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Types of Life Forms and Cover of Coral Reefs in the Waters of Tanjung Sauh Island, Batam City, Kepulauan Riau Province, Indonesia

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ABSTRACT

According to the Coordinating Minister for Economic Affairs Regulation Number 21 of 2022, which amends the List of National Strategic Projects, an industrial estate development has been designated as one of the national strategic projects, located on Tanjung Sauh Island, Batam City, Riau Islands Province, Indonesia. The development of this industrial estate has the potential to damage the coastal environment, particularly the coral reefs, which are vital ecosystems providing both biodiversity support and coastal protection from erosion. This study aimed to identify the types of coral reef life forms and to determine the percentage of live coral reef cover in the waters surrounding Tanjung Sauh Island. The observation method used was the Line Intercept Transect, conducted at a minimum depth of 3 meters under typical field water conditions. Data collection was carried out through random sampling at four observation sites over three days, from August 6 to August 8, 2023. The coordinates for the observation sites were: Observation location 1 (01.06145°N, 104.16140°E), Observation location 2 (01.05720°N, 104.18027°E), Observation location 3 (00.99408°N, 104.16265°E), and Observation location 4 (00.99408°N, 104.16265°E). The results revealed the types of hard coral reefs found at the observation sites, including Acropora Submassive, Acropora Encrusting, Acropora Tabulate, Acropora Branching, Coral Massive, Coral Encrusting, Coral Submassive, Coral Mushroom, and Coral Branching. The coral reef cover in these locations ranged from 16.30 to 45.74%. This research is expected to serve as a reference for future policy development to ensure a balance between economic growth and the preservation of the marine environment on Tanjung Sauh Island.

INTRODUCTION

Batam City is an area that has been developed by the Indonesian government as an industrial area since 1973. Batam has been designated as a National Strategic Area (KSN) in the National Spatial Plan **(Government Regulation of the Republic of Indonesia Number 13 of 2017 concerning Amendments to Government Regulation of the**

Republic of Indonesia Number 26 of 2008 concerning National Spatial Plan) and in **Presidential Regulation of the Republic of Indonesia Number 87 of 2011** concerning Spatial Plan for Bintan Area, Batam Area, and Karimun Area. In addition, the Presidential Regulation of the Republic of Indonesia on the National Medium-Term Development Plan for 2020-2024 also states that the Batam Free Trade and Free Port Area is a priority project to be developed in that period, including the development of strategic areas and natural resource-based processing industries, such as plantations, fisheries, mining, and aerospace industries. One of the islands in Batam City planned for industrial estate development is Tanjung Sauh Island. Although industrial estates can provide economic and technological benefits, the development of industrial estates on Tanjung Sauh Island has the potential to cause damage to the coastal environment, especially to coral reefs. **Irawan (2013)** stated that direct factors that can cause coral damage are destructive fishing, pollution, sedimentation, marine tourism and coral extraction for building and changes in water quality.

Tanjung Sauh Island is located in Batam City, Riau Islands Province, Indonesia, and is in the northern part of Batam, which is one of the largest islands in the Riau Islands, with many small islands around it. The island also has a fairly rich ecosystem. One of the marine ecosystems found in the waters of Tanjung Sauh Island is coral reefs. The coral reefs around the island provide habitat for various species of fish and other marine organisms. Coral reef biodiversity is very important for the balance of the local ecosystem. **Zamdial *et al*. (2020)** stated that the potential biodiversity in the area must be preserved, protected, maintained, and managed properly so that it can function optimally and sustainably.

Countless coral reefs are found in Indonesian waters, which have a tropical climate, very supportive of the survival and growth of coral reefs **(Fadli *et al*., 2013)**. **Veron (2002)** stated that Indonesia has the highest coral reef biodiversity in the world, with approximately 590 species of hard corals. More than 95% of coral species recorded in the Coral Triangle Center are found in Indonesia **(Veron *et al*., 2009)**. Coral reefs have various important functions, in terms of ecological, economic, and social. **Widhiatmoko *et al*. (2020)** stated that coral reefs are important habitats with biodiversity that have high economic value and provide significant benefits to society. Coral reefs also have functions as habitats for high-value marine biota, as recreational areas, both for coastal and underwater tourism, and as a refuge for various rare biota **(Nybakken, 2001; Suharsono, 2008)**. Coral reef ecosystems are also strongly linked to the tourism industry and the circulation of money, especially on small islands **(Kurniawan *et al*., 2019)**. **Puspitasari *et al*. (2016)** also stated that coral reef ecosystems support marine tourism industry activities in Indonesia, provide jobs, and open significant business opportunities.

