Journal of Coastal and Ocean Sciences *e-issn: 2746-4512*
Volume 5 No. 3, September 2024: 143-150 *p-issn: 2745-4355*

Sea Surface Temperature Distribution Mapping and the Relation with Coral Reef Distribution Using Modis Aqua Imagery in the Waters of Padang City

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Received: 1 August 2024; Accepted: 9 September 2024

ABSTRACT

Mapping sea surface temperature and coral reef distribution is vital for understanding the marine environment's dynamics and developing effective conservation strategies. The ideal temperature for coral reefs is between 27-29ºC. This research aims to describe and analyze the relationship between sea surface temperature and chlorophyll-α to the potential zone of coral reefs in Padang City, West Sumatra. The data used in this research is MODIS Aqua level 3 imagery data with 4 km resolution. The imagery processing stages include imagery data processing using SeaDAS software, namely the cropping and reprojection process, and ArcGIS software, namely the interpolation and classification process and map layouting. The results showed that the classification of the distribution of sea surface temperature in Padang City ranged from 26-29ºC, and the average concentration of chlorophyll-α distribution was 1.41 mg/m^3. Based on these results, it can be concluded that Padang city waters have an ideal sea surface temperature for coral reefs and are supported by a reasonably high chlorophyll-α concentration.

Keywords: Sea Surface Temperature, MODIS Aqua Imagery, Chlorophyll-a, Coral Reefs

1. INTRODUCTION

Sea surface temperatures have increased due to global warming caused by increased concentrations of greenhouse gases. Coral reef ecosystems, which are very sensitive to temperature changes, will be impacted. Sea surface temperature (SST) is an important factor for marine life because temperature affects the metabolic activities of organisms in the ocean. Sea Surface Temperature (SST) is also used to determine water quality.

One of the main impacts of increasing sea temperatures is the phenomenon of coral bleaching. Bleaching occurs when warmer water temperatures cause the symbiotic algae that live in coral tissue (zooxanthellae) to be expelled. This causes coral to lose color and become more susceptible to disease and death. Mapping sea surface temperatures and coral reef distribution is vital for understanding the marine environment's dynamics and developing effective conservation strategies. With mapping technology such as satellite imagery, researchers can monitor changes in ocean temperature and coral reef conditions in real time, enabling rapid responses to environmental threats. Remote sensing technology that can survey the sea surface synoptically to detect very dynamic physical changes in the sea surface compared to in situ observations in the field has made it easier to measure the current Sea Surface Temperature (SST). Remote sensing systems can measure SST and other spatial and temporal water indicators (Arta et al., 2016).

Mapping sea surface temperatures and coral reef distribution is vital for understanding the marine environment's dynamics and developing effective conservation strategies. With mapping technology such as satellite imagery, researchers can monitor changes in ocean temperature and coral reef conditions in real time, enabling rapid responses to environmental threats. With mapping technology such as satellite imagery, researchers can monitor changes in ocean temperature and coral reef conditions in real time, enabling rapid responses to environmental threats (Siburian & Ningrum, 2019).

Sea Surface Temperature (SST) mapping is related to locations or zones that are good for the growth and development of coral reefs. Sea surface temperature, which can be classified as the ideal temperature for the growth and

development of coral reefs, is around 27-29ºC at a depth of ≤35 m (Siburian & Ningrum, 2019). This warm temperature also relates to the concentration of chlorophyll-α in phytoplankton. Chlorophyll-α is a green pigment found in algae, plants, and cyanobacteria. According to Agung et al. (2018), chlorophyll-α is an active pigment in plant cells that has a vital role in photosynthesis in water, and it can be used as an indicator of water fertility. This mapping data can support marine management policies and conservation programs. Accurate information about potential zones and the condition of coral reefs helps policymakers and conservation organizations plan more appropriate and effective protection actions.

This research aims to describe and analyze the distribution of sea surface temperature and its relationship to the distribution of chlorophyll-α and the potential distribution zone of coral reefs in the waters of Padang City, West Sumatra. The method used is a method survey in which sea surface temperature data was collected directly in the field to validate MODIS Aqua Sea surface temperature imagery data. This research is expected to provide information regarding sea surface temperature and chlorophyll-α mapping techniques and their relationship to the distribution of coral reefs in the waters of Padang City, West Sumatra, so that they can be used as a reference in further research, as well as considerations for related parties in the basis for taking anticipatory action against the potential distribution of coral reefs. Coral in the waters of Padang City, West Sumatra.

