MONITORING CHANGES IN CORAL REEF HABITAT COVER ON BERALAS PASIR ISLAND USING SPOT 4 AND SPOT 7 IMAGERY FROM 2011 AND 2018

Rosaria Damai[1]*, Viv Djanat Prasita[1], Kuncoro Teguh Setiawan[2]
[1]Universitas Hang Tuah Surabaya
[2]Remote Sensing Applications Center–National Institute of Aeronautics and Space (LAPAN)
*e-mail: rosadamai2@gmail.com

Abstract. Beralas Pasir is part of the Regional Marine Conservation Area (KKLD), which was established by the Bintan Regency Government with Bintan Regent Decree No. 261 / VIII / 2007. Water tourism activities undertaken by tourists on the island have had an impact on the condition of the coral reefs, as have other factors, such as bauxite, granite and land sand mining activities around the island. This research aims to determine changes in the coral reef habitat cover and the condition of the coral reefs around Beralas Pasir Island with a remote sensing function, using SPOT 4 imagery acquired on June 1, 2011 and SPOT 7 imagery from April 5, 2020. Data collection of environmental parameters related to the coral reefs was also made. The image processing used the Lyzenga algorithm to simplify the image classification process. The percentage of coral live cover around the island ranges from 26% - 53%; this has experienced a significant change, from 67,560 hectares in 2011 to 38,338 hectares in 2018, a total decrease in the area of 29,222 hectares. Some of the natural factors found in the research which have caused damage to the reefs were *Drupella* snails, the abundance of *Caulerpa racemosa* algae, and sea urchins. The majority of the coral reef types consist of Non-Acropora: *Coral Massive, Coral, Coral Foliose, Coral Encrusting, Acropora: Acropora Tabulate, Acropora Encrusting, and Acropora Digitate.*

Keywords: *Monitoring, Coral Reefs, SPOT 4, SPOT 7, Beralas Pasir Island.*

1 INTRODUCTION

The coast of Bintan Regency has a coral reef area of 17,394.83 hectares (DKP, 2007 as cited in Adriman et al., 2013). There was 14 families and 78 type of coral in bad to moderate condition (Giyanto et al., 2017). Since 2006, the coastal area of Bintan Regency has been determined by the government to be one of the locations for the Coral Reef Rehabilitation and Management Program (COREMAP) (Adriman et al., 2013). Beralas Pasir Island is one of 3000 large and small islands in Bintan Regency, Riau Islands Province, and is a marine tourism area known as the "private islands". The island is part of Gunung Kijang District, which is one of the two sub-districts where COREMAP is being implemented. In addition, Beralas Pasir Island is a Regional Marine Conservation Area (KKLD,) which was established by the Bintan Regency Government with the Bintan Regent Decree No. 261 / VIII / 2007. The island has an area of around 6 hectares (Lumbantoruan, 2017).

Environmental conditions on the island are influenced by seasonal winds and include currents, some of which are quite complex as a result of the interaction between various fixed and seasonal currents, and other factors such as the water topography and coastlines. Moreover, tides also affect the movement of various chemical pollutants, such as oil pollution. The geographical position of

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Beralas Pasir Island, which is part of Bintan, is at the confluence of the Indian Ocean through the Malacca Strait and the Pacific Ocean through the South China Sea, causing the Riau Islands waters to experience tidal currents with an alternating pattern (Lumbantoruan, 2017). The weather on Beralas Pasir Island is influenced by the monsoons, which change direction according to the position of the sun to the earth, meaning the climate on the island is wet tropical, with the highest rainfall in September to February (Lumbantoruan, 2017), and with an average monthly temperature of 24.8 °C (Lumbantoruan, 2017). Land elevation above sea level is around 10 m, and the topography of the Beralas Pasir Island is a sloping base with a sand substrate (Lumbantoruan, 2017).

The island was previously uninhabited, but in September 2015 PT. Indo Bintan Trijaya opened it to the public as a tourist destination. The number of activities undertaken by tourists in the sea waters of around the island have an impact on the condition of the coral reefs. Another factor which is a reason for the study is the influence of bauxite mining, which together with the development of the resorts on the coast, has an impact on changes in the coral reef cover. CRITC Bintan (2009) as cited in Adriman et al., 2013) reported a decrease in live coral cover in the East Bintan Marine Protected Area (KKLD), allegedly the result of bauxite, granite and land sand mining activities. Based on the problems mentioned above, this research was conducted to monitor changes in the coral reef cover on Beralas Pasir Island using remote sensing methods in 2011 with SPOT 4 images and comparing them to ones from 2018 from SPOT 7, together with the conducting of ground truths in the field using a confusion matrix accuracy test. Irawan et al. (2017) and

Azka et al. (2019) previously conducted research on changes in coral reef areas utilising remote sensing and the water column correction method using the Lyzenga algorithm, together with Landsat imagery. Remote sensing is a method that is often used in research both on land and at sea as it can facilitate large scale research, such as studies of one island or several islands at the same time.

2   MATERIALS AND METHODOLOGY
2.1   Research Location and Time

The research was conducted from March to May 2020, with steps including the preparation stage, field survey and field data collection on Beralas Pasir Island, Riau Islands Province. The field data processing was conducted at the Hydro-Oceanography Laboratory, Hang Tuah University, Surabaya and that of the satellite imagery at the Remote Sensing Utilization Center, LAPAN. The tools used for the study were a secchidisc, roller meter, thermometer, underwater camera, underwater paper, floating ball, salinometer and a laptop for the image data processing, as well as ErMapper 7.1, ENVI 5.3, ArcGIS 0.3 and CPCe 4.1 software. The research materials can be seen in Table 2-1.

Table 2-1: Research Materials

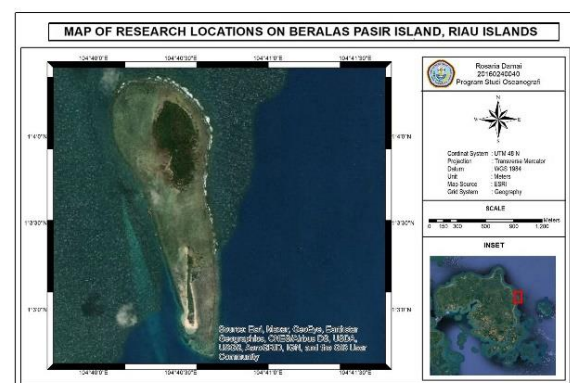| Type of Data	Date of Acquisition
SPOT 4	June 6, 2011
SPOT 7	April 5, 2018

Figure 2-1: Research Location

2.2   Standardization of Data
2.2.1 Ground Truths

Field validity checks were performed to establish the condition of coral cover and the environmental conditions, in accordance with the conditions in the field. Determination of the data collection points was made using the purposive sampling method.

a.   Retrieval of coral reef data

Retrieval of coral reef data with a size of 9 m x 9 m was made from ten points spread across locations around the island. The 9 m x 9 m data size aimed to be a sample point for the SPOT 7 image pixels, representing a resolution of 6 m x 6 m for each pixel, with the remaining size used for errors. There were 30 sampling points for the reclass and accuracy tests, ten comprising details of data on coral reefs, ten on seagrass, and ten on sand. The coral reef data were then processed using CPCe 4.1 software.

b.   Environmental Parameters

Environmental parameter data were collected to observe the limiting factors for coral reef growth. Some of the parameters used in the study were temperature, brightness, salinity and current velocity.