Based on the description above, this study aimed to (1) determine the types of coral reef life forms that exist in the waters of Tanjung Sauh Island, and (2) determine the percentage of live coral reef cover in the waters of Tanjung Sauh Island. The information

obtained from this research is expected to provide insight for the local government and community regarding the condition of coral reefs in the waters of Tanjung Sauh Island, as well as providing a consideration in making more sustainable policies in the future to maintain a balance between economic development and preservation of the marine environment on Tanjung Sauh Island.

MATERIALS AND METHODS

Time and place of research

Data collection was conducted from August 6, 2023 to August 8, 2023 in the waters of Tanjung Sauh Island, Batam City, Riau Islands Province. The method used for data collection was random sampling. Data were collected from four (4) observation locations (Table 1).

Table 1. Research data collection locations

No.	Data Collection Location	Coordinate Point
1.	Site 1	01.06145°N, 104.16140°E
2.	Site 2	01.05720°N, 104.18027°E
3.	Site 3	00.99408°N, 104.16265°E
4.	Site 4	01.04427°N, 104.15503°E

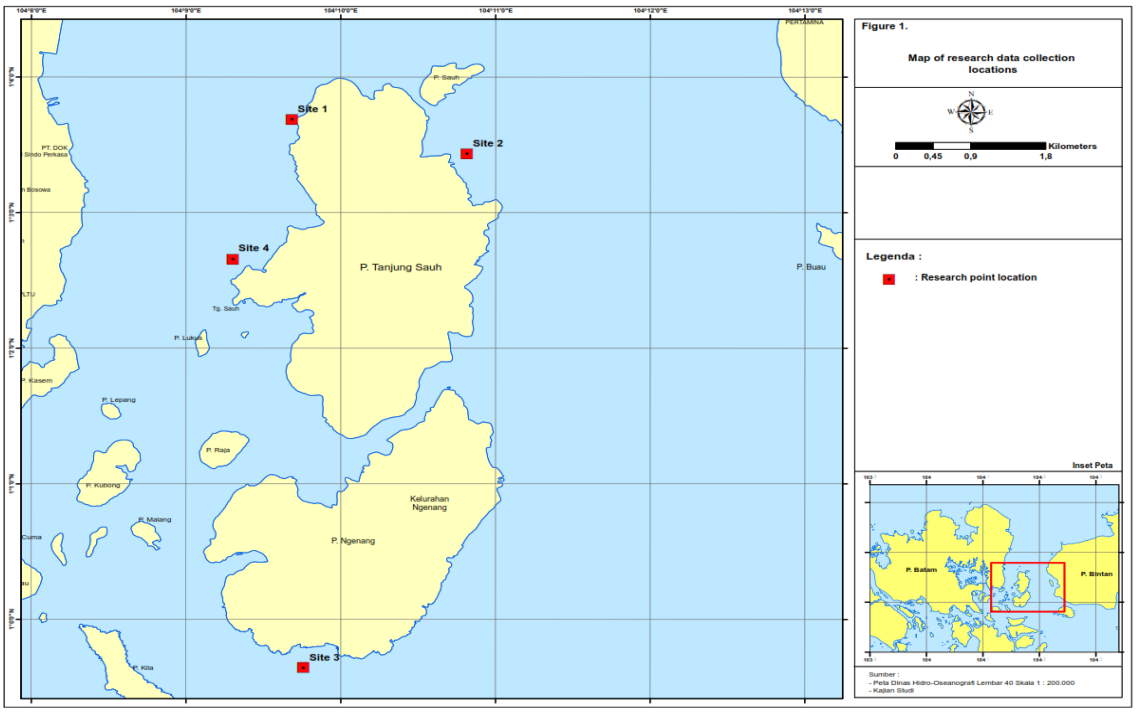


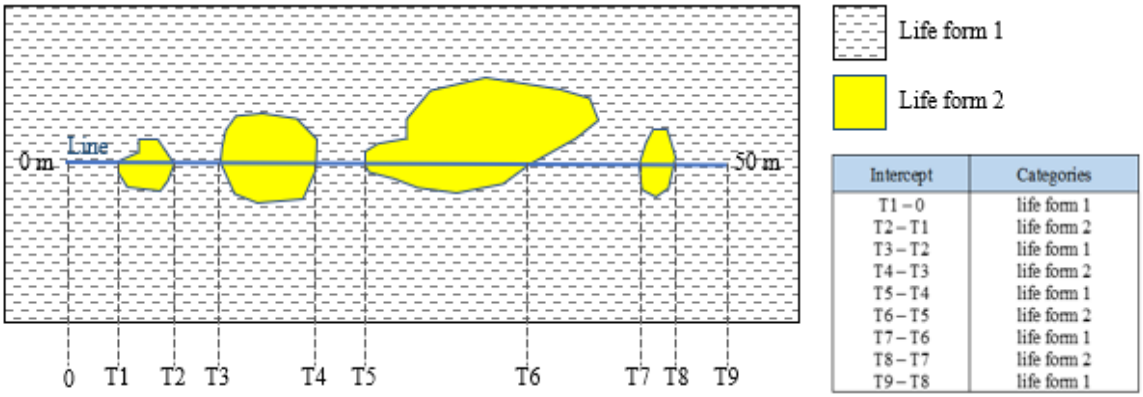
Fig. 1. Map of research data collection locations

Research method

The data collection technique used in this research is direct observation using the Line Intercept Transect (LIT) method. The observation method is a research method

carried out by conducting observational studies to record all parameters and relevant aspects, as well as seeing directly things that can support the smooth implementation of the research. **Hardani (2020)** states that observation is a technique or way of collecting data by observing ongoing activities. While the Line Intercept Transect (LIT) method is a technique used to monitor and evaluate the condition of coral reefs by measuring the length of the line traveled by coral reefs in a certain area. Measurements are made by drawing a line (transect) and recording the type and number of organisms along the line. According to **Sarbini *et al*. (2016)**, the advantages of this method are that it requires little equipment, is relatively simple in its application, and is an accurate and efficient technique for obtaining quantitative data on coral cover.

