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SPATIAL COMPOSITION OF BENTHIC SUBSTRATE AROUND BONTOSUA ISLAND

Muhammad Banda Selamat[1*], Mahatma Lanuru[1], Amir Hamzah Muhiddin[1]

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ABSTRACT

Coral reefs and seagrass are natural fortress for small islands from waves and ocean currents. The spatial distribution of these benthic substrate should be known and monitored regularly. This study aims were to map existing benthic substrates on the reef flat of Bontosua Island, determine the spatial composition and develop index ratio. Benthic substrates were surveyed using geotagging technique. Their distribution were estimate using Quickbird image that was rectified and classified using ISOcluster method and validate by 240 selected photos. The seagrass were surveyed at 8 stasions to record percent cover and species composition. Depth profiles were track along 10 reef flat line segment. Bontosua Island has an elongated shape from South to Northwest. This study had produced a benthic substrate distribution map with thematic accuracy 76%. Total area able to map were 54.2 hectares. About 43% benthic substrates at Bontosua were mixture of coral rubble, seagrass and algae, 20% was mixture of rubble and algae, 16% dominated by seagrass, 13% mixture of sand and seagrass and 8% substrate were dominated by live coral. There were eight seagrass species found with average percent cover 37.2 ± 12.5 percent. The spatial ratio of live coral, seagrass and mixed substrate for West side reef flat was 2:20:49 and 1:9:9 for East side. This indicate that the distribution of benthic substrates on the West side is much wider than on the East side. This approach potentially applied to study the relationship between benthic substrate composition and the deformation of small islands.

Keywords: benthic substrate, spatial composition, spatial ratio index, small islands, seagrass

INTRODUCTION

Coastal ecosystems such as coral reefs, seagrass and mangroves play an important role in maintaining coastal stability (Spalding *et al*. 2014). The ecosystem services are function of various variables such as ecosystem size, season, type of disturbance, and species interaction (Barbier *et al*. 2008). For example, sea wave reduction by seagrass beds is only optimal when the size and density of the sea grass is maximum..

Coral reefs in Spermonde, South Sulawesi are threatened by sedimentation, destructive fishing (Sawall *et al*. 2013) and coral bleaching. Based on Landsat image analysis, the rate of coral damage in Spermonde is about 300 hectares per year (Rauf and Yusuf, 2004). Recent mapping found that there has been a decline in live coral cover over period of 20 years starting from 1994 with a rate of 174 ha/year (Yasir Haya and Fujii, 2017). Indicates that detailed information of benthic substrate distribution in this region is still highly needed. Moreover, the coral reefs may act as absorbant of wave energy that propagate to the shore (Ferrario *et al*., 2014), so the knowledge of its distribution also important for disaster mitigation. Satellite imagery proved to be effective for mapping coral reefs habitat when supported by sufficient field data (Roelfsema *et al*, 2013; Selamat *et al*, 2012). The spatial pattern of coral reefs has a positive relationship with topographic variation form (Fuad, 2010).

[1]Department of Marine Science, Hasanuddin University
Jl. Perintis Kemerdekaan Km.10, Makassar 90245, Indonesia
[*]Muhammad Banda Selamat
Email: mbandas2006@yahoo.com

The complexity of coral reefs occupies a wide spatial range that can be approximated using different satellite imagery depend on study objective (Ferrari *et al*., 2016).

The Small islands in Spermonde can be classified as coral islands by the origin of its formation. The islands like these are commonly surrounded by seagrass and coral reef ecosystems with various variations of geomorphic zones. Coral reefs and seagrass beds have a very important role for these islands, especially in blocking waves and ocean currents so that coastal erosion remains minimum.

This study aims were to map existing benthic substrates on the reef flat of Bontosua Island, determine their spatial composition and develop a simple index value to represent the composition of live coral, seagrass and mixed substrate. This information can be optimized to see how variation of benthic substrate composition may affect the magnitude of environmental services, for example in maintaining the stability of the shoreline.