2.2.2 *Image processing*

The image processing can be seen in the flow chart shown in figure 2-2.
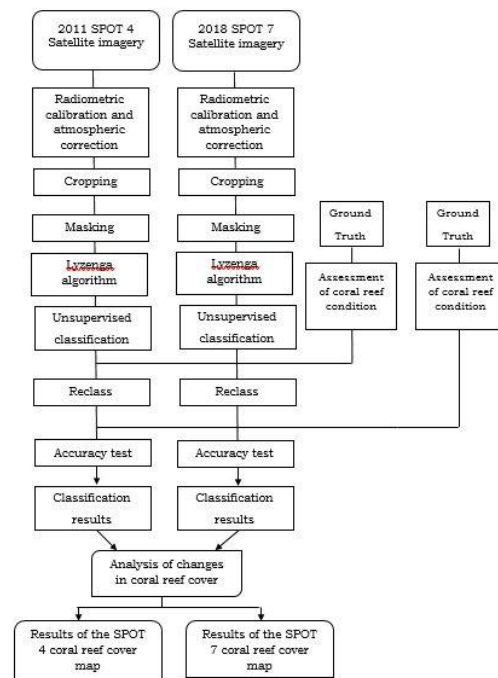
Figure 2-2: Flow Chart

1.   Radiometric Calibration

Radiometric calibration is a satellite image processing process that aims to convert data in images that are generally stored in the form of a digital number (DN) into radiance (LTOA) or reflectance (ρTOA), which can be in the form of brightness temperature for Thermal Infrared (Jaelani, 2017).

2.   Atmospheric Correction

The method used to eliminate atmospheric effects is the histogram adjustment method (Chavez et al., 1988).

3.   Image Cropping

The satellite images obtained had a wide coverage, so it was necessary to cut the image to the required research area.

4. Masking

The separation stage between land and water/ocean was performed to make it easier to analyse the ocean as the main object, by entering the formula if (I1 / I2)> 0.7 then 255 else I2.

5. Lyzenga's Algorithm

The Lyzenga algorithm is a step taken in water column correction which is applied to satellite images to eliminate the influence of water columns:

$$Y = Ln\,(TM1) + (Ki/Kj * Ln\,(TM2)) \qquad (2\text{-}1)$$

Where:

Y = image extracted from the bottom of the water

TM1 = digital number on *Band* TM1

TM2 = digital number on *Band* TM2

Ki/Kj = attenuation coefficient value

6. Unsupervised Classification

Image classification in this research was made using unsupervised classification with the ISODATA (Iterative Self-Organizing Data Analysis Technique) method for images from 2011 and 2018. Classification is a clustering algorithm that allows the number of clusters to be adjusted automatically based on the iteration process performed (Rahmawan et al., 2020).

7. Reclass

Reclass is the stage of improving the unsupervised classification so that it matches the actual situation with the help of field data to match the image results with the actual field conditions.

8. Accuracy Test

A classification accuracy test was performed to test the accuracy of the usage map generated from the digital classification process, with test samples from the results of the ground truth. The sample used as the training area and that used for the accuracy test was not the same sample; that for the accuracy test was taken from a different place so that its accuracy was more acceptable. The method used to test the accuracy of image classification was a configuration, or error matrix (Jensen, 2005 as cited in Wulansari 2017). This matrix can be seen in Table 2-2.

Table 2-2: Error Matrix

| | Reference Data | | | | | | | |
	PL I	PL II	PL III	PL IV	PL V	PL VI	PL VII	Total Row
PL I	A	a	b	c	D	e	f	Σ row 1
PL II	g	B	h	i	J	k	l	Σ row 2
PL III	m	n	C	o	P	q	r	Σ row 3
PL IV	s	t	u	D	V	w	x	Σ row 4
PL V	y	z	a'	b'	E	c'	d'	Σ row 5
PL VI	e'	f	g'	h'	I'	F	j'	Σ row 6
PL VII	k'	l'	m'	n'	o'	p'	G	Σ row 7
Total column	Σ row 1	Σ row 2	Σ row 3	Σ row 4	Σ row 5	Σ row 6	Σ row 7	Σ total column/row

Confusion matrix analysis (Banko, 1998) employs the following equation:

$$K = \frac{\text{number of rows and columns}}{\text{sum of all data}} x100\% \quad (2\text{-}2)$$

9. Coral Reef Assessment

The condition of coral reefs is based on the percentage cover of live coral (rock coral) and other living components, together with dead coral, as shown in the Table 2-3.

Table 2-3: Category of Coral Reef Cover Condition (English et al., 1997 as cited in Raazy, 2018).

Coral Reef Cover (%%)	Condition Category
00 - 25	Bad
26 - 50	Moderate
51 - 75	Good
76 - 100	Best

10. Calculation of Coral Reef Area

The area and changes can be seen from image data that have been processed and converted to .shp, as shown in the attribute table in ArcGIS 10.3 software. Calculation of the area of and change in coral reefs is made in hectares (ha).

2.2.3 Environmental Parameter Data Analysis

1 Visibility

The visibility value is calculated by taking the percentage value of the strap length when the Secchi disc is still visible or not visible at all, which is then converted into a percent brightness value. The following formula is used:

$$\frac{visibility\ (m)}{depth\ (m)} x\ 100\% \quad (2\text{-}3)$$

2 Current Velocity

The current velocity measured in

the field can be calculated using the formula:

Rated current velocity, v = s / t   (2-4)

where
s = length of the current floating ball (m)
t = current time (seconds)

3 RESULTS AND DISCUSSION

3.1 Pre-processing results of SPOT 4 and SPOT 7 imagery of Beralas Pasir Island

3.1.1 Radiometric Calibration

The results of the radiometric calibration are image data initially in the form of a digital number (DN), which is then converted into radiance (LTOA). The results of the radiometric calibration are shown in Figure 3-1.
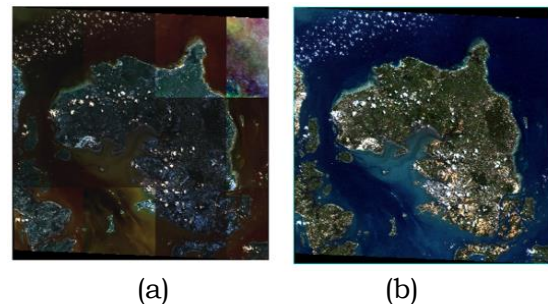

(a)   (b)

Figure 3-1: (a) before radiometric calibration; (b) after radiometric calibration

3.1.2 Atmospheric Correction

The method used to eliminate the effects of the atmosphere is the histogram shift method (histogram adjustment); the approach commonly used is dark object substraction (DOS). The digital number (DN) in an image if there is no atmospheric influence, then the minimum pixel value is zero and the maximum value is one or less (Chavez et al., 1988). If the minimum DN pixel in the image histogram is not equal to zero, this indicates a disturbance from atmospheric impact. The results of the atmospheric correction are shown in Tables 3-1 and 3-2.

