SPATIO-TEMPORAL ANALYSIS OF CHANGES IN CORAL REEF AREA USING LANDSAT 8 SATELLITE IMAGERY ON PARI ISLAND, KEPULAUAN SERIBU, DKI JAKARTA

Faisal Akmal[1,*], Bambang Semedi[1], Azura Ulfa[2]

[1]University of Brawijaya
[2]Research Center for Remote Sensing, National Research and Innovation Agency (BRIN)

e-mail: babangfaisal15@gmail.com

Received: 19-09-2023; Revised: 19-04-2024; Approved: 24-04-2024

Abstract. Coral reefs are ecosystems that are sensitive to change. High pressure can cause damage to coral reefs. Monitoring the condition of coral reefs needs to be done to know the current condition. One way that can be used to monitor coral reefs is by utilizing remote sensing. The research was conducted to know the changes in the coral reef area and the factors that influence the changes in the coral reef area in Pari Island, Kepulauan Seribu, DKI Jakarta in the period 2013 to 2022. The research was conducted using Landsat 8 image data from 2013 to 2022. Image data processing was done with an object-based classification method. Coral cover measurements were conducted using the Line Intercept Transect (LIT) method. The results showed a change in coral reef area of 7.02 ha with the condition of live coral cover ranging from 27-43% which is included in the fair category. The results of field measurements show that the condition of water parameters falls into the unsuitable category. The increase in area that occurred was thought to be due to management activities carried out by the Pari Island community and activities carried out by LIPI in 2016, namely conducting coral reef restoration. The decrease in area is partly due to coastal reclamation activities, destructive tourist activities, and parameter conditions.

Keywords: *Area Change, Coral Reef, Landsat 8, Pari Island*

1. INTRODUCTION

Indonesia is known as a maritime country because it has high potential in coastal and marine areas. Various kinds of organisms grow and develop in this region, one of which is coral reefs. According to research conducted by (Hadi et al., 2018), it is estimated that Indonesia has a coral reef area of around 2,5 million hectares. The coral reefs are spread from the eastern to western regions of Indonesian waters. The existence of coral reefs is influenced by various factors. Significant changes in water conditions can be fatal for coral reefs. According to (Nybakken, 1988), factors that limit coral reef growth include temperature, depth, light, salinity, precipitation, and waves.

Pari Island is one of the island groups located in the Thousand Islands, DKI Jakarta. Pari Island has a complex coastal ecosystem because it has three important ecosystems such as mangrove, seagrass, and coral reef ecosystems (Purwanto et al., 2022). The existence of coral reefs makes this island one of the destinations for marine tourism objects. According to data (Rahardjo & Antokida, 2022), in 2021 the total number of tourists visiting Pari Island was 30,351 tourists. One of the marine tourism activities that are often carried out is snorkeling and diving.

Coral reefs in the waters of Pari Island continue to decline in quality. Several previous studies have been conducted to determine the condition of coral reefs on Pari Island, including

(Maulana et al., 2018), which states that the condition of coral reefs on Pari Island is in the moderate to poor category because it has a coral cover of 24,20%-41-64%. Other research has also been conducted by (Manaloe et al., 2020), It is known that the value of live coral cover only ranges from 9,42-53,20% which is included in the good to very poor category. Both studies resulted in different ranges of live coral cover so it is interesting to study considering Pari Island is one of the marine tourism islands that relies on the potential of its coral reefs. Temporal research on the condition and extent of coral reefs on this island is still minimal. Research that is often conducted on coral reefs is still more focused on measuring the condition of coral reefs and mapping corals at one time. Information on the current condition of coral reefs is also needed to be able to manage tourism sustainably.

Remote sensing is one way that can be used to detect the earth's surface area. Remote sensing can be applied to monitoring coastal and marine areas such as detecting the presence of coral reefs. One of the remote sensing satellite images that can be used to map coral reefs is the Landsat 8 satellite image. The process of mapping coral reefs using satellite images requires a classification method to produce accurate information. Object-based image classification methods are currently used as an alternative to classifying objects on the Earth's surface (Mastu et al., 2018).