Observations were made in four locations by installing a 50m roller meter with a minimum depth of 3m and adjusted to the water conditions. The installation of transects or roller meters was adjusted parallel to the shoreline **(English *et al*., 1994)**. After the roller meter was installed, data collection of coral reefs located along the transect was carried out using SCUBA or diving equipment. Data collection was carried out by recording each coral reef life form along or past the transect on the data collection sheet that had been prepared. The selection of this method is because the LIT method can describe the structure of the coral reef community by looking at the condition of live and dead coral cover, substrate shape, dead coral, and growth form.



Intercept	Categories
T1 – 0	life form 1
T2 – T1	life form 2
T3 – T2	life form 1
T4 – T3	life form 2
T5 – T4	life form 1
T6 – T5	life form 2
T7 – T6	life form 1
T8 – T7	life form 2
T9 – T8	life form 1

Fig. 2. Coral reef life form data recording model

Data analysis

Coral reefs life form was identified directly based on specific characteristics. This identification process was supported by a coral reef identification guide. According to **English *et al*. (1998)**, the formula for calculating the percentage of coral reef cover is done by comparing the size of the substrate cover with the length of the transect line, using the following equation:

$$L = \frac{Li}{N} \times 100$$

Description:

L = Percentage cover

Li = Total length of life form

N = Transect length

The condition of coral reef cover from the observation was then compared with the **Decree of the Minister of Environment of the Republic of Indonesia Number 4 of 2001** concerning Quality Standard Criteria for Coral Reef Damage (Table 2).

Table 2. The standard criteria for coral reef damage according to the Decree of the Minister of Environment of the Republic of Indonesia Number 4 of 2001

Live Coral Cover (%)	Coral Reef Damage Standard Criteria (in %)
75 – 100	Excellent
50 – 74.9	Good
25 – 49.9	Medium Damaged
0 – 24.9	Bad Damaged

RESULTS

Types of coral reef life forms

Based on the results of observations conducted at the research data collection sites, varying conditions were observed. These conditions at each data collection point are presented in Table (3).

