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Research Article
Analysis of Changes in the Area of Coral Reef Cover on Samalona Island, Mariso District, Makassar City, South Sulawesi

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Abstract

Background and Objective: Coral reefs on Samalona Island have been under pressure both by natural events and by human (anthropogenic) activities, which have caused area degradation. Research on changes in the area of coral reefs is urgently needed. Hence, the objective of this research was to determine changes in the area of coral reefs from 2017, 2020 and 2023 and to determine the percentage of coral reef cover on Samalona Island. **Materials and Methods:** The method used to determine changes in the area of coral reef is the (unsupervised) method using Sentinel 2-A imagery and processed with ArcMap 10.8 while determining the percentage of coral reef cover (UPT) and processing with CPCe software. **Results:** From the results of image processing, it was found that changes occur every 3 years, namely 0.22 Ha, while the results of the accuracy test from the results of image interpretation with a ground check were 87.44%. The results of the percentage of coral reef cover obtained at station I, amounted to 6.99%, at station II 20.55% and at station III, 29.39%. The percentage of coral reef cover on Samalona Island in poor condition refers to the Decree of the Minister of State for the Environment No. 4 of 2001 concerning standard criteria for damage to coral reefs. **Conclusion:** There is a change in the area of coral reefs on Samalona Island which is heading to a damaged or declining condition every three years from 2017, 2020 to 2023.

Key words: Samalona Island, coral reefs, remote sensing, sentinel 2-A, unsupervised, underwater photo transect

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Coral reef ecosystems are a wealth of marine resources that have several important roles in supporting the survival of various aquatic bodies of water, including as a place to live, a place to find food, a place to live and a breeding ground for most marine biota[1]. In general, the condition of coral reefs has changed little. Caused by anthropogenic factors are factors that affect the condition of corals in Indonesia[2]. Along with population growth, demand for marine products and use of coastal land will increase and this will threaten coastal ecosystems, including coral reefs[3,4].

In general, the tendency for the proportion of live coral cover to decrease, the main cause is global warming where the sea surface temperature increases resulting in a bleaching phenomenon[5]. In Indonesia, the last bleaching phenomenon occurred from 2015 to 2016. However, not all areas of Indonesia experienced severe bleaching. These locations include Pangkep, Spermonde, Ternate and Biak. These locations are thought to be places where the mass of water flows continuously so that it can reduce the impact of increasing sea surface temperatures. The Spermonde Archipelago is an area with relatively high marine biodiversity, however, the live coral cover in the Spermonde Archipelago can be said to be concerning because the intensive level of exploitation of certain groups of organisms has caused a drastic population decline in nature. Samalona Island is one of the islands in the Spermonde Islands group and is administratively included in the Mariso Village area.

Maintaining the existence of the coral reef ecosystem as an important asset in attracting tourists, it is necessary to think about the form of its management and on the other hand it is still used as a tourist area for snorkeling and diving[6]. Therefore, it is necessary to study and analyze the existence of coral reef ecosystems for the purpose of protecting certain areas as conservation areas[7,8]. One of the basics of this interest is the analysis of changes in the area of coral reefs as a first step that can be taken to determine changes in the area of coral reefs every year in the waters of Samalona Island[9]. Mapping is a grouping of a collection of areas that are connected to several geographic locations which include highlands, mountains, resources and population potential that affect socio-culture which has special characteristics in the use of the right scale[10]. The emergency application used to support this activity is ArcGIS. The importance of mapping is to ensure that data and information related to the GIS of an area are relevant. The author's reason for choosing this title is to find out changes in the area of coral reefs from 2017, 2020 to 2023, as well as the percentage of coral reef cover so that countermeasures can be carried out for damaged coral reef ecosystems.

Therefore, the purpose of this study was to analyze changes in the area of coral reefs from 2017, 2020 and 2023 and find out the proportion of coral reef cover on Samalona Island, Mariso District, Makassar City, South Sulawesi.

MATERIALS AND METHODS

Location and time of research: This research was conducted from March to May, 2023 on Samalona Island, Mariso District, Makassar City, South Sulawesi.

Implementation stages: The research was carried out according to the work procedure stages which can be seen in Fig. 1.

Data processing

Image data preparation: This research uses Sentinel 2-A satellite imagery. To download satellite imagery, you can go through NASA's website. Where on this website, at the Path/Row in accordance with the provisions based on the acquisition of Sentinel 2-A satellite imagery based on the Worldwide Reference System (WRS) for the area you want to take the image of and setting the date of image recording and cloud cover made it difficult for us to correct the image.

Satellite image pre-processing: The satellite image pre-processing process is a process in which downloaded images are processed which can later display image results that are ready for further processing such as composite bands, cropping, masking and water column correction (lyzenga algorithm).