Coral reefs are ecosystems that are sensitive to change. High pressure around coral reefs can be harmful to corals. Pari Island is one of the islands that has a high level of tourist visits around the Thousand Islands. In addition, Pari Island's proximity to Jakarta Bay is thought to affect the quality of its waters. Therefore, regular monitoring of the condition of coral reefs needs to be done. This study was conducted to determine the changes and causes of changes in the coral reef area in Pari Island in the period of 2013 to 2022

2. MATERIALS AND METHODOLOGY

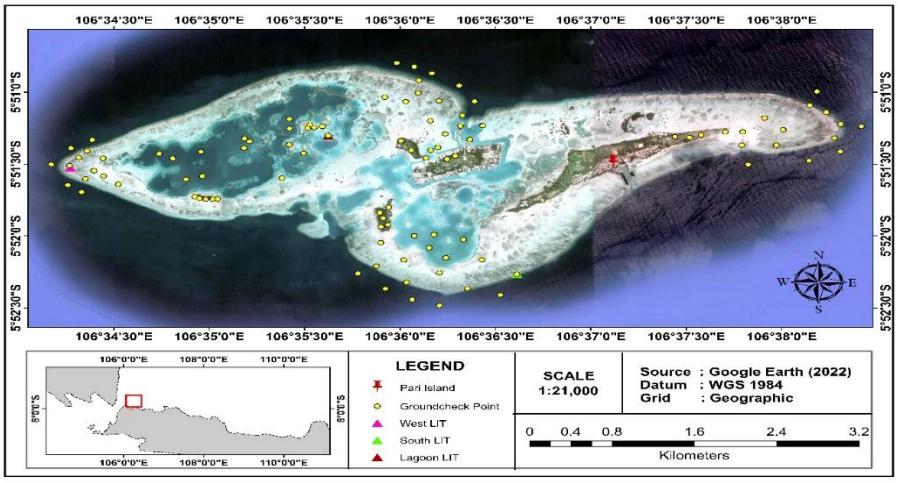

Figure 2-1. Map of The Research Location.

2.1 Locations and Data

The research was conducted around the shallow waters of Pari Island, Thousand Islands Regency, DKI Jakarta (Figure 2-1). The research was conducted on several sides of Pari Island, namely on the north, west, lagoon, south, and east sides. The ground check was conducted on March 13-16, 2023. The ground check process was carried out to obtain data on test points, live coral cover, and water parameter conditions. The ground check process was carried out at 100 observation points spread across the

five stations. Measurements of coral cover and water parameter conditions were only carried out at the west, lagoon, and south stations

Table 2- 1. Detailed Cloud Cover Satellite Image Data

Date Acquired	Cloud Cover
August 25, 2013	1,11
September 13, 2014	0,10
August 31, 2015	0,72
May 13, 2016	2,74
June 17, 2017	3,98
July 6, 2018	0,04
September 11, 2019	0,00
July 27, 2020	1,02
May 11, 2021	1,21
July 1, 2022	6,44

The tools used in this research include a laptop, and several software such as eCognition 9.0, ArcMap 10.8, and Microsoft Excel 2016. Other tools are GPS, basic diving equipment, underwater camera, refractometer, thermometer, secchi disk, roll meter, sabak, and pencil. Meanwhile, the data used consists of primary and secondary data. Primary data consists of temperature, salinity, and brightness data. While secondary data is Landsat 8 Collection 2 Level 2 satellite image data with path 122 row 64. The image data was selected because it has the most minimal cloud cover so that the image conditions are quite clear. The following are the details of the Landsat 8 image data used (Table 2-1).

METHODOLOGY

The field survey method used to validate image processing data is the ground check method. This method is one of the fastest and simplest methods to use. This method only compares the conditions in the field with the results of image processing (Pahleviannur, 2019). Determination of sample points in this study was carried out using a purposive sampling method. The determination of sample points is based on the variability of image processing results. Areas that are detected to have many coral reefs will be a reference in the ground check process for data validation. The following is the flow of research conducted.