Table 3-1: Digital numbers of SPOT 7 before atmospheric correction

Band	Min	Max	Mean	St.Dev
Band 1	0	4095	225.15	172.98
Band 2	0	4095	418.28	135.23
Band 3	0	4095	539.42	98.55
Band 4	0	4095	254.57	424.09

Table 3-2: Digital numbers of SPOT 7 after atmospheric correction

Band	Min	Max	Mean	StDev
Band 1	0.0	0.0045	0.0006	0.0002
Band 2	0.0	0.0039	0.0004	0.0002
Band 3	0.0	0.0036	0.0002	0.0002
Band 4	0.0	0.0024	0.0003	0.0003

3.1.3 Image Cropping

After atmospheric correction, the imagery is cropped cut according to the location required to be observed. The results of the cropping can be seen in Figure 3-2.
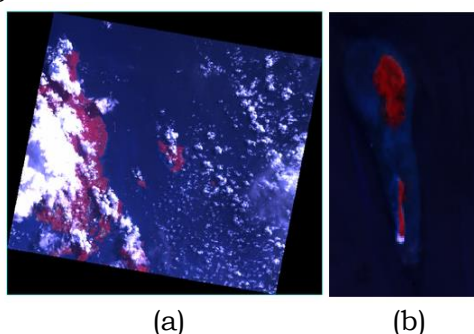

(a)　　　　　　　　(b)

Figure 3-2: (a) SPOT 4 image before cropping; (b) image after cropping

3.1.4 Masking

Separation is made of land from ocean, in order for all land values to become 255 so as not to disturb the value of the marine waters during the next process. The results of the masking are shown in Figure 3-3.
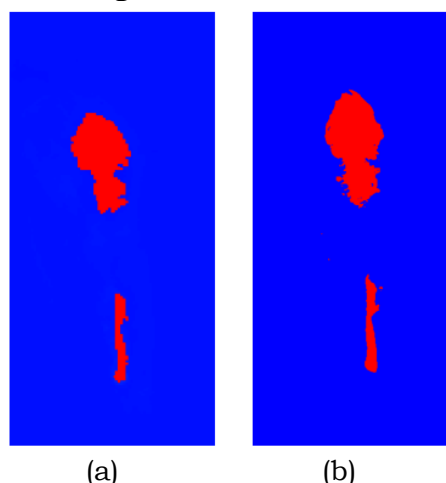

(a)　　　　　　　　(b)

Figure 3-3: (a) Masking SPOT 4, (b) Masking SPOT 7

3.2 Results of SPOT 4 and SPOT 7 Image Data Processing from Beralas Pasir Island

3.2.1 Lyzenga's Algorithm

The application of the Lyzenga algorithm uses SPOT 4 green and red channels, and SPOT 7 blue and red channels. The value of the Ki/Kj coefficient is obtained by creating a training area of 30 regions in the image which have homogeneous colours in the coral reef area. The results of the calculation of the creation of the area are shown in Tables 3-3 and 3-4. The results of the Lyzenga algorithm can be seen in Figure 3-4.

Table 3-3: 2011 SPOT 4 Results of calculation create region

a	0.96277804
Ki/Kj	0.925556078

Table 3-4: 2018 SPOT 7 Result of calculation create region

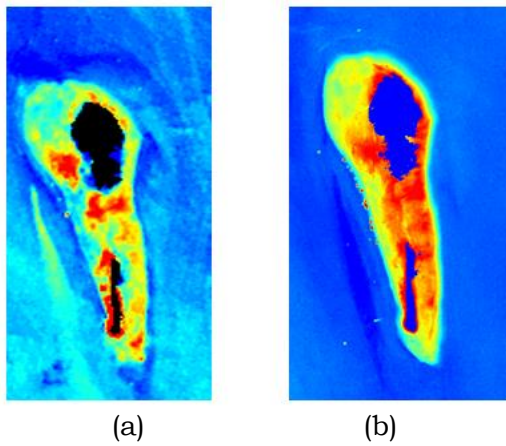| a	0.32264807
Ki/Kj	0.64529615

(a) (b)

Figure 3-4: Results of the application of the Lyzenga algorithm: (a) SPOT 4 image from 2011; (b) SPOT 7 image from 2018

3.2.2 Image Classification

The results of the classification of the images of the coral reefs around Beralas Pasir Island using SPOT 4 and the ISODATA classification method resulted in ten classes. In the next class processing step, the SPOT 4 2011 image is not reclassified using field data, but instead the reclassification process refers to the shallow water object key when conducting ground truth, with the help of Google Earth to observe the condition of Beralas Pasir Island in 2011. The results of the classification can be seen in Figure 3-5.
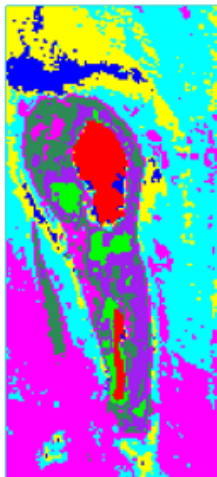

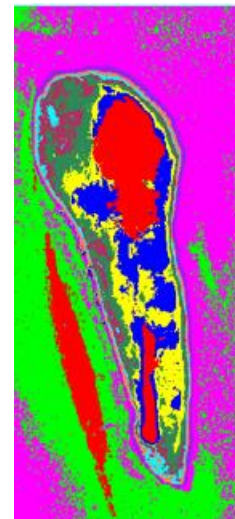Figure 3-5: Unsupervised classification results of SPOT 4

Image 3-6: Unsupervised classification results of SPOT 7

The results of the SPOT 7 image classification using the ISODATA method produced ten classes. Each class represented the characteristics of aquatic objects. Then for the SPOT 7 image after being classified into 10 classes, the next process was the reclassification process to improve the results so they match the ground truth data. The results of the classification can be seen in Figure 3-6.

3.2.3 Reclassification

Recolouring was performed to match the results of the images with the ground truth data that had been obtained, which were divided into five classes: coral reefs, seagrass, sand, land and sea. Each class was assigned a different colour to make it easier to recognise each water object. The coral ground truth location can be seen in Figure 3-7. Table 3-5 shows the details of the station for the reclassification process, consisting of the coral reef, seagrass and sand reclassification points.

Table 3-5: Station coordinate points for the 2018 SPOT 7 reclassification.