MATERIALS AND METHODS

This study was conducted from August to October 2016 at Bontosua Island, Liukang Tupabbiring District, Pangkejene Islands (Figure 1). The equipment and materials used are presented in Table 1. Research was generally divided into two major sections. The first section were a hydrographic and ecological survey that includes measurements of bathymetry on reef flat area, continuous substrate photo shooting (coral, macroalgae, seagrass) and seagrass cover survey.

The second section focuses on the processing and analysis of photographs and satellite imagery to map the distribution of benthic substrates in the study area. Spatial analysis was performed to see the distribution of substrate types along the reef flat profile at wind direction and to calculate the substrate (distance) composition from the shoreline.

Table 1. Equipments and Materials in The Study

Material and Equipments	Functions
Quickbird satellite image	To produce benthic map
Quadrats with rectangular grid (50 cm X 50 cm)	Seagrass observation
Global Positioning System (GPS) e10	Positioning the sampling stasions
Roll Meter (30 m)	Line transect on seagrass sampling
Navigation compass	Direction guidance on seagrass sampling
Seagrass cover photos (Mc Kenzie, 2003)	Guidance on seagrass percent cover estimation
Underwater cameras	To potray benthic substrate
Mapsonder 420	Depth profiling
Katingting	Survey mobilization
IDRISI Terrset 18	Image processing and GIS data analysis
Picasa 3	Photo processing
Mapsource 6	GPS data processing
Ms. Excell	Statistical spreadsheets

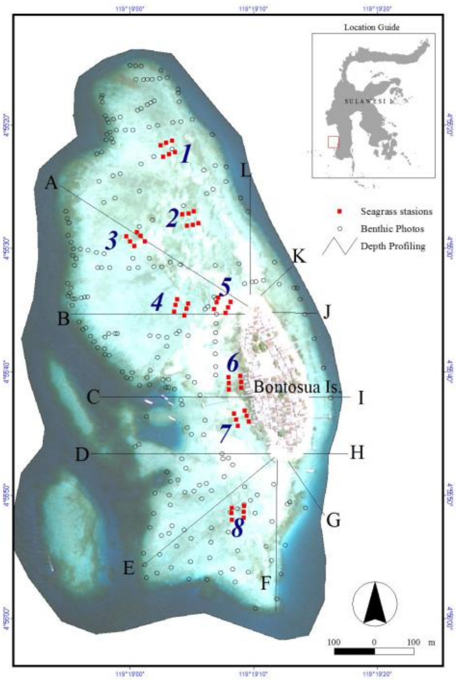

Figure 1. Study Location and Sampling Stations at Bontosua Island

Determination of Survey Track

The tracks plan was plotted on to the image of Bontosua Island using Google Earth software. These tracks were then input to GPS using mapsource software. The profile and distribution of benthic depth on reef flats of western side Bontosua Island are represented by transects A to F and on the East side by G to L (Figure 1). Field positioning was using two satellite navigation constellations which are GPS and Glonass in order to limit Horizontal Dilution Of Precession (HDOP) better than 3 meters.

Benthic Substrate Survey

Benthic substrate survey was done by using lapse time photo shooting technique. The cameras were placed at the side of the katingting which parallel to the mapsonder about 30 cm below the waterline. The position of camera lens was faced downward and perpendicular to the seabed. Camera time clock was unified to GPS time clock so that made possible to apply geotagging technique. Each photos then have same coordinate system as on satellite image. Recording of GPS positioning was done by using tracking technique (Selamat *et al*, 2012). Of the 1.954 photographs produced there were 240 selected photos to analyzed.

Seagrass Survey

The seagrass survey was conducted by modifying Seagrass Watch method (Mc Kenzie, 2003). Each sampling stations were consist of three parallel lines and separated 15 meters far. The length of each transect lines were about 30 meters. The position of start and end point of transects were defined and recorded by using GPS. After line transect installation was complete, then observation of seagrass cover on each plot was done by using quadratic frame which size 50 cm x 50 cm. The distance between plots were 5 meter starting from marked line 0 meter to meter 30. Thus the number of observation plots in each station were 21 and there were 8 seagrass stations surveyed (Figure 1). The seagrass species on each plot was identified and the percentage of seagrass cover was estimated based on the number of grids. Seagrass data processing was refer to sea grass monitoring guide book (Rahmawati *et al*. 2014).