Water column correction is the process of identifying basic water objects such as coral reefs, in this process there are several stages, namely:

- **Creation of training areas:** The process of creating training by providing polygons of at least 30 samples with different colors and randomly distributed with the assumption that they represent one island, where the 30 samples will produce statistical values (ROI values)
- **K_iK_j:** At this stage, the processing of image statistical data is carried out into Microsoft Excel 2020 software with the aim of obtaining the K_iK_j value by Lyzenga[11]:

$$K_i/K_j = a+\sqrt{(a^2+1)}$$

Meanwhile, to determine the value of a, use the equation:

$$a = \frac{\text{var}(b_2)\text{-var}(b_3)}{2\text{cov}(b_2, b_3)}$$

Where:

a = Comparison between variance and covariance values

K_i/K_j = Variance and covariance values

- **Equation input (Lyzenga algorithm):** The Lyzenga transformation is carried out with the aim of reducing th effect of the water column, the equation used is the equation of the lyzenga algorithm with the aim of helping to analyze bottom water objects by Lyzenga[11]:

$$Y = (\ln \text{Kanal1} + K_i/K_j \ln \text{Kanal2})$$

where, Y is the result of the Lyzenga algorithm, In (channel 1) is the natural logarithm of the blue channel, K_i/K_j is the value of the variance and covariance in the blue and green channels, In (channel 2) is the natural logarithm of the channel green

- **Basic object classification:** Basic object classification is the process of grouping image data according to the colors displayed in the image data which has a description of each color

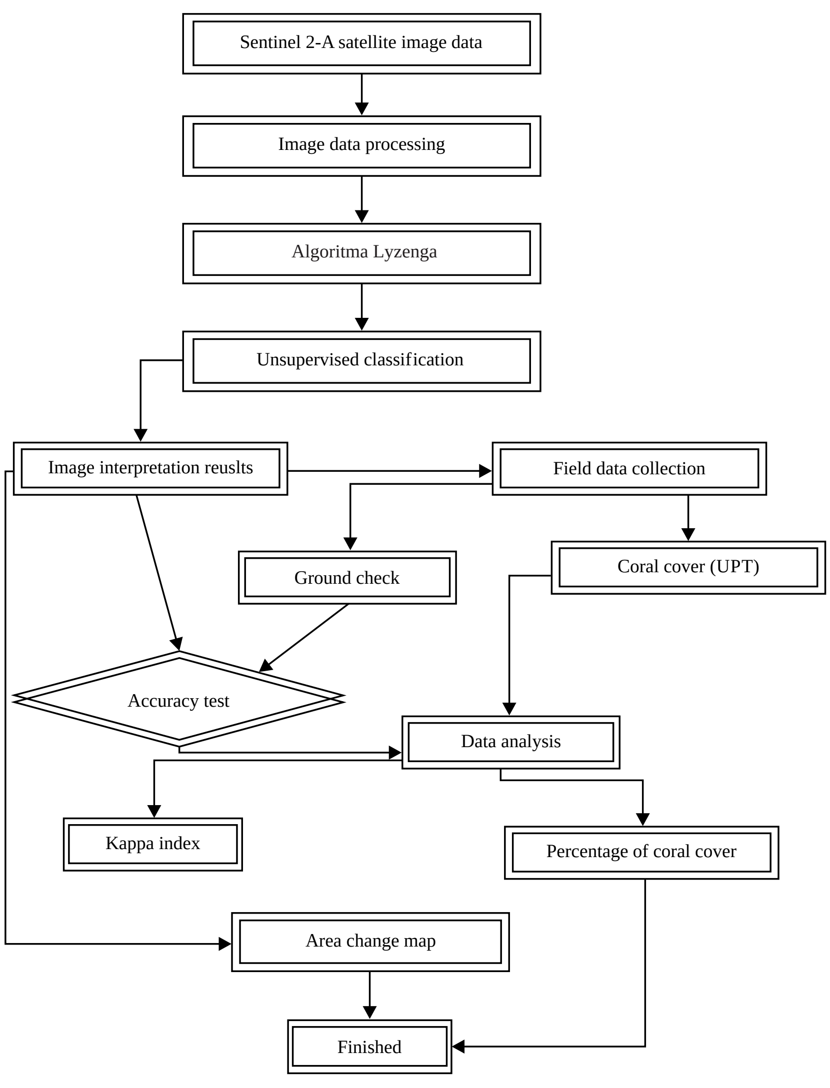


Fig. 1: Stages of seagrass ecosystem mapping work changes in the area of coral reefs
Method used is the Unsupervised method to determine the extent of coral reefs

Determination of sampling points: Determination of sampling points is the process of providing a minimum of 50 points in an image which is randomly distributed through ArcGIS 10.8 software, to determine the number of sampling points depending on the image resolution used.