Table 3. Visual observation results in the research location

Data Collection Location	Description of Data Collection Location	Image Description of Data Collection Location
Site 1	Site 1 is located near Tanjung Sauh village, on the west side of Tanjung Sauh, and directly facing the roro boat shipping lane from Tanjung Uban to Punggur, Batam. The water condition at this location is quite calm with not too strong current. Visibility at location 1 is very poor, less than 1 meter. The dominant bottom substrate consists of dead coral and silt.	
Site 2	Site 2 is located on the eastern side of Tanjung Sauh Island and directly opposite Bintan Island. The water conditions at this location are calm and the currents are not strong. Visibility at location 2 is very poor, less than 1 meter. The dominant bottom substrate consists of dead coral, hard coral, and silt.	

Data Collection Location	Description of Data Collection Location	Image Description of Data Collection Location
Site 3	Site 3 is located on the south side of Tanjung Sauh Island and directly faces the fast boat shipping lane from Bintan Island to Batam Island. The water conditions at this location are quite calm with not too strong currents. Visibility at Site 3 is very poor, less than 1 meter. The dominant bottom substrate consists of live and dead corals.	
Site 4	Site 4 is located on the western side of Tanjung Sauh Island and directly facing the roro boat shipping lane from Tanjung Uban to Punggur, Batam. The water condition at this location is quite calm with not too strong current. Visibility at location 4 is very poor, less than 1 meter. The dominant bottom substrate consists of dead corals and rocks.	

The results showed that the types of life forms of hard coral cover found in location 1 consisted of 6 life forms of hard corals cover consisting of Acropora Submassive (ACS), Acropora Encrusting (ACE), Coral Massive (CM), Coral Encrusting (CE), Coral Submassive (CS) and Coral Mushroom (CMR). The composition of hard corals cover at site 1 is shown in Fig. (3).


Fig. 3. Some life forms of coral reefs and associated substrate types at site 1

The types of hard coral cover life forms found at site 2 consisted of 8 life forms of hard coral cover consisting of Acropora Tabulate (ACT), Acropora Encrusting (ACE), Acropora Submassive (ACS), Coral Massive (CM), Coral Encrusting (CE), Coral Submassive (CS) and Coral Mushroom (CMR). The composition of hard corals cover at site 2 is shown in Fig. (4).