Station	Habitat Cover	Coordinate point	
		X	Y
1	Coral Reefs	117995.00 m N	463096.00 m E
2	Coral Reefs	118127.00 m N	464138.00 m E
4	Coral Reefs	116059.00 m N	463850.00 m E
10	Coral Reefs	115533.00 m N	464114.00 m E
2	Seagrass	116348.00 m N	463814.00 m E
4	Seagrass	116488.00 m N	463814.00 m E
7	Seagrass	116242.00 m N	464026.00 m E
10	Seagrass	115809.00 m N	464028.00 m E
1	Sand	115924.27 m N	463875.43 m E
4	Sand	115841.73 m N	463985.96 m E
5	Sand	115874.70 m N	463903.59 m E
8	Sand	116085.97 m N	463880.55 m E

(a) (b) (c)

Figure 3-7: Coral ground truth location points for reclassification of SPOT 7 Figure: (a) coral reef; (b) seagrass; (c) sand (source: Google Earth)
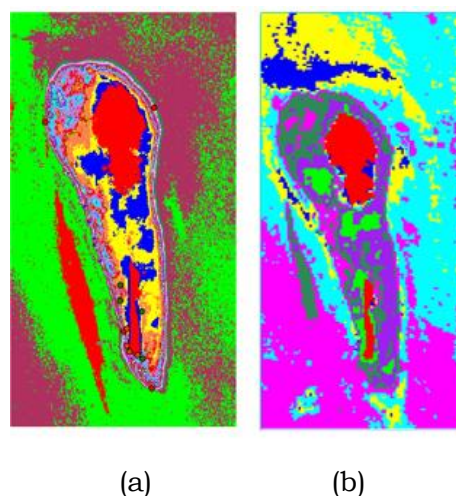

(a) (b)

Figure 3-8: (a) unsupervised SPOT 7 classification results; (b) unsupervised SPOT 4 classification results
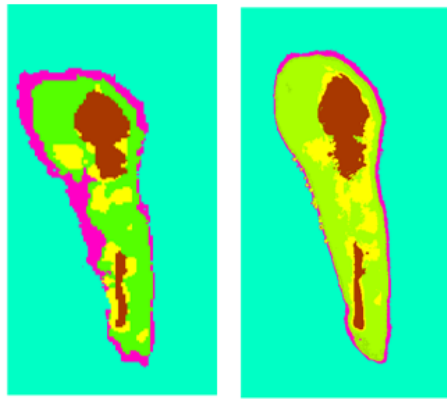
Figure 3-9: Reclassisication Results: (a) SPOT 4 in 2011 (b) SPOT 7 in 2018

Table 3-6: Confusion Matrix Accuracy Test.

Image Classification Results	Information on Ground Truth Results			
	Class	Coral	Seagrass	Sand	Total
	Coral	5	0	0	5
	Seagrass	1	5	1	7
	Sand	0	1	5	6
	Total	6	6	6	18
	Accuracy				83.3%

Figure 3-8 shows the results of the classification process, after which a reclassification process was conducted to correct classes not in accordance with the conditions in the field. Figure 3-9 shows the results of the reclassification process, which comprise five classes: coral reef, seagrass, ocean, land and sand.

3.2.4 Accuracy Test

Based on the results of the accuracy test shown in Table 3-6, the test value from the confusion matrix method is 83.333%. In remote sensing, the results of the accuracy tests are divided into 3 classes, namely if K> 80%, the accuracy value is very strong (strong agreement); if K = 40% - 80% the value is moderate (moderate agreement); and if K <40% the value is not good (poor agreement) (Jensen, 2005). The level of research accuracy therefore falls into the very strong category). Table 3-7 shows the details of the stations for the accuracy tests, consisting of the accuracy test points of the coral reefs, seagrass and sand.

3.2.5 Calculation of the Coral Reef Area

Based on the results of the processing of the 2011 and 2018 images, which were tested for accuracy with ground truth data, there are differences in the areas of all types of Beralas Pasir Island habitat cover, as shown in Table 3-8. Maps of the condition of the coral reef areas around the island can be seen in Figure 3-10 - 3-12.

Table 3-7: Station coordinate points for the 2018 SPOT 7 accuracy test.

Station	Habitat Cover	Coordinate Point	
		X	Y
3	Coral	115720.00 m N	463872.00 m E
5	Coral	116139.00 m N	463805.00 m E
6	Coral	116217.00 m N	463783.00 m E
7	Coral	116415.00 m N	463726.00 m E
8	Coral	116488.00 m N	463702.00 m E
9	Coral	116571.00 m N	463675.00 m E
1	Seagrass	116150.00 m N	463872.00 m E
3	Seagrass	116397.00 m N	463820.00 m E
5	Seagrass	116569.00 m N	463782.00 m E
6	Seagrass	116334.09 m N	464000.95 m E
8	Seagrass	116021.00 m N	464103.00 m E
9	Seagrass	115909.00 m N	464071.00 m E
2	Sand	115990.21 m N	463885.14 m E
3	Sand	115876.73 m N	464016.33 m E
6	Sand	115846.35 m N	463925.67 m E
7	Sand	116034.62 m N	463894.05 m E
9	Sand	115905.24 m N	463877.89 m E
10	Sand	115968.39 m N	463883.50 m E

Table 3-8: Difference in the findings on coral reefs cover in 2011 and 2018.

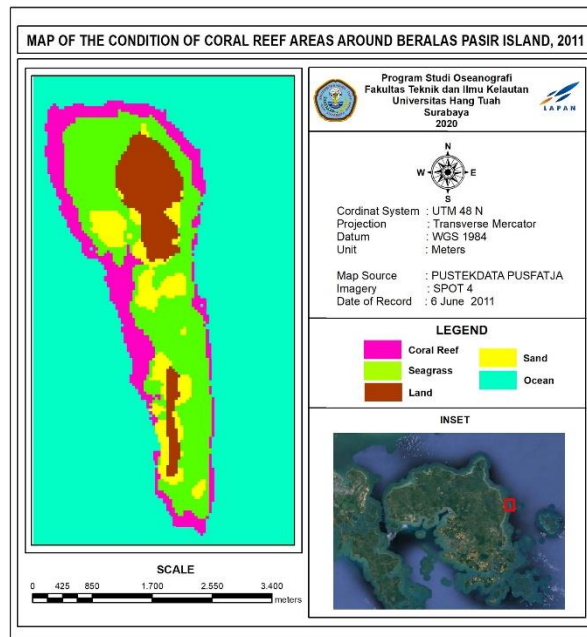| Substrate	Substrate area (ha)		Area Difference (ha)
	2011	2018	
Sand	27.48	25.62	-1.85
Seagrass	85.52	189.93	104.41
Coral	67.56	38.33	-29.22
Total	180.56	253.90	73.34

Figure 3-10: Map of the Condition of Coral Reef Areas around Beralas Pasir Island, 2011
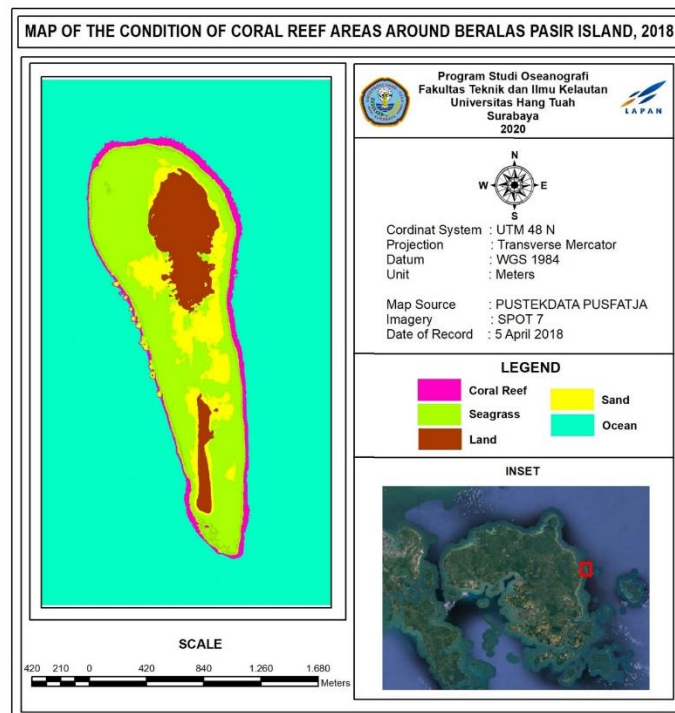