Ground check: Ground check is one of the methods used to obtain more accurate image data which will be used as a comparison with the results of the image data that has been made.

Analysis of data: The kappa index is a process in which we test ground check results (Supervised) for accuracy and validation of test data with previous image data (unsupervised) by Green *et al.*[12]:

$$\text{Accuracy test (\%)} = \frac{\text{Correct number of data points}}{\text{Total number of data points}} \times 100 = 84\%$$

Percentage of coral cover: Analysis based on photographed photos was carried out using a computer and CPCe 4.1 software as many as 30 random point samples were selected for each photo frame and each point was coded according to the code of each category and the biota and substrate at that random point[13]:

$$\text{Category cover (\%)} = \frac{\text{Number of category points}}{\text{Lots of random points}} \times 100$$

RESULTS

Image classification results for 2017, 2020 and 2023: The results of sentinel 2-A image data processing using the Lyzenga algorithm method with a resolution of 10 m found that the bottom substrate of the waters was classified into 5, namely live coral (green) which includes coral reefs that can grow well, dead coral (yellow) including rabel and coral towards dead and sand (red) includes crushed coral and fine sand and coarse sand. While the black is the land and the blue is the deep sea can be seen in Fig. 2a-c.

Changes in coral area from 2017, 2020 and 2023: Makassar City is the change in the area of live coral reefs, medium coral, dead coral and sand from 2017, 2020 to 2023 which was presented in Fig. 3. The results of changes in the area of coral reefs can be seen in Fig. 4, where the area of live coral was obtained in 2017 of 18.57 ha, but in 2020 it will be 20.12 ha while in 2023 it will be 17.39 ha. The area of live coral decreased by 0.59 ha every three years. Dead coral in 2017 had the highest value of 9.92 ha, in 2020 it had a value of 8.8 ha, while in 2023 it continued to decline with a value of 7.73 ha. Dead coral changes by 1.07 ha every three years. Sand in 2017 had a value of 2.04 ha, in 2020 it reached a value of 1.8 ha and in 2023 it experienced a much higher increase than the previous year with a value of 5.84 ha.

The results of field data analysis with image data obtained can be seen in Table 1. The results of image classification with ground check found 4 classes, namely sand meets sand 7 points, live coral meets live coral 39 points, seagrass meets seagrass 7 points, while dead coral found dead coral, namely 18 points. A total of 80 points with an accuracy level of image data of 71 points while an error in data interpretation is 9 points, from the results obtained the data accuracy is 87.44% which can be said to be accurate or valid data.

As for the results of the image of the distribution of the bottom substrate on Samalona Island which has been tested for accuracy in the form of a map layout can be seen in Fig. 4.

Percentage of coral cover: After taking field data on the condition of coral cover on Samalona Island for 3 days, the percentage of coral cover was obtained as shown in Fig. 5. The basic substrate at point 1 is an abiotic bottom substrate with a cover percentage of 73.27%, dead coral (DC) 13.98%, coral (C) 6.99%, other (OT) 5.72%, TWS 0.07% and non-coral (NC) 0.04%. At point 2 is the basic abiotic substrate with a cover percentage of 42.99%, dead coral (DC) 24.92%, coral (C) 20.55%, other (OT) 7.59%, algae (MA) 3.94 % and TWS 0.09%. At point 3 is the basic abiotic substrate with a cover percentage of 45.03%, coral (C) 29.39%, other (OT) 14.79%, dead coral (DC) 10.48% and algae (MA) 0. 31%.

Table 1: Accuracy test of image classification

	Ground truth					
Classification results	Sand	Seagrass	Live coral	Dead coral	Total (ground truth)	Total (%)
Sand	7	0	0	0	7	100.00
Seagrass	0	7	0	0	7	100.00
Live coral	0	0	39	7	46	84.78
Dead coral	2	0	0	18	20	90.00
Total image	9	7	39	25	80	
Total (%)	77.78	100	100.00	72.00	100	
Total accuracy (%)					87.44	