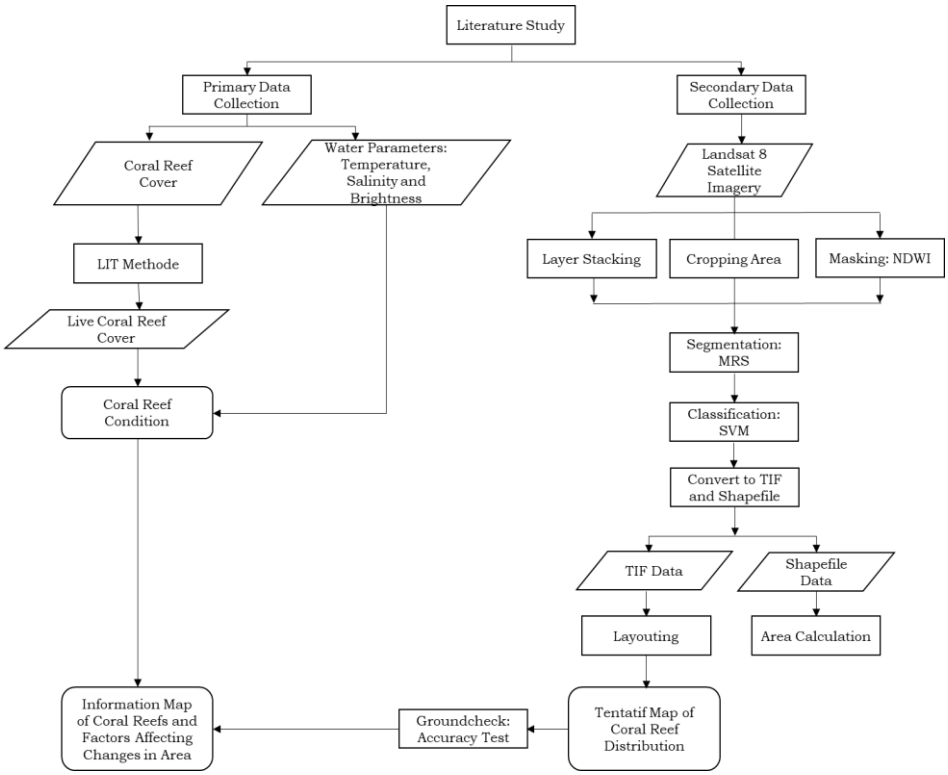

Figure 2- 2. Research Flowchart.

2.2 Satellite Image Data Processing

Landsat 8 Image Download

This study uses data derived from Landsat 8 Collection 2 Level 2 satellite imagery. This data was obtained by downloading it from https://earthexplorer.usgs.gov/. Level 2 data is not pre-processed because this data has been corrected both geometrically and radiometrically.

Image Masking

Image masking is a stage carried out to cover the land so that the land area is separated from the sea and can be distinguished. Image masking is done by utilizing the NDWI (Normalized Difference Wetness Index) index presented in Formula 1. This index can clearly distinguish water bodies and land areas (Lestari et al., 2018).

$$\text{NDWI} = \frac{Green-NIR}{Green+NIR} \ldots\ldots\ldots(1)$$

Image Segmentation

Image segmentation is the stage of creating segments from pixels. This stage aims to divide the image into homogeneous regions (Navulur, 2006). Segmentation is performed using the machine learning multiresolution segmentation (MRS) algorithm. This algorithm uses three parameter values, namely scale, shape, and compactness. In this research, the parameter values used for all images are the same. The values used for the three parameters are scale 30, shape 0.4, and compactness 0.6. The values of these three parameters are obtained through a trial and error process to obtain optimal segment results. The use of the same three parameter values in each year is because the appearance of the image results each year does not show a significant difference. Good segmentation results are needed because segmentation results greatly affect classification results when using object-based classification methods (Purwanto et al., 2022).

Image Classification

The making of classes in this study was carried out based on the results of observations of the characteristics of the research location both using the help of Google Earth and direct observation in the field. Until now, there is no standard standardization in determining the benthic habitat classification scheme (Mastu et al., 2018). The classification scheme made in this study consists of marine, land, coral, non-coral, and lagoon classes. In this study, the naming of classes was made based on the dominant composition in the field. The classification process is carried out using a machine learning algorithm, namely the support vector machine (SVM) contained in the eCognition 9.0 software. This algorithm is quite well used on images that have low texture resolution (Sari & Syah, 2021).

Area Calculation

The results of image classification are calculated for each class. The calculation of coral reef area was carried out to determine how much coral reef area was lost or increased from 2013 to 2022 so that changes in its area could be known and analyzed to determine the factors that influenced changes in its area.

2.4 Field Data Collection

Measurement of Aquatic Parameters

The water parameters measured in this study consisted of temperature, salinity, and water brightness. Measurement of these three parameters is done three times to get accurate results. The results of the measurement of water parameters will then be adjusted to the quality standards contained in KepMen LH No. 51 of 2004 concerning seawater quality standards for marine biota presented in Table 2-2.

Table 2- 2. Seawater Quality Standards for Marine Biota.