Seagrass cover in one squared was calculated according to the formula

Seagrass cover (%) = total seagrass cover value / 4

The average seagrass cover per station was calculated according to the formula:

Average seagrass cover (%) = Number of seagrass cover of all transects / 21

Quickbird Image Processing

The satellite imagery used was the Quickbird satellite image of the November 1, 2014 recording date obtained freely from Google Earth (https://www.google.com/earth/). About 52 tile images were mosaicing and geometrically rectified to RMSE = 0,5. The original color composite image was then classified using ISOcluster unsupervissed technique with minimum number of cell in a valid class is 10 and the sample interval is 5 pixel. The classification map contains five benthic classes:

1) class wich dominated by seagrass, abbreviate as: dom.sg
2) class that mixed between sand and seagrass, abbreviate as: mix.sa.sg
3) class that mixed between rubble, seagrass and macroalgae, abbreviate as: mix.rb.sg.al
4) class that mixed between rubble and macroalga, abbreviate as:mix.rb.al
5) class wich dominated by live coral, , abbreviate as: dom.livc

We use 230 benthic photos to validate and produced image thematic accuracy matrix using method that similar to that developed by Congalton and Green (2009) and Stehman (2009). With all procedures and data limitations it was reasonable to set passing value for accuracy minimal 75%.

RESULTS AND DISCUSSION

Geomorphic Profile of Bontosua Reef Flat

Terminology for coral reef structures is often contextually defined, sometimes referring only to photographs or images (Stoddart, 1978). Studies about reef are commonly focus on the organism distribution along the area and rarely connected to variation of depth (stoddart, 1969). The geomorphic of a reef system may consist of back reef region, reef crest, seaward slope or fore reef. Each region divided into several zone like shore zone, lagoon, rear zone, reef flat and buttress zone (Goreau, 1959). The reef flat zone commonly has average 0.5 to 3 metres depth. Corals are rarely occur in reef flat except in deeper area. This is because the area is normally dry at low tides.

The reef flat zone around Bontosua Island can be divided into two parts: windward areas along West side and leeward areas along East side. Bontosua Island has an elongated shape from the south to the Northwest. If measured from the midpoint of the island then the reef flat of the west side has a wider size than the Eastern side. The northwest reef flat is the most wide zone compare to other side. The depth at reef flat is less than 1 meter and exposed at the lowest tide. Generally the depth change on East side is fast and form a steep cliff edge or can be named as reef slope. This is contrast to west side area where the depth change is small along reef flat zone to reef slope (Figure 2)

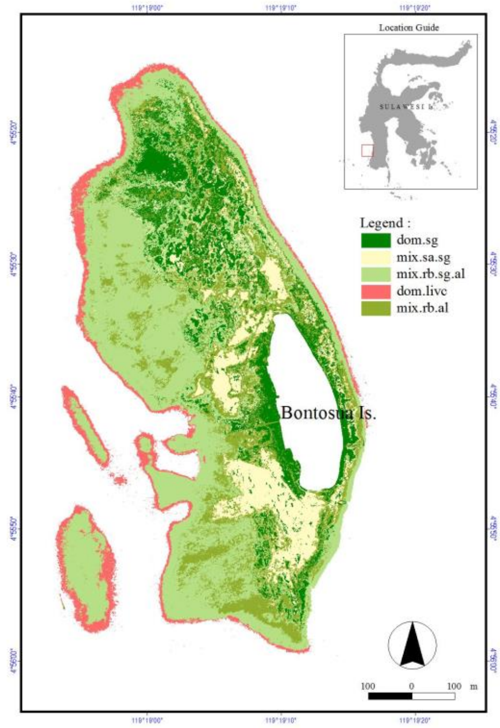

Figure 2. Depth Profile of Reef Flat Zone at Bontosua Island. A to F are represent West side of the Zone and G to L for East side (see Figure 1 for detail location)

The substrate distribution along depth profile line are obtained from field photographs. The live coral substrate (often mix with dead corals) was commonly found at west side reef slope at minimum depth was 1 meter. Live corals at east side of Bontosua island are limited and usually damage due boat anchoring. Seagrass substrates are common on both sides but more widely distribute on west side. Macro algae are easier to find at northwest and southwest of the island. The substrate of algae and rubble was more dominant at western reef flats compared to the eastern part (Figure 3).