2. RESEARCH METHOD

Time and Place

This research was carried out in October 2023 in Padang City, West Sumatra. Data analysis was conducted at the Physical Oceanography Laboratory, Department of Marine Science, Faculty of Fisheries and Marine, Universitas Riau. Determining the coordinates of the research station was carried out using GPS. Field sea surface temperature data was collected in Nirwana Beach, Padang City, West Sumatra waters at 5 station points (Figure 1).

Method

The purposive sampling method determines the location for collecting sea surface temperature data, namely sampling techniques and data sources with specific considerations (Chan et al., 2019). The purposive sampling method was carried out to obtain sea surface temperature data, which can be used to carry out imagery data validation tests so that the imagery data used can describe sea surface temperature data in the waters of Padang City.

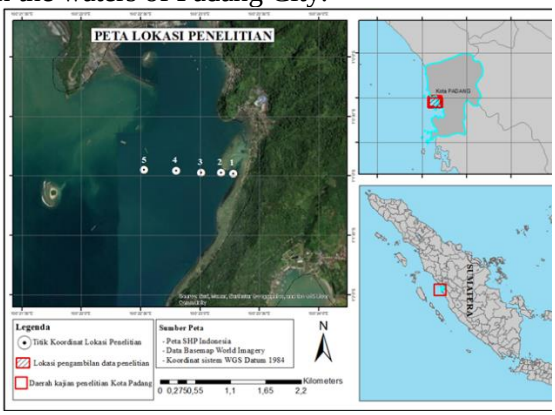

Figure 1. Map of Research Location

Procedures

Determining Research Locations

Field data collection on sea surface temperatures in Padang city waters was carried out in Nirwana coastal waters, Padang City, West Sumatra. The beach, located at coordinates -1º00'59" S and 100º23'24" E, has a coastline of ± 6 km and is one of the tourist beaches in Teluk Kabung District, West Sumatra Province. Sea surface temperature data was collected in Nirwana coastal waters at 5 station points, where station 1 was carried out at the coordinate point -1º00'59" S 100º23'17" E, station 2 at the coordinate point -1º00'59" S 100º23'10" E, station 3 at coordinates -1º00'58" S 100º23'0.6" E, station 4 at coordinates -1º00'57" S 100º22'48" E, and station 5 at coordinates -1º00'56" S 100º22' 31" E.

Data Analysis

The results of data processing that have been obtained are presented in the form of a map and analyzed descriptively by referring to the literature to provide an overview of the study of sea surface temperature mapping and its relationship to the distribution of coral reefs so that the potential zone for the distribution of coral reefs in the waters of the city of Padang, West Sumatra, can be identified based on the distribution sea surface temperature and chlorophyll-a.

Next, a data validation test process was

carried out between values from daily sea surface temperature data from MODIS Aqua imagery with sea surface temperature data obtained from field survey results to determine the level of accuracy or suitability of satellite imagery data with field survey data taken on 16 October 2023 in the waters of the city of Padang, more precisely in the waters of Nirwana beach. The data analysis used is to determine the mean relative error value. According to Rifai et al. (2020), Data verification is done by calculating the MRE. Relative error correction or average relative error can be calculated by:

$$RE = \left[\frac{X - C}{X}\right] x\ 100\%$$

$$MRE = \frac{\sum_1^n RE}{n}$$

Description:

RE	:	Relative error
MRE	:	Mean Relative Error
X	:	SST data from measurements in the field
C	:	Imagery SST data
N	:	Amount of data

3. RESULT AND DISCUSSION

General Conditions of Research Locations

Padang City is the oldest city on the west coast of Sumatra in the Indian Ocean. The largest city on the west coast of Sumatra Island is the capital of West Sumatra Province, Indonesia. The waters of the town of Padang are part of the Indian Ocean, characterized by mixed tidal types dominated by double-type tides, where in this area, there are two high tides and two low tides every day. The relatively straight coastline of Padang City extends from the northwest to the southeast, while the northern part is sloping and has a steep gradation of coastal waters towards the south.