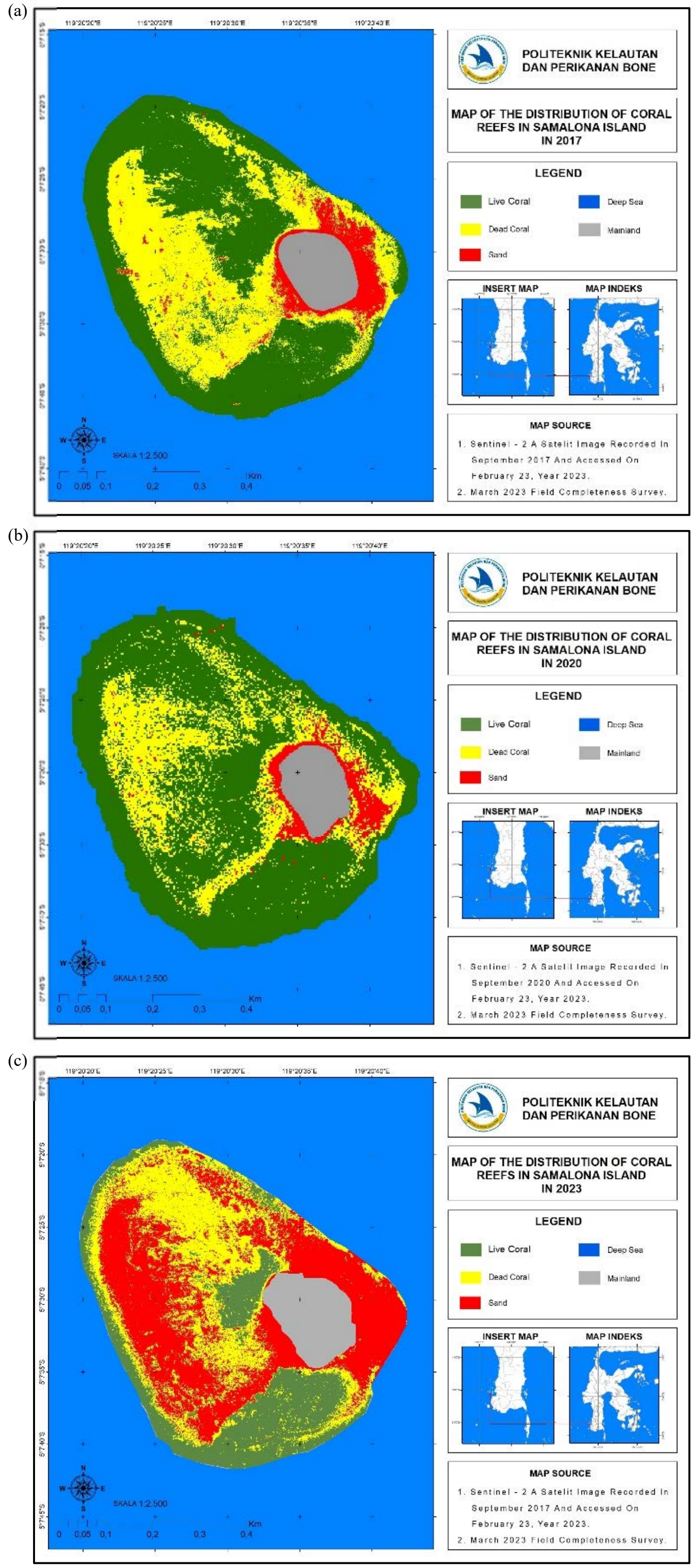


Fig. 2(a-c): Image classification results (a) 2017, (b) 2020 and (c) 2023

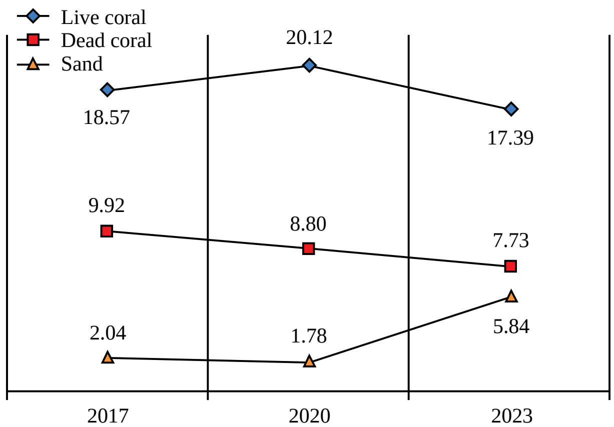


Fig. 3: Change in coral reef area

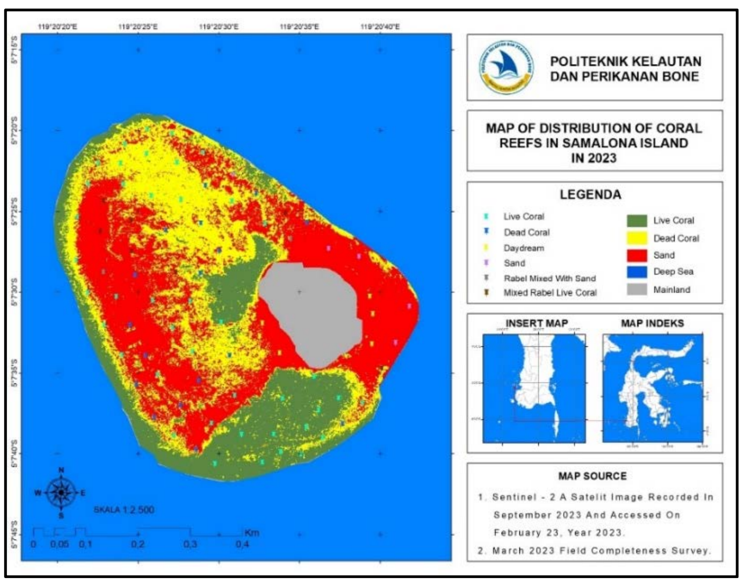
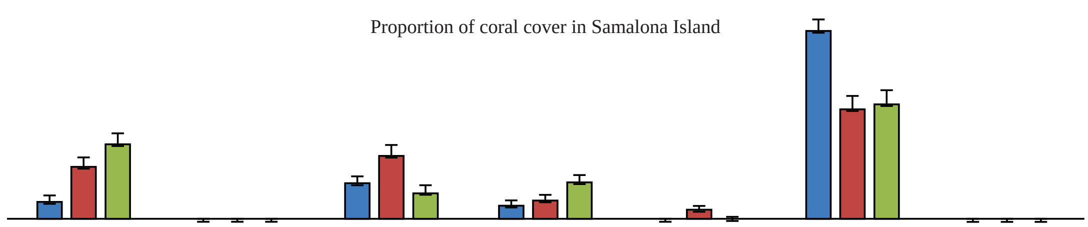


Fig. 4: Samalona island basic substrate distribution map

Proportion of coral cover in Samalona Island



	C	NC	DC	Other	Algae	Abiotik	TWS
Point 1	6.99	0.04	13.98	5.72	0.00	73.27	0.07
Point 2	20.55	0.00	24.92	7.59	3.94	42.99	0.09
Point 3	29.39	0.00	10.48	14.79	0.31	45.03	0.00

Category

Fig. 5: Percentage of coral cover

DISCUSSION

From the results of the data analysis the condition of the coral at point 1 was damaged, in this case, it was classified as bad. This assessment refers to the Decree of the Minister of State for the Environment No. 4 of 2001 concerning standard criteria for damage to coral reefs, where at point 1 the percentage of cover is obtained at 6.99%. This is in accordance with the Decree of the Minister of State for the Environment No. 4 of 2001 where coral conditions are declared bad if the percentage of coral cover ranges from 0 to 24.9%. The condition of the coral at point 2 was damaged with a coral cover of 20.55%, said to be classified as bad. This is based on the Decree of the Minister of State for the Environment No. 4 of 2001 concerning standard criteria for damage to coral reefs, where the reference says that coral conditions are said to be bad if they range from 0 to 24.9%. Point 3, which is 29.39%, is included in the moderate category of coral conditions, this refers to Decree of the Minister of State for the Environment No. 4 of 2001 concerning standard