Figure 3-11: Map of the Condition of Coral Reef Areas around Beralas Pasir Island, 2018
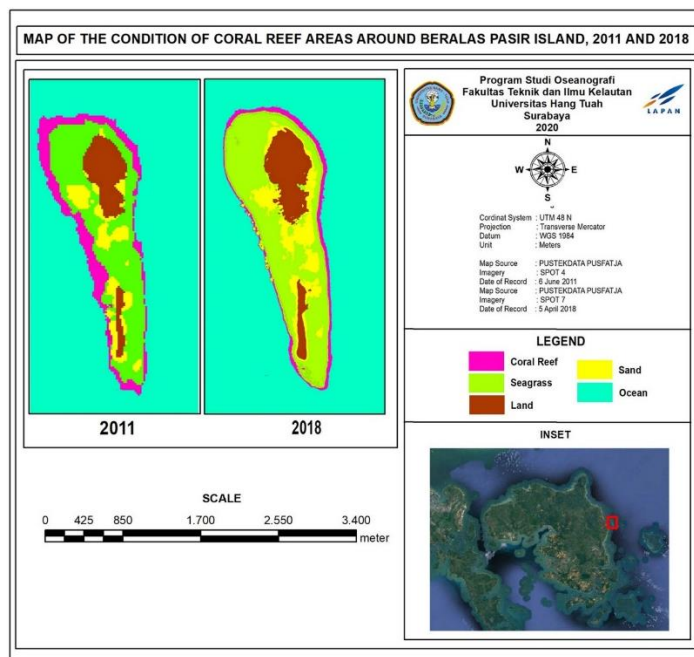
Figure 3-12: Map of the Condition of Coral Reef Areas around Beralas Pasir Island, 2011 and 2018

3.3 Results of the Field Data Retrieval

3.3.1 Water Conditions around Beralas Pasir Island

The condition of marine waters is also a component that affects the life, condition and growth of coral reefs. Some of the environmental parameter data taken for coral reefs in this study include salinity, visibility, temperature and current velocity, as shown in Table 3-8. Beralas Pasir Island is unique in its ocean currents. To the south of the island, the currents have different directions. Those to the west are in a southwesterly direction, while to the east they are northerly.

Table 3-9: Water Parameter Data around Beralas Pasir Island.

Station	Salinity (‰)	Depth (m)	Visibility (m/%)	Temp. (°C)	Cur.Vel (m/s)
1	35	6.8	6.8 (100%)	30.8	0.12
2	35	4	4 (100%)	30.4	0.53
3	35	2.5	2.5 (100%)	30.3	0.53
4	35	1.2	1.2 (100%)	30.9	0.12
5	35	1.4	1.4 (100%)	30.9	0.12
6	35	2	2 (100%)	30.7	0.12
7	35	4	4 (100%)	31.8	0.12
8	35	4.2	4.2 (100%)	30.9	0.12
9	35	1.5	1.5 (100%)	30.6	0.53
10	35	6.5	6.5 (100%)	30.5	0.53

3.3.2 Coral Reef Condition around Beralas Pasir Island

Coral reef assessment was made by entering photos of coral reef condition documented under water into the CPCe 4.1 software. The results of the assessment from the software could then be opened in Microsoft Excel. Coral reef cover can be seen in Figure 3-13.
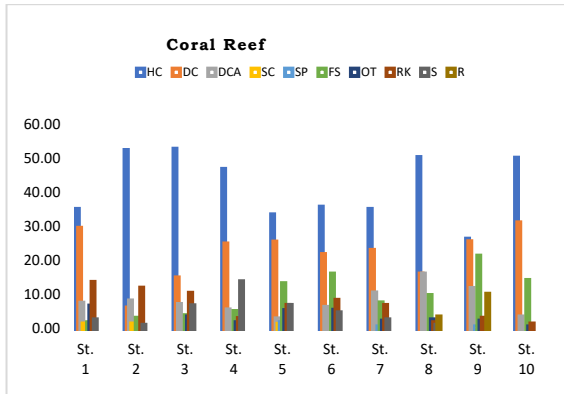
Coral Reef

HC DC DCA SC SP FS OT RK S R

Figure 3-13: Coral reef cover around Beralas Pasir Island

1. Station 1

Station 1 was located to the northwest of the island, at a depth of 6.8 metres, with a sloping topographical condition of the sea floor. The percentage of habitat cover is shown in Figure 3-14.
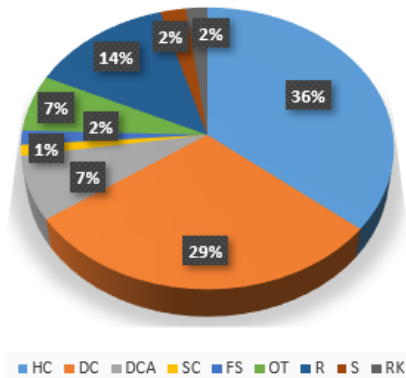
HC DC DCA SC FS OT R S RK

Figure 3-14: Percentage of coral reef cover at station 1

Its "medium" category indicates that its condition of coral reef is neither good nor bad. According to information from the manager of the Sand Island tourist area, the location of Station 1 is often used as a place for fishing, and many boats pass to taking tourists around the island to see the scenery. The percentage of the diversity of coral reef species at the station can be seen in Table 3-10.

Table 3-10: Percentage of diversity of coral reef species at station 1.

Species	(%)
Acropora	
Acropora Digitate (ACD)	0.41
Acropora Tabulate (ACT)	2.86
Non-Acropora	
Coral Encrusting (CE)	1.22
Coral Foliose (CF)	21.63
Coral Massive (CM)	2.45
Coral Mushroom (CMR)	2.86
Coral Submassive (CS)	4.49

It can be seen that the type of coral reef that is most abundant at station 1 is non-Acropora coral foliose (sheet), at 21.63%, while the least abundant is Acropora digitate (fingers), at 0.41%. An image of coral foliose is shown in Figure 3-15.

Figure 3-15: Most abundant coral species at station 1: non-Acropora coral foliose (Source: private collection, P. Beralas Pasir)

2. Station 2

Station 2 was to the northeast of the island, at a depth of 4 metres, with the topography of the seabed sloping from the coastline 200 metres into the open sea. Based on the results of the ground truth data collection, the percentage of coral reef cover at station 2 is 52%, which is in

the "good" category. Based on a statement by the manager of the Beralas Pasir Island tourist area, the location of station 2 is rarely used for snorkeling, diving, canoeing or other water tourism by tourists. The percentage of habitat cover at station 2 is shown in Figure 3-16.
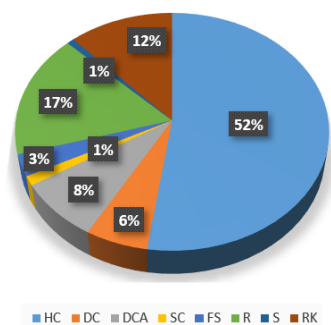

Figure 3-16: Percentage of coral reef cover at station 2

Based on literature regarding the sea conditions around Beralas Pasir Island, station 2 is in a location with quite strong currents and high waves, with a current circulation coming from the Natuna Sea. The percentage of diversity at station 2 is shown in Table 3-11.