Nirwana Beach is one of the beaches in Padang City. This beach in South Padang is not far from Teluk Bayur Harbor and has rocks and coral scattered along the beach. Nirwana Beach is more precisely located on Jl. Raya Padang-Painan, Bayur Bay, South Padang, Padang City, West Sumatra. Beach has a sand substrate almost throughout the beach area, but if it is close to residential areas, it has a muddy sand substrate.

MODIS Aqua Level 3 Satellite Imagery

The imagery data used in this research is MODIS imagery data products; MODIS imagery data for waters includes sea surface temperature and chlorophyll-a. The MODIS Aqua imagery itself has three types of imagery data. MODIS Aqua imagery data level 1 (a and b) 1a is raw data processed using an algorithm to separate the data in the MODIS Aqua imagery. In contrast, level 1b is data that already has its application, which results from sensor calibration at level 1a; MODIS Aqua level 2 imagery is combined image data from level 1a and 1b data. Level 2 is Modis Aqua imagery data for which an algorithm has been processed (Febriani & Sukojo, 2016), and level 3 MODIS Aqua imagery data is the data used in this research, where this data is a data product that has been processed.

The advantages of MODIS Aqua satellite imagery are that it has spectral wavelengths (radiometric resolution), more thorough land coverage (spatial resolution), and more frequent observation frequencies (temporal resolution) (Kurnianingsih et al., 2017). Meanwhile, the weakness of the MODIS Aqua satellite imagery is that several pixels were empty during data processing if it was used for an area that was too small.

Imagery Data Processing Using SeaDAS 7.5.3 Software

SeaDAS (SeaWiFS Data Analysis System) is a software used to process satellite imagery data to obtain the required data, namely sea surface temperature (SPL) and other uses issued by NASA. Satellite imagery data processing in SeaDAS 7.5.3 software includes Cropping and Reprojection. Cropping in this software reduces the size of the imagery to be processed to speed up the process. Apart from that, it aims to cut imagery data so that the data used is only in the research area of sea surface temperature and chlorophyll-a. Reprojection functions to change data from the initial format, namely (.nc) to NetCDF-BEAM, where this tool is found in the SeaDas software as Modis Aqua satellite imagery processing software. Reprojection functions are also used to set the I/O parameters selected by NetCDF-BEAM and the geodetic datum WGS 84. NetCDF is a file format for storing multidimensional (variable) scientific data such as temperature, humidity, pressure, speed, and wind direction. Each of these variable data can be displayed in ArcGIS.

Imagery Data Processing Using ArcGIS 10.4 Software

ArcGis is a software developed by ESRI (Environment Science & Research Institute) that combines the functions of different GIS software such as desktop GIS, server, and web-based GIS. ArcGis was released by ESRI in 2000. The main product of ArcGis is ArcGis desktop, which is comprehensive professional GIS software and is grouped into three components, namely: ArcView (a component that focuses on comprehensive data use, mapping, and analysis), ArcEditor (more focused towards editing spatial data) and ArcInfo (more complete in presenting GIS functions including for geoprocessing analysis purposes). ArcGIS desktop consists of 4 basic applications: ArcMap, ArcCatalog, ArcGlobe, and ArcScene.

Data Validation

A Data Validation Test was carried out to determine the level of accuracy between field sea surface temperature values and MODIS Aqua Imagery Sea surface temperature data. This level of accuracy is a benchmark for whether the imagery data recorded can represent the actual sea surface temperature value in the waters. A comparison between field sea surface temperature data and Citra MODIS Aqua Sea surface temperature data can be seen in Figure 2. Sea surface temperature (SST) data for Padang, West Sumatra waters were obtained based on MODIS Aqua Imagery Sea surface temperature data.

The results of the verification that have been carried out show a relative error correction value with an average percentage error (MRE) of 0.01%. The closer the MRE value is to zero, the better the imagery correction (Sukojo & Ariandi, 2019). From the relative error correction value, it can be concluded that the sea surface temperature data from MODIS Aqua imagery can be used to determine the distribution of sea surface temperatures in the waters of Padang City, West Sumatra. Observing the distribution of sea surface temperature directly using a thermometer in water is difficult for observations in a large study area, and changing sea surface temperature is also an obstacle to directly observing the distribution of sea surface temperature. For this reason, observing the distribution of sea surface temperatures using satellite imagery is considered appropriate because it can simultaneously record sea surface temperatures over large areas (Alfajri et al., 2017).