criteria for damage to coral reefs, which in this reference says that coral conditions are classified as moderate if the value ranges from 25-49.9%. From the results of the study, it can be seen that there has been a change in area, namely decreasing every three years starting from 2017, 2020 to 2023. This was in accordance with the condition of coral reefs in Indonesia which are decreasing day by day in line with the results of field surveys by obtaining data on the percentage of coral cover. In Fig. 7, this was confirmed by several marine people who stated that Samalona Island would completely sink into seawater in the future, this was caused by damage to coral reefs so the abrasion that occurred could be very fast[14].

The decline in live coral is thought to be due to damage due to drastic weather changes and the migration of biota to other biota[15]. The change in area occurred not because biota disappeared, but moved to other biota, meaning that lime-producing biota (polyps) can move to other reefs that can still grow[16,17]. This was in line with the results of a study conducted by Hoegh-Guldberg *et al.*[18] which stated that changes in the area of coral reefs are thought to have occurred due to the movement of biota to other biotas as well as environmental factors such as changes in weather and climate, causing coral bleaching to occur. Lack of nutrition for corals can also affect the health of coral reefs[19]. The damage to coral reefs causes coral bleaching caused by increasing levels of carbon dioxide and ocean acidification which can increase coral pressure thereby accelerating the loss of polyps on corals so that the health of coral reefs decreases[20].