Table 3-11: Percentage of diversity of coral reef species at station 2

Species	(%)
Acropora	
Acropora Branching (ACB)	5.06
Acropora Digitate (ACD)	1.27
Acropora Encrusting (ACE)	2.95
Acropora Tabulate (ACT)	10.55
Non-Acropoora	
Coral Branching (CB)	0.84
Coral Encrusting (CE)	1.69
Coral Foliose (CF)	4.22
Coral Massive (CM)	16.88
Coral Submassive (CS)	8.86

It can be seen that the type of coral reef that is most abundant at station 2 is non-Acropora coral massive (solid), at 16.88%, and the least abundant Acropora digitate (fingers), at 1.27%. An image of coral massive is shown in Figure 3-17.

Figure 3-17: Most abundant coral species at station 2: non-Acropora coral massive (Source: private collection, P. Beralas Pasir)

3. Station 3

Station 3 was located to the south of the island, at a depth of 2.5 metres, with the topography of the seabed sloping from the coastline 150 metres into the open sea. The percentage habitat cover at the station is shown in Image 3-18.
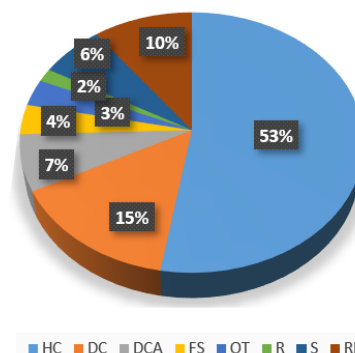

Figure 3-18: Percentage of coral reef cover at station 3

Based on the results of the ground truth data collection, the percentage of live coral cover at station 3 is 53%, which is in the "good" category.

Based on a statement by the manager of the Beralas Pasir Island tourist area, the location of station 3 is rarely used as a location for snorkeling or diving by tourists because it is in a location that has fairly strong currents, coming from the east of the island, circulating to the south, and originating in the Natuna Sea. The percentage of diversity at the station is shown in Table 3-12.

Table 3-12: Percentage of coral reef species diversity at station 3.

Species	(%)
Acropora	
Acropora Encrusting (ACE)	2.47
Acropora Tabulate (ACT)	10.29
Non-Acropora	
Coral Encrusting (CE)	2.88
Coral Foliose (CF)	7.82
Coral Massive (CM)	17.28
Coral Mushroom (CMR)	0.41
Coral Submassive (CS)	11.52

It can be seen that the type of coral reef that is most abundant at station 3 is non-Acropora coral massive (solid), with a percentage of 17.28%, with the least abundant being non-Acropora coral mushroom (mushroom), at 0.41%. An image of coral massive is shown in Figure 3-19.

Figure 3-19: Most abundant coral species at station 3: non-Acropora coral massive (Source: private collection, P. Beralas Pasir)

4. Station 4

Station 4 was located to the west of Beralas Pasir Island, at a depth of 1.2 metres, with the topography of the sea floor sloping from the coastline 120 metres into the open sea. The percentage habitat cover at the station is shown in Figure 3-20.
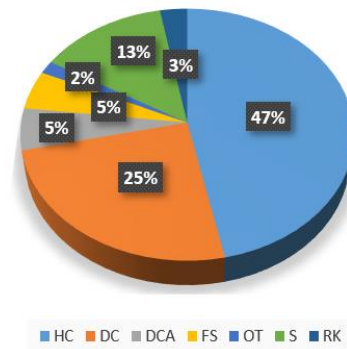

Figure 3-20: Percentage of coral reef cover at station 4

Based on the results of the field data collection, the percentage of live coral reef cover at station 4 is 47%, which is in the "medium" category.

The manager of the Beralas Pasir Island tourist area stated that the location of the station was the main spot for snorkeling and diving by tourists as it had weak currents, it was not too deep, and its location is not too far from the island. In addition, the various types of coral made the station the main tourist location of the island. The percentage of diversity at station 4 is shown in Table 3-13.

Table 3-13: Percentage of coral reefs species diversity at station 4.

Species	(%)
Acropora	
Acropora Encrusting (ACE)	1.24
Acropora Tabulate (ACT)	6.61
Non-Acropora	
Coral Encrusting (CE)	0.41
Coral Foliose (CF)	1.65
Coral Massive (CM)	23.97
Coral Submassive (CS)	12.81

It can be seen that the type of coral reef that is most abundant at station 4 is non-Acropora coral massive (solid), with a

percentage of 23.97%, while the least abundant type is non-Acropora coral encrusting (creeping), at 0.41%. An image of coral massive is shown in Figure 3-21.

Figure 3-21: Most abundant coral species at station 4: non-Acropora coral massive (Source: private collection, P. Beralas Pasir)

5.   Station 5

Station 5 was located to the west of Beralas Pasir Island; this station had a depth of 1.4 metres, with a wide topography of the seabed from the coastline, up to 130 metres into the open sea. The percentage habitat cover at station 5 is shown in Figure 3-22.
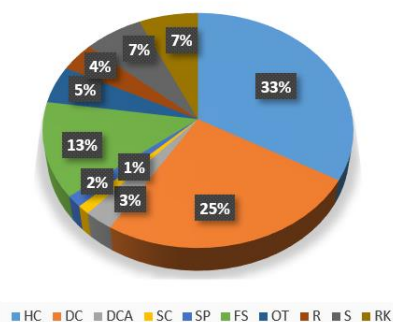

Figure 3-22: Percentage of coral reef cover at station 5

From the results of the ground truth data collection, the percentage of live coral reef cover at the station is 33%, which is in the "medium" category, so it can be said that the condition is quite good. The manager of the Sand Island tourist area said that the location of station 5 was often used for snorkeling, diving, playing kanau or other water

tourism by tourists, as it has calm currents, the water is not too deep, it is located near to Beralas Pasir Island and various types of coral can be found there. The percentage of diversity at station 5 is shown in Table 3-14.

Table 3-14: Percentage of coral reef species diversity at station 5.

Species	(%)
Acropora	
Acropora Digitate (ACD)	3.17
Acropora Submassive (ACS)	5.56
Acropora Tabulate (ACT)	10.71
Non-Acropora	
Coral Encrusting (CE)	4.76
Coral Foliose (CF)	0.79
Coral Massive (CM)	7.14
Coral Mushroom (CMR)	0.4
Coral Submassive (CS)	0.79

It can be seen that the type of coral reef that is most abundant at station 5 is Acropora tabulate (table) coral, with a percentage of 10.71%, while the least abundant type is non-Acropora coral mushroom (mushroom), with a percentage of 0.40%. An image of Acropora tabulate is shown in Figure 3-23.