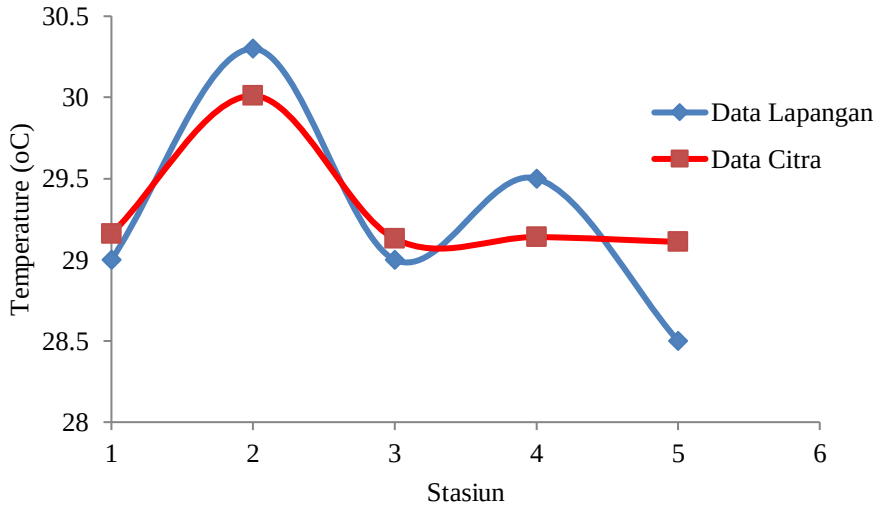

Figure 1. Field temperature data validation graph with modis aqua imagery data

Sea Surface Temperature

After processing the sea surface temperature imagery data, a map of sea surface temperature classification results is obtained, as shown in Figure 3.

Based on the results of the sea surface temperature classification map, it can be seen that the distribution of sea surface temperatures in Padang city waters is in the range of 26–29ºC. Direct sea surface temperature measurements were carried out at 5 station points. The measurement results from these 5 station points can be seen in Table 1.

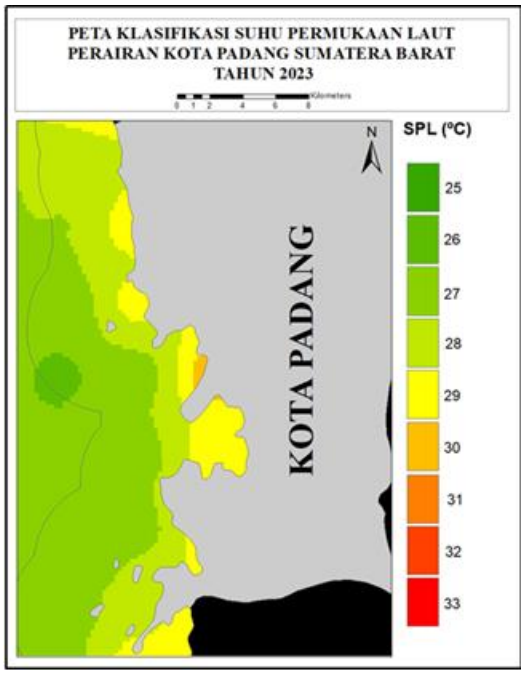

Figure 2. Sea surface temperature classification

Table 1. Sea surface temperature

Research Station	Temperature (°C)
Station 1	29
Station 2	30.3
Station 3	29
Station 4	29.5
Station 5	28.5

Based on the field data obtained, it can be seen that the sea surface temperature data values range from 28.5 - 30.3 °C. The highest temperature is at Station 2, around 30.3 °C, while the lowest is at Station 5, around 28.5 °C.

Chlorophyll-α

Based on the map of the distribution of chlorophyll-α in the waters of the city of Padang, West Sumatra, in Figure 4, it can be seen that the chlorophyll-α concentration with the minimum value obtained is 0.77 mg/m^3, which is found offshore waters. Meanwhile, the maximum chlorophyll-α concentration in the waters of Padang city, West Sumatra, is at 2.05 mg/m^3, with an average of 1.41 mg/m^3. The concentration of chlorophyll-α in the coastal and coastal waters of the city of Padang, West Sumatra, based on the results of Modis Aqua level 3 satellite imagery data extraction in October, is relatively high.