No	Parameters	Quality Standard
1	Temperature	28-30°C
2	Salinity	33-34 ppt
3	Brightness	>5 m

Source: (KLH, 2004)

Coral Life Forms

The condition of a coral reef can be determined by its coral cover. Coral cover can be determined by measuring the length of each coral life form. Measurement of coral life forms is done with the Line Intercept Transect (LIT) method. Measurement of live coral cover was carried out on March 14, 2023 starting at 09.00 WIB until completion. Calculation of the percentage of live coral cover (Formula 2) is calculated using a formula that refers to (English et al., 1998) as follows.

$$\%Cover = \frac{Total\ Length\ of\ Category}{Length\ of\ Transect} 100 \ldots\ldots(2)$$

The determination of the coral reef condition category based on coral cover refers to (Hadi et al., 2018) which is presented in Table 2-3 below.

Table 2- 3. Coral Cover Category.

No	%Cover	Category
1	HC≤25	Jelek/*poor*
2	25≤HC≤50	Cukup/*fair*
3	50≤HC≤75	Baik/*good*
4	HC>75	Sangat baik/*excellent*

Source: (Hadi et al., 2018)

Accuracy Test

An accuracy test is conducted to determine the quality of image data processing results. The accuracy test process is carried out using the confusion matrix method. Image interpretation results can be said to be accurate if they have a maximum survey error value of 30% (Semedi, 2019). The results of the calculation of the confusion matrix method are followed by calculating the Kappa value to show the degree of agreement. The calculation of the accuracy test value is carried out by referring to (Hidayat et al., 2018) as follows.

$$OA = \frac{\sum_{i=1}^{k} nii}{n} \ldots\ldots\ldots(3)$$

$$PA = \frac{njj}{n+j} \ldots\ldots\ldots\ldots(4)$$

$$UA = \frac{nii}{ni+} \ldots\ldots\ldots(5)$$

$$Kappa = \frac{N\times\sum_{i=1}^{r} xii - \sum_{i=1}^{r}(xi+ \times x+i)}{N^2 - \sum_{i=1}^{r}(xi+ \times x+i)} \ldots\ldots\ldots(6)$$

k = number of rows in the matrix, n = number of observations made, n_{ii} = number of observations in the i-th column and i-th row, n_{jj} = number of observations in the j-th column and j-th row, n_{i+} = total rows, n_{+j} = total columns, r = number of rows in the matrix, x_{ii} = number of observations in the i-th row and i-th column, x_{i+} and x_{+i} = total of the i-th row and i-th column, N = Number of observations.

This process was carried out at 100 points with 20 points of each class around the Pari Island area, Thousand Islands, DKI Jakarta. The accuracy test was carried out by comparing the processed data with the actual conditions in the field. The image data used as a reference during the ground check process is the result of image data processing in 2022. The selection of this year's data is assumed to represent the conditions when ground check activities are carried out, namely in March 2023 because this data is the data with the closest available time distance. The results of the 2022 data accuracy test are considered to represent the level of accuracy of image processing results in previous years.

Analysis of Area Change

Analysis of the changes that occurred was carried out to determine how much the rate of change occurred. Measurement of the rate of change in coral reef area was carried out by referring to the formula (Putra et al., 2018), as follows.

$$V = \frac{N2-N1}{N1} \text{.....(7)}$$

V = rate of change of area (%), N1 = area in the first year, N2 = area in the n-th year

3. Result and Discussion

Image Processing Results

Image data processing was carried out within a period of 10 years starting from 2013 to 2022. The results of image data processing show that the distribution of coral reefs on Pari Island is generally on the edge of the island. The dominant distribution of coral reefs around the edge of the island causes the coral reefs on this island to be of the fringing reef type (Manaloe et al., 2020). In addition, the distribution of coral reefs is also found in the Lagoon water area. The following is the result of the image classification of coral reef distribution each year shown in Figure 3-1.