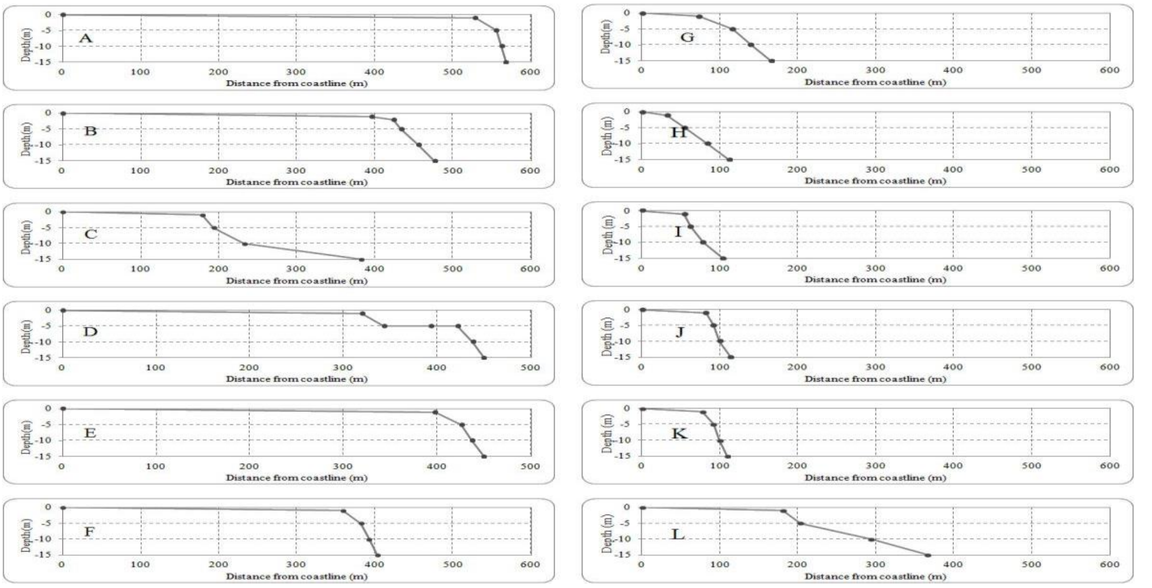

Figure 3. Benthic Substrate around Bontosua Island. A to F are represent West side of The Zone and G to L for East side (see Figure 1 for detail location)

Spatial Characterization of Substrate

Quickbird image classification using ISOcluster unsupervised techniques had produced a map of benthic substrate distribution for Bontosua Island (Figure 4). The thematic error for this map was 24% hence means that its level for thematic accuracy was 76% (Table 2). This level of accuracy was pass the critical value and the map was available for advance analysis. The total area spatially mapped was about 54.2 hectares. Thematic accuracy is influenced by many things, including the number of thematic classes displayed. Selamat *et al*. (2012) had compared two algorithms for mapping the benthic substrates with satellite imagery and concluding that for the same satellite imagery source, higher thematic accuracy can be generated by reducing the thematic class presented. Roelfsema *et al*. (2013 study had resulted in thematic accuracy of benthic community maps for Kubulau, Kadavu and Roviana areas in Fiji Islands respectively 66%, 68% and 65%. Satellite images used were Quickbird and IKONOS.

According to the map produced, benthic substrate composition around Bontosua island are 43% consist of mixture of coral rubble, seagrass and algae; mixture of rubble and algae about 20%; dominated by seagrass about 16%; mixture of sand and seagrass about 13% and substrate that dominated by live coral about 8%. Live corals communities were more easy to found at reef slope area of Nortwest side of the island. Seagrass beds are commonly found at West coast of the island and distribute sparsely around the reef flat.