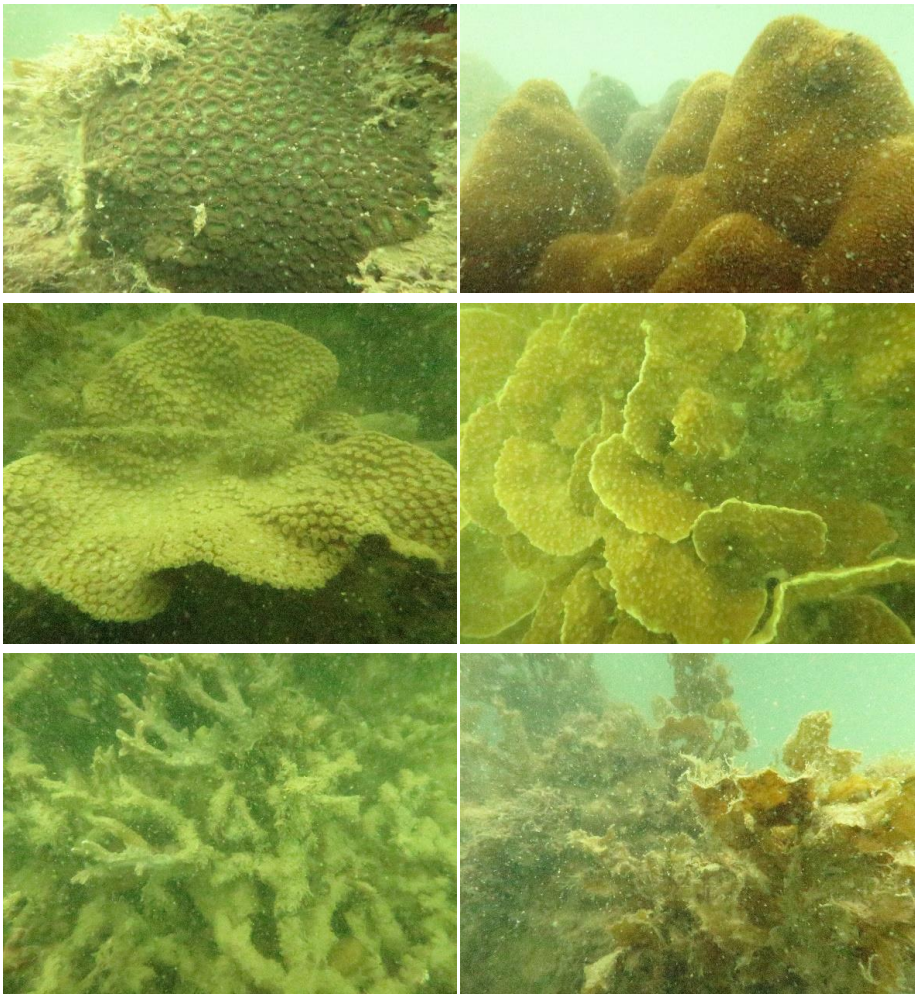


Fig. 4. Some life forms of coral reefs and associated substrate types at site 2

The types of hard coral cover life forms found at site 3 consisted of 7 life forms of hard corals cover consisting of Acropora Tabulate (ACT), Acropora Encrusting (ACE), Acropora Submassive (ACS), Coral Massive (CM), Coral Encrusting (CE), Coral Submassive (CS) and Coral Mushroom (CMR). The composition of hard corals cover at site 3 is shown in the following Fig. (5).

Fig. 5. Some life forms of coral reefs and associated substrate types at site 3

The types of hard coral cover life forms found at site 4 consisted of 5 life forms of hard corals cover consisting of Acropora Encrusting (ACE), Coral Branching (CB), Coral Massive (CM), Coral Encrusting (CE), Coral Submassive (CS). The composition of hard corals cover at site 4 is shown in Fig. (6).

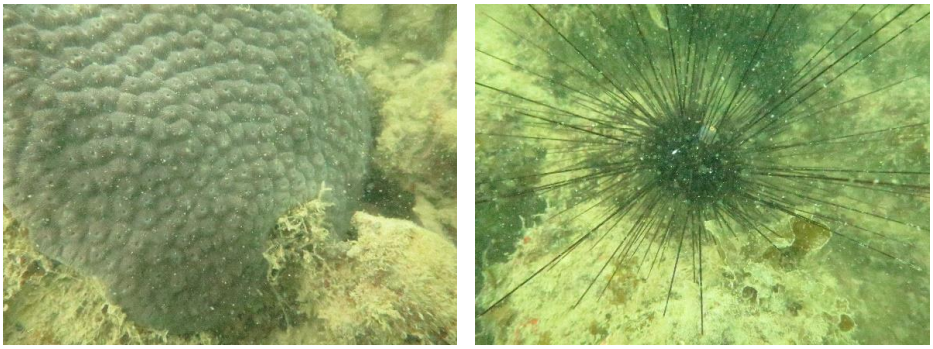


Fig. 6. Some life forms of coral reefs and associated substrate types at site 4

In general, the types of hard coral cover life forms found in the four (4) observation sites consisted of 9 coral group cover life forms consisting of 4 Acropora coral group cover life forms and 5 non-Acropora coral group cover life forms. The types of hard coral cover life forms found in the four (4) observation sites are Acropora Submassive (ACS), Acropora Encrusting (ACE), Acropora Tabulate (ACT), Acropora Branching (ACB), Coral Massive (CM), Coral Encrusting (CE), Coral Submassive (CS), Coral Mushroom (CMR) and Coral Branching (CB).

Coral reef cover

Observations of coral reef cover in location 1 were dominated by dead corals with a substrate cover of 37.34%. While the percentage of hard coral cover in the observation location is 25.76%. Based on the Decree of the Minister of Environment of the Republic of Indonesia Number 4 of 2001, it shows that coral cover in location 1 is included in the medium damage category. The percentage of coral cover along the LIT transect line in location 1 is shown in Table (4).