Chlorophyll-α distribution data from MODIS Aqua level 3 imagery data processing can be used, as described in Arta et al. (2016) that the results of statistical analysis of chlorophyll-α data analysis of Aqua MODIS satellite imagery with chlorophyll-α laboratory analysis using the T-test show that Aqua MODIS satellite imagery data does not have a high difference in value with laboratory data results so that it can be used to determine the value of chlorophyll-α in the field with reasonably good results.

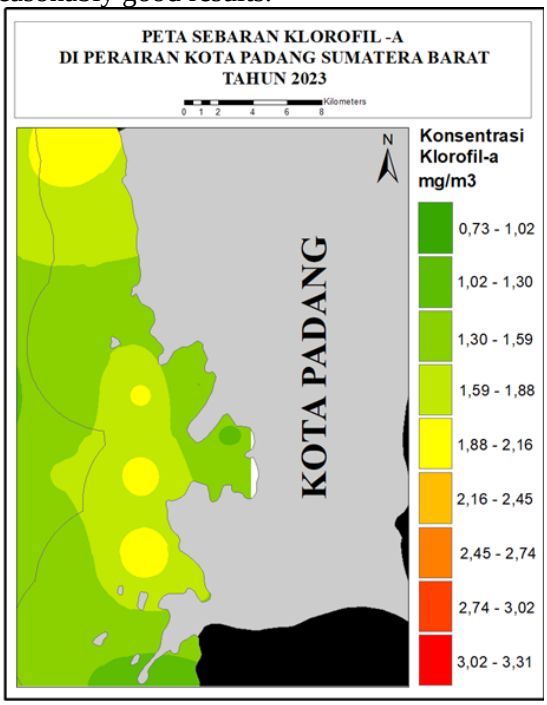

Figure 3. Map of chlorophyll-α distribution

Sea Surface Temperature and Its Relation to Chlorophyll-α Distribution and Coral Reef Distribution

One of the ideas shaping the world today is climate change. Climate change or global warming is often associated with various activities that we do every day, such as the use of gasoline, electricity, and so on. Increasing human activity and population are driving greater energy consumption. In the end, more emissions are produced. Greenhouse gas is a dangerous emission that hurts the environment. Ocean warming and climate change are among the possible impacts. According to oceanservice.noaa.gov, ocean change and climate change are the same thing. This is because the sea stores the carbon dioxide (CO_2) produced.

Thermal stress on coral reefs can occur when the sea absorbs excessive carbon dioxide the sea absorbs excessive carbon dioxide. Due to warming, death and infectious diseases will occur in corals. Sea levels will rise,

and existing ice will melt due to this warming. As a result of rising sea levels, coral sedimentation will increase, especially on coral reefs that are close to land sediments. As a result, substances and particles resulting from sedimentation are carried away, squeezing the coral so the coral reef becomes suffocated. Runoff from sedimentation, fresh water, and pollutants carried by rainwater will cause the growth of algae so that the water becomes cloudy. This happens because rainfall changes. Not only has rainfall changed, but climate change can also change storm patterns. The storm will become stronger and can damage coral reefs.

Coral reefs include animals living in shallow seas or depths of 25 to 100 m. This animal can live with an environmental temperature of 20-29ºC. "If sea surface temperatures continue to rise, coral reefs will have difficulty surviving. Sea surface temperature describes the temperature of ocean waters that are still below 100 m or can be considered shallow due to entering the mixed layer zone. High sea surface temperatures can cause coral bleaching, where corals lose their symbiotic algae, providing color and food sources. If high sea temperatures last too long, coral can die.

Based on the explanation above, it can be concluded that Sea surface temperature mapping, usually abbreviated as SST, is related to locations or zones that are good for the growth and development of coral reefs. Corals themselves can live and develop at water temperatures above 18ºC. The ideal temperature for coral growth is between 27-29°C. An increase in seawater temperature above its average temperature can cause coral bleaching so that the color of the coral changes to white, which was also explained in Siburian & Ningrum (2019) that sea surface temperature could be classified as the ideal temperature for growth and development of coral reefs, namely 27-29ºC at a depth of ≤ 35 m. This warm temperature also relates to chlorophyll-α concentration, the primary indicator of phytoplankton productivity, an important food source for zooplankton and other organisms that ultimately become food for many species on coral reefs.