In addition to these two factors, there are anthropogenic factors, namely actions taken by humans that can unconsciously affect the condition of corals[21]. The results of research conducted on Pramuka Island by Gerungan and Chia[22] stated that the damage to coral reefs is caused by many human activities, such as underwater diving that pays little attention to the underwater environment and fishing that is not environment friendly. This is exactly the same as what happened on Samalona Island which is one of the visitor-friendly tourist spots. The increase in dead coral and sand that continues to occur due to damage to live coral, is thought to be due to dead coral being deposited into the sand. This is influenced by the color spectrum, where the dead coral has not turned into sand but is detected by the image close to the sand, this is classified as sand by the image. To produce correct results, an objective analysis is required from the observer and it would be better if the observer had special competence regarding the things to be observed. To obtain precise and radiometrically correct results, it is necessary to carry out geometric corrections and observe GCP soil control points in the field[23]. In addition to remote sensing errors in interpreting images, the increase in dead coral is in line with the decrease in live coral which is thought to be caused by the same factors as the changes that occur in live coral[24].

This is reinforced by some literature which states that the level of accuracy of data can be said to be valid if the value reaches 80%[25]. In addition, it is also reinforced by research conducted by Scholkmann *et al.*[26] from the results of his research using the same method and the same data analysis, which stated that the level of truth and accuracy in interpreting images (classification) is >85%. The quality level of a map is not based on the results of a ground check, where the overall value of the results obtained, namely the level of accuracy of the map, cannot be directly used as a guideline for assessing map quality. The number of predetermined classes is not directly related to the accuracy test (ground check)[27].

The high abiotic bottom substrate is due to decreased coral cover caused by strong currents and sedimentation which can damage corals. In addition, currents also play an important role in cleaning dirt or sand that settles on corals. The existence of sufficient currents greatly affects corals because they can clean sand and other objects covering coral polyps, the availability of food for microorganisms, facilitating circulation and sufficient oxygen, however, currents that are too large can have an adverse effect because they can break corals[28]. High sedimentation causes agitation in the waters so that it blocks sunlight from entering the bottom of the waters and this condition can affect the growth of coral reefs and

Sunlight has a major effect on the survival of coral reefs, this is related to the need for symbionts (zooxanthellae) to photosynthesize[29]. The damage that occurred was suspected to be due to natural factors such as sedimentation that occurred caused by the flow of the Tallo River and anthropogenic factors. Sedimentation has an impact on coral reefs, both mild and moderate impacts, where the higher the sedimentation rate, the lower the coral cover[30].

High sedimentation causes turbidity in the waters that blocks the entry of sunlight to the bottom of the waters and this condition can affect the growth of coral reefs and Sunlight has a major effect on the survival of coral reefs, this is related to the need for symbionts (zooxanthellae) to photosynthesize[31]. Lae-lae Island is one of the islands included in the Spermonde cluster that has damaged coral reefs compared to other islands, namely (Salomon Island and Bone Batang Island), which greatly influenced the damage caused by being close to the mainland and from the Jeneberang River where this river carries sediment in the form of silt and clay to the north, namely around lae-lae Island. Along with the density of people and development that continues to occur in the city of Makassar, it greatly affects the total suspended solid (TSS) of the Jeneberang and Tallo Rivers. The existence of construction of facilities and infrastructure that occurs around the Jeneberang River can cause sedimentation to the north of the coast, resulting in consequences that can damage the beach[32]. Human activities indirectly have a negative impact on corals such as throwing anchors, fishing that is not environmentally friendly, pollutants from ship engines and waste from tourism activities and other activities. Damage to coral reefs can be caused by marine tourism factors which can pose a risk to coastal habitats, both directly such as bombings and indirectly such as changing seasons[33]. Furthermore, the condition of coral reefs was pressured by humans who were not aware of what they were doing, such as throwing garbage in the sea, taking coral reefs for development needs and catching fish that were not environmentally friendly.

Results recommended that by using high-resolution satellite imagery such as WorldView-2 and WorldView-3 remote sensing errors in interpreting coral reef classification images can be avoided.

CONCLUSION

The change in the area of coral reefs on Samalona Island from 2017, 2020 to 2023 was 0.22 ha, where there was a change of 0.59 ha of live coral, 1.09 ha of dead coral and 1.90 ha of sand and the percentage of coral cover at station 1 experienced damage with a cover percentage of 6.99%, in this case, is classified as bad, at station 2 there is also damage with a cover percentage of 20.55%, in this case, including bad coral conditions and at station 3 there is damage with a percentage of coral cover of 29.39%, in this case, belong to the medium category. It can be seen that there is a change in the area leading to damaged or declining conditions every three years from 2017, 2020 to 2023, while the total accuracy of the data is 87.44% which can be said to be accurate or valid so that it can be used as basic substrate distribution data waters on Samalona Island. From the results of the study, the degradation of coral reefs in the waters of Samalona Island is caused by a combination of natural factors and human activity factors (anthropogenic). Disturbances that occur in coral reef ecosystems can result in changes in the area of living coral reefs in the waters of Samalona Island.