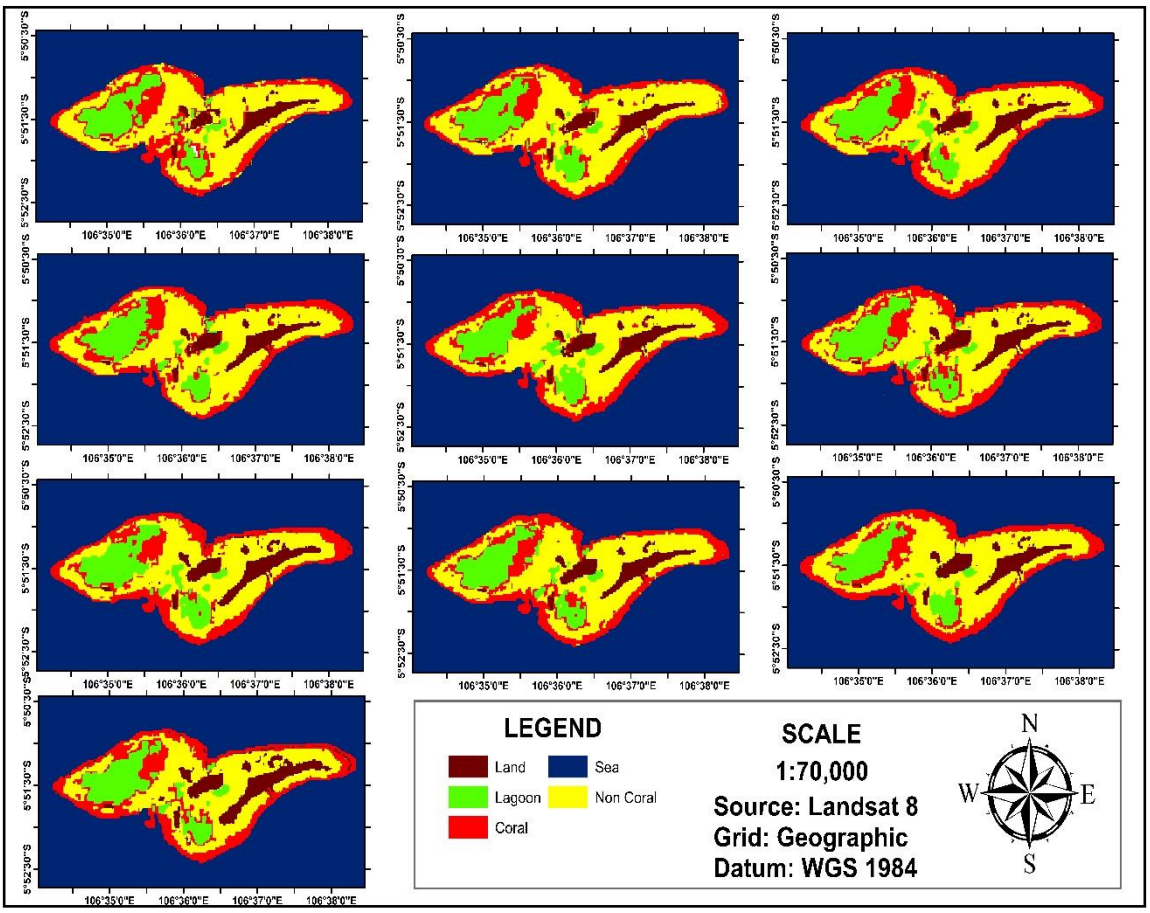

Figure 3-1. Coral Reef Area Change Map.

The results of remote sensing data processing need to be checked for accuracy so that it can be known how much the accuracy of the image is in detecting objects. This research uses image data from 2022 as a reference during the ground check process. The selection of this year's data is assumed to represent the conditions when ground check activities are carried out, namely in March 2023. This study did not conduct an accuracy test on the results of image processing in 2013-2021 due to data limitations. The results of the 2022 data accuracy test are considered to represent the level of image accuracy in previous years so that the extent of coral reef conditions detected is assumed to represent the actual conditions at that time.

The accuracy test calculation was carried out using the confusion matrix method resulting in an overall accuracy value of 74% with a Kappa value of 0,49. This overall accuracy value shows that the level of image accuracy can be said to be following the actual conditions in the field because the value has met the minimum standard of 70% (Semedi, 2019). For comparison, the accuracy of similar research results in an accuracy of 73%. The use of object-based classification on Landsat 8 satellite images using the support vector machine (SVM) algorithm is known to improve accuracy (Wahidin et al., 2015). However, the level of accuracy is also affected by cloud cover conditions in the image, the type of classification algorithm used, and the selection of sample points used for accuracy testing (Green et al., 2000).

