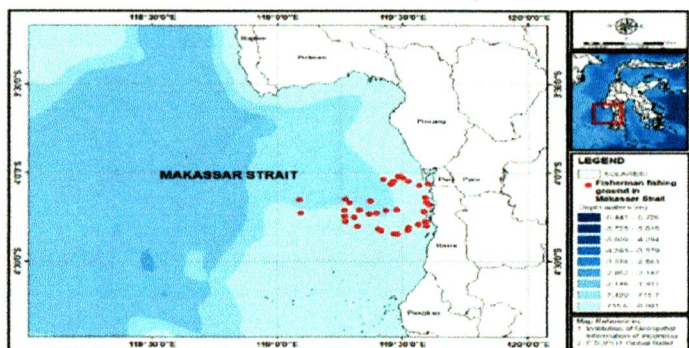


**Figure 16.** The Distribution of Chlorophyll-a Concentration in Waters of Makassar Strait in June 2017

The aquatic environment with a high concentration of chlorophyll-a is very prospective and supportive the life and development of fish in the region especially small pelagic fish group which the main prey is plankton [11]. Coastal area waters usually have high primary and secondary productivity resulting in fish abundance at lower tropical levels to middle tropical levels [12]. The distribution of chlorophyll-a in the water column highly depends on the concentration of nutrients. The nutrient concentrations in the surface layer are very small and will increase in the thermocline layer and its underlying layer. Nutrients had low concentrations and varied at sea level, and their concentration will increase with increasing depth and will reach a maximum concentration at depths between 500 and 1,500m.

3.4. *The depth of Makassar Strait Waters*

The depth of waters greatly affected the distribution of fish, the fish that are distributed specifically at certain depths as contained in Figure 17. The figure showed the depth profile in Makassar Strait waters located in the depth of between 1,6,441 m. Waters of Majene District has topography where its depth was different from other waters. The shallow water region is only about 5 miles towards the open seas, unlikely with the waters of Pangkep District around the Spermonde archipelago where shallow of waters was the extent to nearly 50 miles toward the open seas.



**Figure 17.** The Depth of Waters around of Makassar Strait Overlaid to the Position the Fishermen

#### 4. Conclusion

Oceanographic conditions (distribution of sea surface temperature and density of chlorophyll-a) in Makassar Strait waters were very dynamic in spatially and temporally. In general, sea surface temperatures are relatively warm in coastal waters, but chlorophyll-a concentration tended to be high in this region. Monthly variation in oceanographic conditions greatly affected the distribution and abundance of fish and impacted the shifting of the potential fishing ground of key economic fish in the waters of Makassar Strait. The results of the chlorophyll-a analysis can predicted fishing potential area with a high chlorophyll-a concentration and have an optimum temperature. The fish potential area also predicted accurately by compared within a fishing ground value or the amount of fish caught by fishermen.

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