Figure 3-23: Most abundant coral species at station 5: Acropora tabulate (Source: private collection, P. Beralas Pasir)

6.   Station 6

Station 6 was located to the west of Beralas Pasir Island, with a sea floor depth of 1.4 metres from the coastline to 170 metres into the open sea. From the results of the ground truth data

collection, the percentage of live coral cover here was 32%, in the "medium" category. The percentage of habitat cover is shown in Figure 3-24.
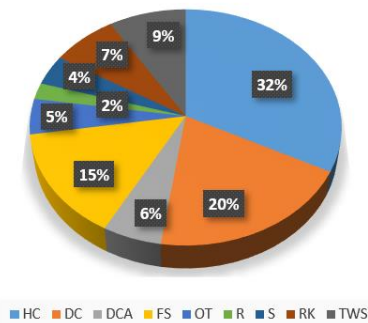

Figure 3-24: Percentage of coral reef cover at station 6

The manager of the Beralas Pasir Island tourist area stated that the location of station 6 was a spot often used for snorkeling, diving, playing kanau or other water tourism by tourists, because the water is calm and not too deep and its location is not too far from Beralas Pasir island and various types of coral near the station. Natural factors that could cause damage to coral at station 6 or even kill it included drupella snails, which are coral reef-eating animals (Figure 3-25). The percentage of diversity at station 6 is shown in Table 3-15.
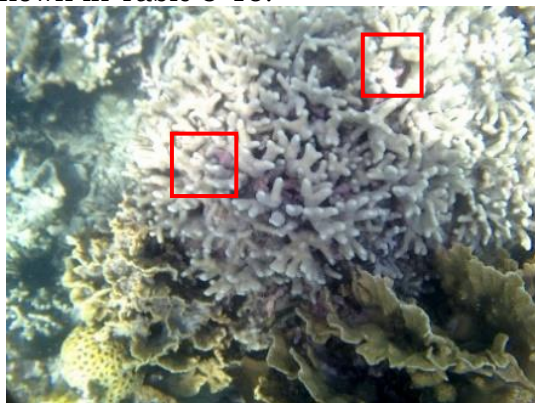

Figure 3-25: Coral-eating Drupella snails (source: private collection, Beralas Pasir Island)

Table 3-15: Percentage of coral reef species diversity at station 6.

Species	(%)
Acropora	
Acropora Digitate (ACD)	4.51
Acropora Encrusting (ACE)	0.82
Acropora Tabulate (ACT)	2.46
Non-Acropora	
Coral Branching (CB)	0.82
Coral Foliose (CF)	4.51
Coral Massive (CM)	13.9
Coral Mushroom (CMR)	0.82
Coral Submassive (CS)	7.79

The type of coral reef that is most abundant at station 6 is non-Acropora coral massive (solid), with a percentage of 13.93%, while the least abundant type is non-Acropora coral mushroom (mushroom), at 0.82% and Acropora encrusting (creeping), also at 0.82%. An image of coral massive is shown in Figure 3-26.

Figure 3-26: Most abundant coral species at station 6: non-Acropora coral massive (Source: private collection, Beralas Pasir Island)

7. Station 7

Station 7 was located to the west of the island, with a depth of 4 meters, and a seabed topography sloping from the coastline 230 metres into the open sea. Based on the results of the ground truth data collection, the percentage of live coral reef cover is 35%, which is in the "moderate" category, therefore, the condition is quite good. The percentage habitat cover is shown in Figure 3-27.
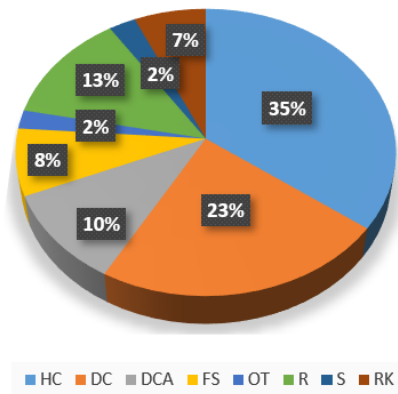
Figure 3-27: Percentage of coral reef
cover at station 7

According to the manager of the Beralas Pasir Island tourist area, the location of station 7 is a location that is also often used for snorkeling, diving, playing kanau or other water tourism by tourists. The percentage of diversity at the station is shown in Table 3-16.

Table 3-16: Percentage of coral reef
species diversity at station 7.

Species	(%)
Acropora	
Acropora Branching (ACB)	0.42
Acropora Digitate (ACD)	0.42
Acropora Encrusting (ACE)	2.08
Acropora Submassive (ACS)	0.83
Acropora Tabulate (ACT)	3.75
Non-Acropora	
Coral Encrusting (CE)	2.08
Coral Foliose (CF)	5.00
Coral Massive (CM)	16.6
Coral Mushroom (CMR)	0,42
Coral Submassive (CS)	3.33

The type of coral reef that is most abundant at station 7 is non-Acropora coral massive (solid), with a percentage of 16.67%, with the least abundant species, with a percentage of 0.42%, being non-Acropora coral mushroom (mushrooms),

Acropora branching (branching) and Acropora digitate (fingers). An image of coral massive is shown in Figure 3-28.

Figure 3-28: Most abundant coral species
at station 7: non-Acropora
coral massive (Source:
private collection, Beralas
Pasir Island)

8. Station 8

Station 8 was located to the west of Beralas Pasir Island, at a depth of 4.2 metres, with the topography of the seabed sloping from the coastline 250 meters into the open sea. Based on the results of the ground truth data collection, the percentage of live coral reef cover was 50%, which is in the "good" category. Percentage habitat cover at the station is shown in Figure 3-29, and the percentage of diversity in Table 3-17.
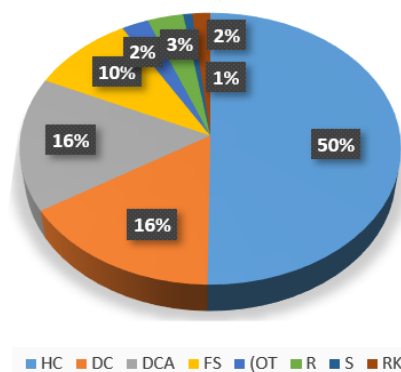

Figure 3-29: Percentage of coral reef cover at
station 8

Table 3-17: Percentage of coral reef species diversity at station 8.

Species	(%)
Acropora	
Acropora Digitate (ACD)	1.26
Acropora Encrusting (ACE)	1.26
Acropora Tabulate (ACT)	5.44
Non-Acropora	
Coral Branching (CB)	16.74
Coral Massive (CM)	18.83
Coral Mushroom (CMR)	1.67

The type of coral reef that is most abundant at station 8 is non-Acropora coral massive (solid), with a percentage of 18.83%, and the least abundant species, with a percentage of 0.42%, are Acropora encrusting (creeping) and Acropora digitate (fingers). An image of coral massive is shown in Figure 3-30.