Changes in Coral Reef Area

The distribution of coral reefs detected each year fluctuates (Figure 3-2). In 2013 through 2015, the area of coral reefs was 324.81 ha, 327.51 ha, and 329.49 ha, respectively. In 2016, there was a decrease in coral reef area to 317.25 ha. Since 2016, coral reefs have increased again to 321.84 ha in 2017, 322.47 ha in 2018, 326.07 ha in 2019, 331.11 ha in 2020, and 337.23 ha in 2021. Coral reefs again experienced a decrease in area in 2022, which amounted to 331.83 ha.

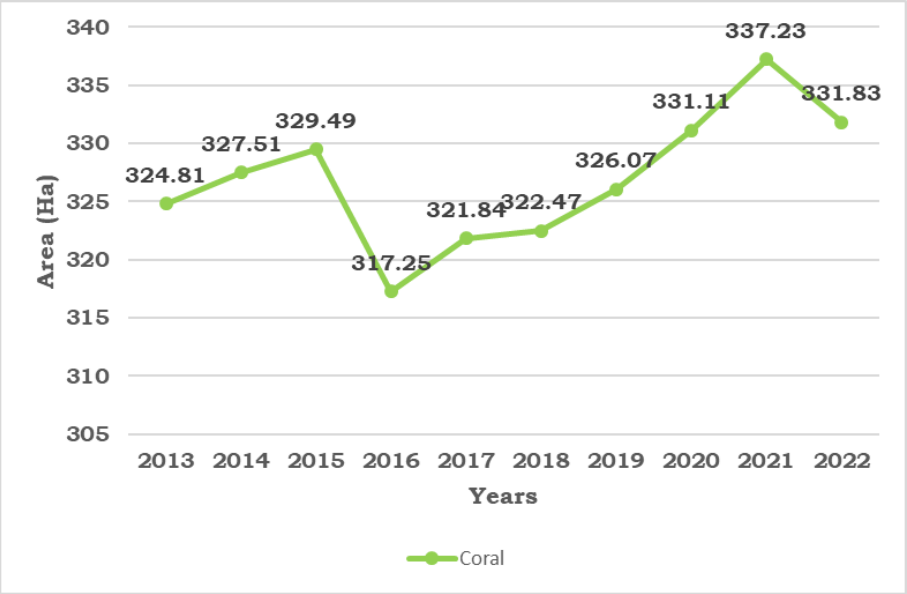

Figure 3-2. Graph of Changes in Coral Reef Area 2013-2022.

From 2013 to 2015, there was a slight change in the coral reef area. Coral reefs increased in area by 4.68 ha. Coral reefs experienced a decrease in area in 2016. The decrease in area that occurred was thought to be due to the impact of the El Nino phenomenon that occurred. In 2016, an El Nino event occurred which increased sea surface temperatures in the Pacific Ocean waters. This was the strongest El Nino phenomenon in history. It is known that there was damage to coral reefs around 40% in the waters of Liukang Loe Island, Flores as a result of the 2016 El Nino phenomenon (Rani et al., 2017).

According to research (Setiawan et al., 2017), the increase in sea surface temperature has occurred since September 2015. This temperature increase occurred until mid-2016 around May with temperatures reaching 30,5°C. As a result, coral colonies in the waters of NTB province experienced bleaching up to 50%. In the following years, coral reefs on Pari Island tended to increase in area. This is due to the start of active marine protected areas (Wouthuyzen & Abrar,

2020). However, the area of coral reefs decreased again in 2022 which was thought to be due to the impact of the increasing number of tourists after the pandemic.

Changes in coral reef areas that occur are inseparable from activities carried out by the surrounding community. Based on information obtained from the surrounding community, there have been coral reef management activities carried out by the community since 1996. In addition, in 2017 a community group engaged in ecosystems and marine sustainability was formed, namely DPL-BM Ekopuri. Various activities are carried out to maintain and improve the condition of coral reefs, such as rehabilitation by planting coral seeds into the substrate that has been made. Other activities are in the form of monitoring where this activity is routinely carried out.

The increase in coral reef area is also thought to be due to the influence of activities carried out by LIPI in 2016, namely conducting a coral reef habitat restoration program. This activity conducts physical and biological restoration by creating artificial reefs, transplanting corals, and restocking biota related to coral reefs to accelerate coral recovery. In addition, the COVID-19 pandemic is also thought to be one of the causes of the increase in coral reef areas in 2020 and 2021. This is because during the pandemic all tourism activities were closed so that coral reefs could recover to better conditions without any interference from human activities such as marine tourism. The rate of change in coral reef area that occurred from 2013 to 2022 is presented in Table 3-1.