SIGNIFICANCE STATEMENT

Coral reefs and their marine biota have high potential economic value, but coral reef ecosystems are vulnerable to degradation. This research found that there are changes in the area of coral reefs that occur on Samalona Island every three years, namely 2017, 2020 to 2023. From the results of the study it can be seen that there is a change in the area of coral reefs leading to a damaged or declining condition in Samalona Island every three years from 2017, 2020 to 2023. The main reasons of this damage are human activities and construction sites which need to be control by high authorities to avoid this damage.

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REFERENCES

1. Arthington, A.H., N.K. Dulvy, W. Gladstone and I.J. Winfield, 2016. Fish conservation in freshwater and marine realms: Status, threats and management. Aquat. Conserv: Mar. Freshwater Ecosyst., 26: 838-857.
2. Bachtiar, I. and T.A. Hadi, 2019. Differential impacts of 2016 coral bleaching on coral reef benthic communities at Sekotong Bay, Lombok Barat, Indonesia. Biodiversitas, 20: 570-575.

3. Hernández-Delgado, E.A., 2015. The emerging threats of climate change on tropical coastal ecosystem services, public health, local economies and livelihood sustainability of small islands: Cumulative impacts and synergies. Mar. Pollut. Bull., 101: 5-28.
4. Martyr-Koller, R., A. Thomas, C.F. Schleussner, A. Nauels and T. Lissner, 2021. Loss and damage implications of sea-level rise on small island developing states. Curr. Opin. Environ. Sustainability, 50: 245-259.
5. Putra, R.D., M.P. Suhana, D. Kurniawn, M. Abrar and R.M. Siringoringo *et al*., 2019. Detection of reef scale thermal stress with aqua and terra MODIS satellite for coral bleaching phenomena. AIP Conf. Proceed., Vol. 2094. 10.1063/1.5097493.
6. Shokri, M.R. and M. Mohammadi, 2021. Effects of recreational SCUBA diving on coral reefs with an emphasis on tourism suitability index and carrying capacity of reefs in Kish Island, the Northern Persian Gulf. Reg. Stud. Mar. Sci., Vol. 45. 10.1016/j.rsma.2021.101813.
7. Graham, N.A.J., J.P.W. Robinson, S.E. Smith, R. Govinden, G. Gendron and S.K. Wilson, 2020. Changing role of coral reef marine reserves in a warming climate. Nat. Commun., Vol. 11. 10.1038/s41467-020-15863-z.
8. Stuart-Smith, R.D., C.J. Brown, D.M. Ceccarelli and G.J. Edgar, 2018. Ecosystem restructuring along the great barrier reef following mass coral bleaching. Nature, 560: 92-96.
9. Teichberg, M., C. Wild, V.N. Bednarz, H.F. Kegler and M. Lukman *et al*., 2018. Spatio-temporal patterns in coral reef communities of the spermonde archipelago, 2012-2014, I: Comprehensive reef monitoring of water and benthic indicators reflect changes in reef health. Front. Mar. Sci., Vol. 5. 10.3389/fmars.2018.00033.
10. Terry, J.P., G.J.H. Oliver and D.A. Friess, 2016. Ancient high-energy storm boulder deposits on Ko Samui, Thailand, and their significance for identifying coastal hazard risk. Palaeogeogr. Palaeoclimatol. Palaeoecol., 454: 282-293.
11. Lyzenga, D.R., 1981. Remote sensing of bottom reflectance and water attenuation parameters in shallow water using aircraft and Landsat data. Int. J. Remote Sens., 2: 71-82.
12. Green, E.P., P.J. Mumby, A.J. Edwards and C.D. Clark, 2000. Remote Sensing Handbook for Tropical Coastal Management. UNESCO Publishers, Paris, ISBN: 92-3-103736-6, Pages: 216.
13. Brower, J.E., J.H. Zar and C.N. von Ende, 1990. Field and Laboratory Methods for General Ecology. 3rd Edn., WM. C. Brown Publishers, USA, ISBN: 0-697-05145-5, Pages: 237.
14. Qin, Q., Q. Meng, H. Yang and W. Wu, 2021. Study of the anti-abrasion performance and mechanism of coral reef sand concrete. Constr. Build. Mater., Vol. 291. 10.1016/j.conbuildmat.2021.123263.
15. Glynn, P.W., A.B. Mones, G.P. Podestá, A. Colbert and M.W. Colgan, 2017. El Niño-Southern Oscillation: Effects on Eastern Pacific Coral Reefs and Associated Biota. In: Coral Reefs of the Eastern Tropical Pacific: Persistence and Loss in a Dynamic Environment, Glynn, P.W., D.P. Manzello and I.C. Enochs (Eds.), Springer, Dordrecht, Netherlands, ISBN: 978-94-017-7498-7, pp: 251-290.
16. Stacey, N., E. Gibson, N.R. Loneragan, C. Warren and B. Wiryawan *et al*., 2021. Developing sustainable small-scale fisheries livelihoods in Indonesia: Trends, enabling and constraining factors, and future opportunities. Mar. Policy, Vol. 132. 10.1016/j.marpol.2021.104654.
17. Aswani, S., 2019. Perspectives in coastal human ecology (CHE) for marine conservation. Bio. Conserv., 236: 223-235.
18. Hoegh-Guldberg, O., E.S. Poloczanska, W. Skirving and S. Dove, 2017. Coral reef ecosystems under climate change and ocean acidification. Front. Mar. Sci., Vol. 4. 10.3389/fmars.2017.00158.
19. Peters, E.C., 2015. Diseases of Coral Reef Organisms. In: Coral Reefs in the Anthropocene, Birkeland, C. (Ed.), Springer, Dordrecht, Netherlands, ISBN: 978-94-017-7248-8, pp: 147-178.
20. Glynn, P.W. and D.P. Manzello, 2015. Bioerosion and Coral Reef Growth: A Dynamic Balance. In: Coral Reefs in the Anthropocene, Birkeland, C. (Ed.), Springer, Dordrecht, Netherlands, ISBN: 978-94-017-7248-8, pp: 67-97.
21. Leinfelder, R., 2013. Assuming responsibility for the anthropocene: Challenges and opportunities in education. RCC Perspect., 3: 9-28.
22. Gerungan, A. and K.W. Chia, 2020. Scuba diving operators' perspective of scuba diving tourism business in Nusa Penida, Indonesia. J. Outdoor Recreat. Tourism, Vol. 31. 10.1016/j.jort.2020.100328.
23. Ramzi, A.I. and M.A.L. El-Bedawi, 2019. Towards integration of remote sensing and GIS to manage primary health care centers. Appl. Comput. Inf., 15: 109-113.
24. Haya, L.O.M.Y. and M. Fujii, 2017. Mapping the change of coral reefs using remote sensing and *in situ* measurements: A case study in Pangkajene and Kepulauan Regency, Spermonde Archipelago, Indonesia. J. Oceanogr., 73: 623-645.
25. Alves, M.M., L. Pirmez, S. Rossetto, F.C. Delicato and C.M. de Farias *et al*., 2017. Damage prediction for wind turbines using wireless sensor and actuator networks. J. Network. Comput. Appl., 80: 123-140.
26. Scholkmann, F., S. Kleiser, A.J. Metz, R. Zimmermann, J.M. Pavia, U. Wolf and M. Wolf, 2014. A review on continuous wave functional near-infrared spectroscopy and imaging instrumentation and methodology. NeuroImage, 85: 6-27.