Figure 3-30: Most abundant coral species at station 8: non-Acropora coral massive (Source: private collection, Beralas Pasir Island)

9.   Station 9

Station 9 was located to the west of Beralas Pasir Island, at a depth of 1.5 metres, with the topography of the seabed sloping from the coastline 250 metres into the open sea. From the ground truth data collection, the percentage of live coral reef cover was 26%, in the "moderate" category, so it can be said that the condition is damaged. The percentage habitat cover at station 9 is shown in Figure 3-31.
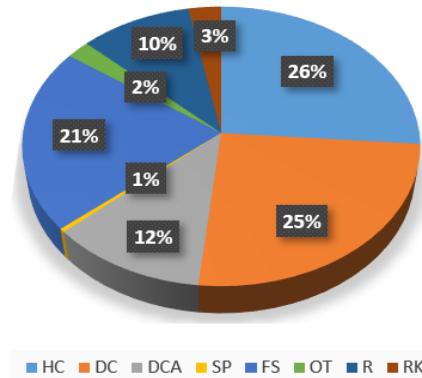

Figure 3-31: Percentage of coral reef cover at station 9

According to the manager of the Beralas Pasir Island tourist area, the location of station 9 is also often used for playing kanau or other water tourism by tourists because the water is calm and not too deep. The percentage of diversity at the station is shown in Table 3-18.

Table 3-18 Percentage of coral reef species diversity at station 9.

Species	(%)
Acropora	
Acropora Digitate (ACD)	0.83
Acropora Encrusting (ACE)	1.25
Non-Acropora	
Coral Foliose (CF)	8.75
Coral Massive (CM)	7.50
Coral Mushroom (CMR)	4.17
Coral Submassive (CS)	3.75

The type of coral reef that is most abundant at station 9 is non-Acropora coral foliose (sheet), at 8.75%, while the least abundant species, with a percentage of 0.42%. An image of coral foliose is shown in Figure 3-32.
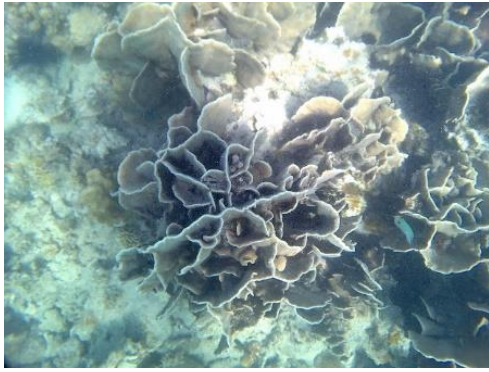
Figure 3-32: Most abundant coral species at station 9: non-Acropora coral foliose (Source: private collection, Beralas Pasir Island)

10. Station 10

Station 10 was located to the south of the island, with a depth of 6.5 metres and a sea floor topography sloping from the coastline 350 meters into the open sea. Based on the field data collection, the percentage of live coral reef cover at the station is 50% which is in the "good" category. The percentage of habitat cover is shown in Figure 3-33.
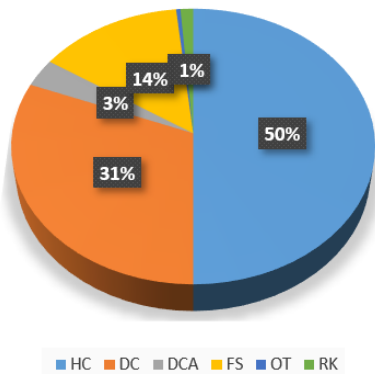

Figure 3-33: Percentage of coral reef cover at station 10

The manager of the Beralas Pasir Island tourist area said the location of station 10 was rarely used for snorkeling or diving by tourists because it had fairly strong currents originating from the east of the island in the Natuna Sea and circulating to the south. The percentage of diversity at station 9 is shown in Table 3-16. Several natural factors have caused damage to the coral reefs in this location, namely the drupella snail, which is a coral-eating snail, and the algae Caulerpa racemose, which lives on coral reefs and can interfere with their growth (Figure 3-34). The percentage of diversity at station 10 is shown in Table 3-19.
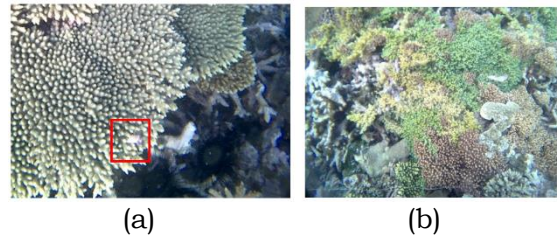

(a) (b)

Figure 3-34: (a) coral-eating drupella snail; (b) algae Caulerpa racemosa living on the coral (Source: private collection, Beralas Pasir Island)

Table 3-19: Percentage of coral reef species diversity at station 10.

Species	(%)
Acropora	
Acropora Branching (ACB)	4.13
Acropora Digitate (ACD)	0.41
Acropora Encrusting (ACE)	2.07
Acropora Tabulate (ACT)	15.29
Non-Acropora	
Coral Foliose (CF)	2.89
Coral Massive (CM)	4.55
Coral Submassive (CS)	20.66

It can be seen that the type of coral reef that is mostly present at station 10 is non-Acropora coral submassive (dense-bumps), with a percentage of 20.66%, with the least abundant species, with a percentage of 0.42%. An image of coral submassive is shown in Figure 3-35.

Figure 3-35: Most abundant coral species at station 10: non-Acropora coral submassive (Source: private collection, Beralas Pasir Island)

3.4 Discussion

1. Changes in the Coral Reef Area between 2011 and 2018

Based on the results of the monitoring research on changes in the area of coral reefs around Beralas Pasir Island using SPOT 4 and SPOT 7 imagery, it can be seen that they experienced a decrease. In 2011, using SPOT 4 images, it was established that the total area of coral reefs was 67,560 hectares, whereas in 2018, using SPOT 7 imagery, the total area of coral reefs was 38,338 hectares, a decline of 29,222 hectares.

2. Condition of Coral Reef Habitat Cover

Based on the results of the research on the condition of coral reef cover around Beralas Pasir Island conducted by Andriman et al. (2013), the percentage of live coral cover in 2010 was 62.38%, while Sidik et al., (2013) found that in 2013 the percentage of cover was 29-57%, while in 2020 this figure ranged from 26-53%, generally being in the medium category. In this study, the highest percentage of coral cover was at station 3, with a percentage of 53%, and the lowest at station 9, with a percentage of 26%. Based on all the research that has been conducted on Beralas Pasir Island, it can be seen that there has been a decrease in the habitat of living coral. According to our study, one of the factors that has caused this has been the disturbance of natural factors, namely drupella snails, an abundance of Caulerpa racemose algae, sea urchins, and the proliferation of seaweed types Padina sp. and Halimeda sp.

4 CONCLUSION

The conclusion from this is that there was a change in the area of coral reef cover between 2011 and 2018, with a fall of 29,222 hectares. The percentage of live coral cover across the stations ranged from 26-53% and was is generally in the medium category. The accuracy rate of the image classification results in the study is 83%, which is in the strong agreement category (strong).

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AUTHOR CONTRIBUTIONS

Monitoring Changes in Coral Reef Habitat Cover on Beralas Pasir Island Using Spot 4 and Spot 7 Imagery from 2011 and 2018. Lead Author: Rosaria Damai, Viv Djanat Prasita, Kuncoro Teguh Setiawan.

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