Based on the results of the area calculation, it is known that from 2013 to 2022, the rate of change in the coral reef area is 2,16%. This means that in the last 10 years, the area of coral reefs in Pari Island waters has increased. It is known that the area of coral reefs has increased by 7,02 ha. Changes in area that occur in a class are also accompanied by changes in the area of other classes. This means that classes that experience extensive changes do not disappear but change to other classes.

Table 3- 1. Rate of Change of Area.

Class	Rate of Change (%)
Coral	2,16
Non Coral	-14,83
Lagoon	8,65
Land	55,25
Sea	-0,28

Source: Research Results, 2023

Marine tourism needs to have good management so as not to damage the existing ecosystem. Based on observations in the study area, conditions that could potentially lead to a reduction in coral reef area are the existence of coastal reclamation activities into land such as those carried out on the north side of the island. This can result in a reduction in coral reef area. In addition, tourist activities are also believed to be one of the causes of reduced coral reef area. According to research conducted by (Manaloe et al., 2020), tourists have an influence of 7,26% in coral reef damage. In addition, global warming has an impact on increasing seawater temperatures. Increased sea water temperature can affect the condition of coral reefs such as bleaching coral reefs that can lead to death. The El Nino phenomenon that occurred in 2016 is known to affect the condition of coral reefs in Indonesia.

Pari Island is one of the islands in the Thousand Islands which is quite close to Jakarta Bay. The activities of the people of Jakarta will eventually end up in the sea through river flow. Based on research (Nugraha et al., 2020), it is known that Jakarta Bay has been degraded in various ways such as fish abundance, habitat, and aquatic environment. Pollution of Jakarta Bay waters over a long and sustainable period has the potential to reduce water quality levels on Pari Island which can result in low live coral cover.

Coral Reef Cover Condition

Measurements of live coral cover in this study were carried out at three stations, namely the west, lagoon, and south stations. The selection of these three stations is because the results of image processing show this area detected coral reefs and direct observation results also found coral reefs. In addition, this area is an area that is often visited by tourists, especially for snorkeling activities (Corvianawatie & Abrar, 2018; Manaloe et al., 2020). The results of live coral cover measurements can be presented in Table 3-2.

Table 3-2. Percentage Coral Cover.

Station	%Cover
South	43,51%
West	31,65%
Lagoon	27,28%

Source: Research Result, 2023

Measurement of live coral cover in Pari Island produces different coral cover at each station. These differences can be influenced by various factors such as differences in water conditions, differences in location, and the intensity of tourists in the area. The existing live coral cover is known to range from 27-43%. According to (Hadi et al., 2018), live coral cover on Pari Island is included in the fair category.

The southern station is located close to the Marine Protected Area (MPA). This area is managed by P2O LIPI which conducts routine activities in preserving coral reefs. This condition causes the southern station to have a higher percentage of live coral cover than the Lagoon and West stations. The MPA area is an area that is protected from various human activities. According to research (Rauf et al., 2015), live coral cover around the DPL area amounted to 50,1%. Another study, namely (Maulana et al., 2018), the condition of live coral cover at station 7 or around the MPA area has a cover of 41,64% which is included in the medium category.

The Lagoon area has the lowest live coral cover at 27,28%. The Lagoon area is a semi-enclosed water or protected area. This condition results in a lot of sediment trapped, resulting in low water brightness. According to (Daniel & Santosa, 2014), the lagoon area has low brightness and low current conditions, resulting in low coral cover. Based on the results of field measurements, it is known that the brightness of Lagoon waters is the lowest among the other two stations. The lack of waves in this area also results in coral reefs that can be covered by trapped sediments that can cause coral death. In addition, this also has an impact on the lack of oxygen and nutrient sources that are useful for coral reefs.

Research on coral cover in Pari Island in 2013 conducted by (Daniel & Santosa, 2014), resulted in cover ranging from 35-65%. Another study on the state of coral reefs in Pari Island waters was also conducted by (Manaloe et al., 2020), which resulted in coral cover of 9,42-53,2%. Based on the three results of this study, it shows that although coral reefs have increased in area, the condition of coral reef cover is still low so it needs more attention in terms of maintaining coral reefs.

Condition of Water Parameters

The condition of water parameters is one of the important factors that support the life of coral reefs. Good water parameter conditions can support coral reef growth. Slight changes to the condition of water parameters can disrupt the growth of coral reefs considering that coral reefs are ecosystems that are sensitive to change. The measurement results can be seen in Table 3-3.