Table 4. Percentage coral cover along LIT transect lines at site 1

Category/ Life form		Code	Cover (%)
Abiotik			**28.38**
	Rock	RCK	3.26
	Silt	SI	24.12
	Sand	S	1.00
Other			**4.38**
	Others	OT	0.84

Category/ Life form		Code	Cover (%)
	Sponge	SP	2.04
	Soft Corals	SC	1.50
Dead Coral			**37.34**
	Dead Coral	DC	37.34
Algae			**4.14**
	Macroalgae	MA	4.14
Hard Coral			**25.76**
	Acropora Submassive	ACS	0.74
	Acropora Encrusting	ACE	2.92
	Coral Massive	CM	13.26
	Coral Encrusting	CE	2.10
	Coral Submassive	CS	6.20
	Coral Mushroom	CMR	0.54
Total			**100**

The results of observations of coral reef life forms in location 2 are dominated by hard coral with a closure rate of 45.74%. Based on the Decree of the Minister of Environment of the Republic of Indonesia Number 4 of 2001, coral closure at location 2 is included in the medium damage category. This is indicated by the percentage of hard coral cover with a percent cover of 45.74%. The percentage of coral reef cover along the LIT transect line in location 2 is shown in Table (5).

Table 5. Percentage of coral reef cover along the LIT transect line at site 2

Category/ Life form		Code	Cover (%)
Abiotik			**11.48**
	Silt	SI	11.48
Other			**8.22**
	Soft Corals	SC	8.22
Dead Scleractinia			**30.36**
	Dead Coral	DC	29.96
	(with Algal Covering)	DCA	0.40
Algae			**4.20**
	Macroalgae	MA	4.20
Hard Coral			**45.74**
	Acropora Branching	ACB	1.94
	Acropora Tabulate	ACT	4.36
	Acropora Encrusting	ACE	3.02
	Acropora Submassive	ACS	2.20
	Coral Massive	CM	11.66
	Coral Encrusting	CE	7.90
	Coral Submassive	CS	14.28

Category/ Life form	Code	Cover (%)
Coral Mushroom	CMR	0.38
Total		**100**

Coral cover in location 3 is dominated by hard coral with a closure rate of 39.48%. Based on the Decree of the Minister of Environment of the Republic of Indonesia Number 4 of 2001, coral cover in location 3 is included in the category of moderate damage. This is indicated by the percentage of hard coral cover with a percent cover of 39.48%. The percentage of coral reef cover along the LIT transect line in location 3 is shown in Table (6).

Table 6. Percentage of coral reef cover along the LIT transect line at site 3

Category/ Life form	Code	Cover (%)
Abiotik		**12.62**
Silt	SI	11.12
Sand	S	1.50
Other		**12.78**
Others	OT	2.80
Soft Corals	SC	7.28
Sponge	SP	2.70
Dead Scleractinia		**26.20**
Dead Coral	DC	24.70
(With Algal Covering)	DCA	1.50
Algae		**8.92**
Macroalgae	MA	8.92
Hard Coral		**39.48**
Acropora Tabulate	ACT	0.72
Acropora Encrusting	ACE	8.64
Acropora Submassive	ACS	5.10
Coral Massive	CM	3.94
Coral Encrusting	CE	1.22
Coral Submassive	CS	13.54
Coral Mushroom	CMR	6.32
Total		**100**

The percentage of hard coral cover in location 4 is 16.30%. Based on the Decree of the Minister of Environment of the Republic of Indonesia Number 4 of 2001 coral closure at site 3 is included in the category of bad damage. In this location, the abiotic category (mud and rock) has a large percentage of substrate cover, reaching 38.48%.

Table 7. Percentage of coral reef cover along the LIT transect line at site 4

Category/ Life form		Code	Cover (%)
Abiotik			**38.48**
	Rock	RCK	36.88
	Silt	SI	1.60
Other			**7.06**
	Others	OT	1.46
	Soft Corals	SC	4.94
	Sponge	SP	0.66
Dead Scleractinia			**37.74**
	Dead Coral	DC	37.74
Algae			**3.42**
	Macroalgae	MA	3.42
Hard Coral			**16.30**
	Acropora Encrusting	ACE	0.28
	Coral Branching	CB	0.44
	Coral Massive	CM	7.46
	Coral Encrusting	CE	3.62
	Coral Submassive	CS	4.50
Total			**100**

Based on the results of the study, the range of coral reef cover at the observation site ranged from 16.30 to 45.74%. According to the Decree of the Minister of Environment of the Republic of Indonesia No. 4 of 2001, the condition of coral reef cover in the location is included in the category of bad damage to moderate damage. The highest hard coral cover life form conditions were found in location 2. While the lowest hard coral cover life form conditions were found in location 4.