Environmental conditions that support the growth of phytoplankton usually also support the health of coral reefs. So, data on the concentration of chlorophyll-α in phytoplankton, in this case, needs to be added to strengthen the research results regarding the potential distribution zone of coral reefs in the waters of the city of Padang, West Sumatra. Trisyani (2004) suggests that to achieve success in planting coral reefs, it is necessary to pay attention to the existence of primary productivity, which in this case is the abundance of phytoplankton because phytoplankton is the lowest link in the food chain in an ecosystem in the ocean.

Potential Distribution of Coral Reefs in the Waters of Padang City, West Sumatra

Based on the results above, if adjusted to sea surface temperature, it can be classified as the ideal temperature for the growth and development of coral reefs, namely 27-29ºC, and based on the chlorophyll-α classification according to (Nontji, 1984), namely low chlorophyll-α concentration (<0.3 mg/m^3), medium (0.3-1 mg/m^3), and high (> 1 mg/m^3) (Figure 5).

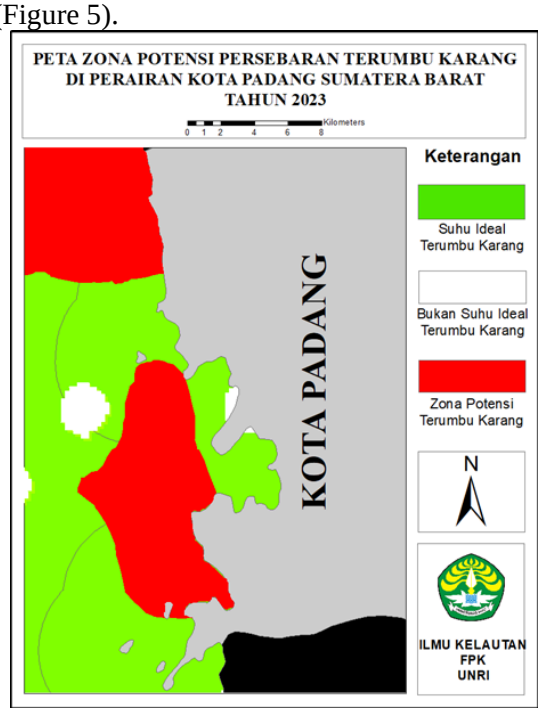

Figure 4. Map of potential zones for the distribution of coral reefs in Padang City

The results of the sea surface temperature classification mapping have also been adjusted to the results of mapping the chlorophyll-α concentration in the waters of Padang City, and an overlay process has been carried out, which is adjusted to the ideal temperature and chlorophyll-α concentration. The aim is to find coral reef distribution locations that have good

potential. This map is a zoning map in the waters of Padang City, which has potential as a coral reef ecosystem habitat based on sea surface temperature classification and chlorophyll concentration.

The location of the potential distribution zone for coral reefs is dominantly in the northern part of Padang City around the waters of Koto Tengah District and also in some of the waters of Bungus Teluk Kabung District and based on the sea surface temperature, the waters of Padang City are waters with an ideal temperature for the growth and development of coral reefs. So, it can be concluded that the waters of the city of Padang, West Sumatra, are a zone that has the potential to be a habitat for many coral reef ecosystems, has a high density as a home for small fish, and is a significant fishing source.

4. CONCLUSION

MODIS Aqua satellite imagery data can monitor sea surface temperature in Padang City, West Sumatra waters, with a relative error correction value or average percentage error (MRE) of 0.01%. Sea surface temperature can be classified as the ideal temperature for the growth and development of coral reefs, namely 27-29ºC. This location must also be adjusted to the distribution location of chlorophyll-a, which is the best chlorophyll to help photosynthesis for living creatures called phytoplankton. Phytoplankton is an important food source for zooplankton and other organisms, and it ultimately becomes food for many species on coral reefs.

The waters of Padang City, West Sumatra, have the potential as a habitat for a large number of coral reef ecosystems, have a high density as a home for small fish, and are a significant source of fishing based on the classification of sea surface temperatures which are ideal for the distribution of coral reefs and also based on the concentration of chlorophyll-α in phytoplankton as an important food source for zooplankton and other organisms which ultimately become food for many species on coral reefs. This location is precisely in the waters of Koto Tengah District and also in some of the waters of Bungus Teluk Kabung District.

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