Table 3- 3. Condition of Water Parameters.

Parameters	Station		
	Lagoon	West	South
Temperature (ºC)	28,53	28,03	28,67
Salinity (ppt)	27,33	25,50	27,00
Brightness (m)	1,78	Up to bottom	3,32

Source: Research Result, 2023

The research resulted in water temperatures in Pari Island ranging from 28,03-28,67ºC. The results showed that the three stations had water temperatures that were still following existing quality standards. Meanwhile, the measured salinity parameter resulted in seawater salinity ranging from 25,50-27,33 ppt. These results indicate that salinity is not suitable for coral reef life because the value is lower than the quality standard of 33-34 ppt. In the brightness parameter, the measurement results show that the brightness in Pari Island waters can be seen to the bottom except in lagoon waters.

Sea water temperature is very influential on coral reefs. Significant temperature changes above the threshold of coral tolerance can cause corals to become stressed and even die. Measurement of temperature parameters in Pari Island waters resulted in temperatures ranging from 28,03 – 28,67ºC. The low-temperature value below the existing quality standards can be caused by various factors. Some of these causes include measurements taken after experiencing rain with weather that is not normal. This is assumed to be one of the causes of low-temperature values. Measurement of temperature parameters around the waters of Pari Island in December 2017 resulted in temperatures ranging from 27-29ºC (Maulana et al., 2018). According to (Nybakken, 1988), the optimal temperature for coral reef growth is 23º-25ºC. However, it is known that coral reefs can tolerate temperatures up to 36º-40ºC.

Seawater salinity is one of the limiting factors for coral reefs, especially for hematite corals. According to (Nybakken, 1988), hematite corals are true marine organisms that can grow optimally at a salinity of 32-35 ppt. Measurement of seawater salinity produces salinity in the range of 25-27 ppt. This seawater salinity value is below the quality standard issued by (KLH, 2004), which is 33-34 ppt. The low salinity of the measurement results is due to measurements taken after rain. The high intensity of rain is due to the implementation of field activities carried out during the first transitional season where in this season there is still frequent rain. Based on the results of research (Erfanda & Widagdo, 2020), seawater salinity will be minimal in the first transitional season and maximum in the east season. In addition, other factors that affect salinity are river flow, rainfall, water circulation patterns, and evaporation (Nontji, 2002).

Water brightness is the amount of light that can penetrate the water column. Brightness affects the growth of coral reefs because the light that enters the water is needed by coral symbionts, namely zooxanthellae, to carry out photosynthesis. Measurements of seawater brightness resulted in maximum brightness at the western and southern stations of 3,32 m. This is because of the area inside the tubir. This is because the area inside the Pari Island shoal has a relatively shallow depth of 1-3 meters. In this area, objects that are at maximum depth can still be seen clearly. Whereas in the lagoon area, light that can penetrate the water column is only able to reach a depth of 1,78 m. Water brightness is usually related to the sedimentation that occurs. The higher

the level of sedimentation, the lower the brightness will be because there will be more substances in the water column that block the incoming light (Daniel & Santosa, 2014). The lagoon region is a semi-enclosed water where the waves are relatively calm. This results in a lot of sediment being deposited so that the brightness of the water is limited. In addition, cloudy weather conditions are also suspected to be one of the causes of not maximizing brightness due to limited sunlight intensity.

4. Conclusion

The results showed changes in the area of coral reefs in the waters of Pari Island, DKI Jakarta. From 2013 to 2022, coral reefs in the waters of Pari Island, DKI Jakarta have increased in area by 7.02 ha with the condition of live coral cover ranging from 27-43% which is included in the moderate category. The results of field measurements show that the condition of water parameters falls into the unsuitable category. The increase in coral reef area is thought to be caused by routine activities carried out by the surrounding community in maintaining and managing coral reefs such as monitoring activities, transplanting corals, and restocking biota associated with coral reefs. Meanwhile, the reduction of reef area that occurred was thought to be due to coastal reclamation activities, destructive marine tourism activities, and unsuitable water parameter conditions.

ACKNOWLEDGEMENTS

On this occasion, the author would like to thank the DPL - BM Ekopuri community group for providing information during the research activities. The author would also like to thank the National Research and Innovation Agency for helping with funding in conducting this research activity. In addition, the authors would also like to thank the Journal Edit and Review Team.

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