DISCUSSION

The types of hard coral reef life forms found at four (4) points of the research location are Acropora Submassive (ACS), Acropora Encrusting (ACE), Acropora Tabulate (ACT), Acropora Branching (ACB), Coral Massive (CM), Coral Encrusting (CE), Coral Submassive (CS), Coral Mushroom (CMR) and Coral Branching (CB). The same thing was also conveyed by **Rahman *et al*. (2023)** through his research which stated that the types of coral reefs in the northern waters of Batam City were dominated by the growth forms of Coral Massive (CM), Coral Submassive (CS) and Coral Foliose (CF). **Ramadhani *et al*. (2019)** also stated that the types of coral reefs around the waters of Batam Island consist of Coral Massive (CM), Coral Mushroom (CMR), Coral

Encrusting (CE), Coral Submassive (CS), Acropora Tabulate (ACT), Coral Branching (CB) and Coral Foliose (CF).

The type of life form cover of hard coral reefs in locations 1 and 4 is dominated by Coral Massive. The Coral Massive life form covered 13.26% of the area in location 1 and 7.46% at location 4. The dominance of the Coral Massive life form in both locations is likely due to its growth form, which is resistant to strong currents. This is supported by **Luthfi *et al.* (2018)**, who stated that corals with a massive growth form have a high resistance to currents, waves, sedimentation, and elevated temperatures. In locations 2 and 3, the Coral Submassive life form was dominant. In location 2, Coral Submassive covered 14.28% of the area, while in location 3, it covered 13.54%. The dominance of this life form in these locations is likely due to its resistance to high sedimentation. Given that sites 2 and 3 are near shipping lanes, it is estimated that the water conditions in these areas are typically more turbid. Coral Massive life forms were present at all sites, and as noted by **Zamani *et al.* (2011)**, massive corals tend to grow more on outer reefs with current waters. Additionally, in areas with strong waves, such as windward zones, corals typically grow in a short, strong, and creeping or submassive branching form. These observations suggest that the waters around Tanjung Sauh Island are influenced by high sedimentation and hydrodynamic pressures, such as waves and strong winds, which occur annually.

According to **English *et al*. (1997)**, coral growth forms are divided into two groups, namely Acropora and non-Acropora. Acropora coral growth forms found at the research site include Acropora Submassive, Acropora Encrusting, Acropora Tabulate, and Acropora Branching. While non-Acropora coral growth forms found at the research site include Coral Massive, Coral Encrusting, Coral Submassive, Coral Mushroom, and Coral Branching. Some forms of Acropora coral growth found in the study site, in accordance with the understanding of **English *et al*. (1997)**, are as follows:

a. Acropora Submassive (ACS), has a form of branching plates and sturdy.
b. Acropora Encrusting (ACE), has a shape that creeps like a crust and usually occurs in rudimentary corals.
c. Acropora Tabulate (ACT), the branching shape is flat and flat like a table.
d. Acropora Branching (ACB), has a branching shape like a tree branch.

While the non-Acropora coral growth form consists of:

a. Coral Massive (CM), the shape is solid like a ball or boulder and has a varied size and smooth surface.
b. Coral Encrusting (CE), has a crust-like shape with a rough surface resembling the bottom of the reef and small holes.
c. Coral Submassive (CS), the shape is solid with protrusions or small columns.
d. Coral Mushroom (CMR), has a mushroom-like shape with many protrusions which eventually form a grooved oval from the edge to the center of the mouth.

e. Coral Branching (CB), this coral shape is like a twig with branches longer than its diameter.

Turbidity, sedimentation, ocean currents and waves as well as coral reef growth forms cause several hard coral reef life forms in the study area to have low coral reef cover and fall into the poor to moderately damaged category.