27. Liu, L., W. Ouyang, X. Wang, P. Fieguth, J. Chen, X. Liu and M. Pietikäinen, 2020. Deep learning for generic object detection: A survey. Int. J. Comput. Vision, 128: 261-318.
28. Roberts, J.M. and S.D. Cairns, 2014. Cold-water corals in a changing ocean. Curr. Opin. Environ. Sustainability, 7: 118-126.
29. Nelson, H.R. and A.H. Altieri, 2019. Oxygen: The universal currency on coral reefs. Coral Reefs, 38: 177-198.
30. Morgan, K.M., M.A. Moynihan, N. Sanwlani and A.D. Switzer, 2020. Light limitation and depth-variable sedimentation drives vertical reef compression on turbid coral reefs. Front. Mar. Sci., Vol. 7. 10.3389/fmars.2020.571256.
31. Hughes, D.J., R. Alderdice, C. Cooney, M. Kühl, M. Pernice, C.R. Voolstra and D.J. Suggett, 2020. Coral reef survival under accelerating ocean deoxygenation. Nat. Clim. Change, 10: 296-307.
32. Suhardi, 2021. Analysis of the center point of Indonesia (CPI) reclamation policy of Makassar City in the environmental political perspective. Int. J. Multicult. Multireligious Understanding, 8: 12-23.
33. Laurans, Y., N. Pascal, T. Binet, L. Brander and E. Clua *et al*., 2013. Economic valuation of ecosystem services from coral reefs in the South Pacific: Taking stock of recent experience. J. Environ. Manage., 116: 135-144.