Wallace *et al*. (2001) stated that there are 91 coral species in Indonesia, but the percentage shows a decline over time. This decline is thought to be caused by human activities, both directly and indirectly, such as water pollution, destructive fishing, and collection of coral reefs for ornamental aquariums. Damage to coral reef structures in various regions can be recognized through a decrease in hard coral reef cover life forms. Clear waters, ideal temperature, proper salinity, and sufficient light availability are essential to support coral reef life. Therefore, changes in the condition of the aquatic environment have the potential to cause the death of coral reefs. **Soenardjo (2013)** argued that changes in environmental conditions can cause stress on coral reef ecosystems, which in turn can increase the virulence of pathogens that infect sensitive corals. Coral reefs play an important role in the marine ecosystem. **Arini (2013)** postulated that coral reefs function to protect the coast from the impact of waves and strong currents, as well as acting as habitats, feeding grounds, nursing grounds, and spawning grounds for marine biota.

Based on the results of the study, the life form of hard coral reef cover in the observation location ranged from 16.30 to 45.74%, with the highest percentage of hard coral reef cover in location 2, while the lowest percentage was in location 4. Based on the Decree of the Minister of Environment of the Republic of Indonesia No. 4 of 2001, the condition of coral reef cover in the research location is included in the category of poor damage to moderate damage. **Ramses (2017)** also stated that the waters of Sarang Island, located northwest of Batam City, had a percentage of coral cover classified as poorly damaged, which was 10% to 20%. **Ramadhani *et al*. (2019)** stated that the percentage value of hard coral cover in Galang Island, Batam City, ranged from 32.67 to 51.33% (moderate to good damage category), with coral cover in the good category only found in one location out of six observation locations. Based on this, the coral reef cover in several locations in Batam City is categorized as damaged (badly damaged and moderately damaged).

Based on the results of the study, it also showed that the highest percentage of dead coral cover was found in location 1 (37.34%) and location 4 (37.74%). The high cover of dead corals in location 1 is thought to be caused by domestic waste that comes from the activities of the surrounding population. Domestic waste has the potential to reduce seawater quality, which can cause coral mortality. Meanwhile, the high cover of dead corals in location 4 is thought to be caused by ship activities in the study area and fisheries activities. In addition to factors derived from human activities, coral reef mortality can also be influenced by natural factors, such as changes in seawater

temperature, decreased dissolved oxygen (DO), and increased total suspended solids (TSS). **Suryanto *et al*. (2015)** stated that hard coral reef cover life forms have a strong relationship with temperature, dissolved oxygen (DO), TSS, and ocean currents. **Sukmara *et al*. (2002)** also elucidated that boat activities, boat propulsion devices, and boat anchors can cause coral reef mortality, where coral reefs can be broken as a result.

Coral reef ecosystems may look robust, but they are highly vulnerable to environmental changes. Coral reefs are very sensitive to environmental changes, especially changes in the quality of the surrounding waters. **Siringoringo and Hadi (2013)** noted that human or anthropogenic activities on land also affect coral reef ecosystems. Another factor that needs to be considered is the impact of climate change related to fluctuations in temperature and sea level. These conditions can disrupt the survival of biota around the coral reef ecosystem. The loss of coral reefs can result in the disruption of important ecological functions not only loss of habitat but also loss of island protection due to the impacts of sea level rise. Impacts from rising ocean temperatures include shifts in the distribution of marine species, ocean acidification due to CO_2 uptake **(Gattuso & Hansson, 2011)**, and increased thermal stress on marine organisms, including coral reefs **(Hughes *et al*., 2017)**. Severe and prolonged coral bleaching can result in mass coral mortality, which damages the structure and function of coral reef ecosystems and threatens marine biodiversity **(Hoegh-Guldberg *et al*., 2007; Wilkinson, 2008)**.

CONCLUSION

Life form cover of coral groups found in four (4) research sites are Acropora Submassive (ACS), Acropora Encrusting (ACE), Acropora Tabulate (ACT), Acropora Branching (ACB), Coral Massive (CM), Coral Encrusting (CE), Coral Submassive (CS), Coral Mushroom (CMR) and Coral Branching (CB). The percentage of hard coral reef cover in the research location ranged from 16.30 to 45.74%. Based on the Decree of the Minister of Environment of the Republic of Indonesia No. 4 of 2001, it is indicated that the condition of coral reef cover in the location is included in the category of poor damage to moderate damage.

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