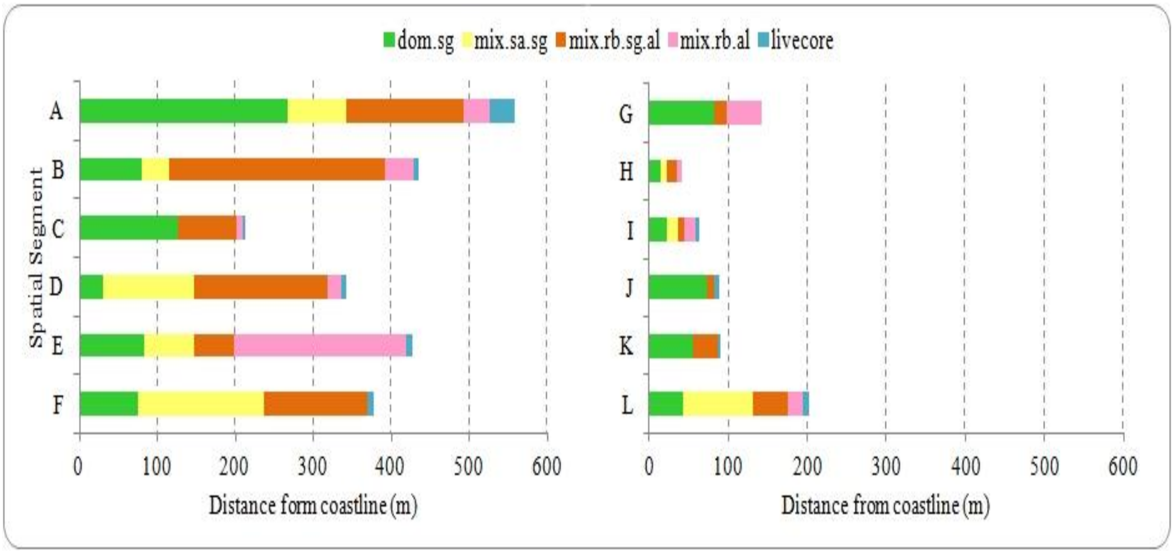

Figure 4. The Map of Benthic Substrate Distribution at Bontosua Island

Table 2. The Matrix Accuracy for Bontosua Substrat Benthic Image Classification

	dom.sg	mix.sa.sg	mix.rb.sg.al	dom.livc	mix.rb.al	Total	ErrorC
dom.sg	24	0	3	0	3	30	0.20
mix.sa.sg	9	11	2	0	0	22	0.50
mix.rb.sg.al	7	1	100	8	5	121	0.17
dom.livc	0	0	2	34	0	36	0.06
mix.rb.al	7	2	4	2	6	21	0.71
Total	47	14	111	44	14	230	
Error0	0.49	0.21	0.10	0.23	0.57		0.24

Seagrass Cover and Composition

There were 8 (eight) seagrass species found on the reefs of Bontosua Island in August 2016, those are *Enhalus acoroides*, *Thalassia hemprichii*, *Halophila ovalis*, *Cymodocea rotundata*, *C. Serrulata*, *Halodule uninervis*, *Syringodium isoetifolium* and *S. isoetifolium*. The percentage of seagrass cover at those observation stations were varied from 20.5 ± 13.3 to 67.5 ± 11.9 percent with average about 37.2 ± 12.5 percent (Figure 5a). The highest seagrass cover was found at station 6 which was the closest location to the residential area and the lowest seagrass cover was found at station 8 located on reef flat of southside the island. The seagrasses are generally spread over the northern side of the island and have the highest cover at the western bank of the island shore.

The species *Cymodocea rotundata* and *Thalassia hemprichii* were found in almost all stations, indicating that they have a wide distribution compared to other species (Figure 5b). The composition of seagrass in an area is more influenced by the adaptability of the seagrass to the environmental factor. The species *Cymodocea rotundata* and *Thalassia hemprichii* generally grow predominantly at carbonate and rubble sand substrate, forming a mixed community (Waycott *et al*., 2004).

Based on field observations, several factors that cause the low percentage of seagrass cover at South side of Bontosua Island were: ship anchorage activity around the seagrass area, coral reef damage that causing rubble to cover the seagrass and the presence of biota that digging hole around seagrass communities

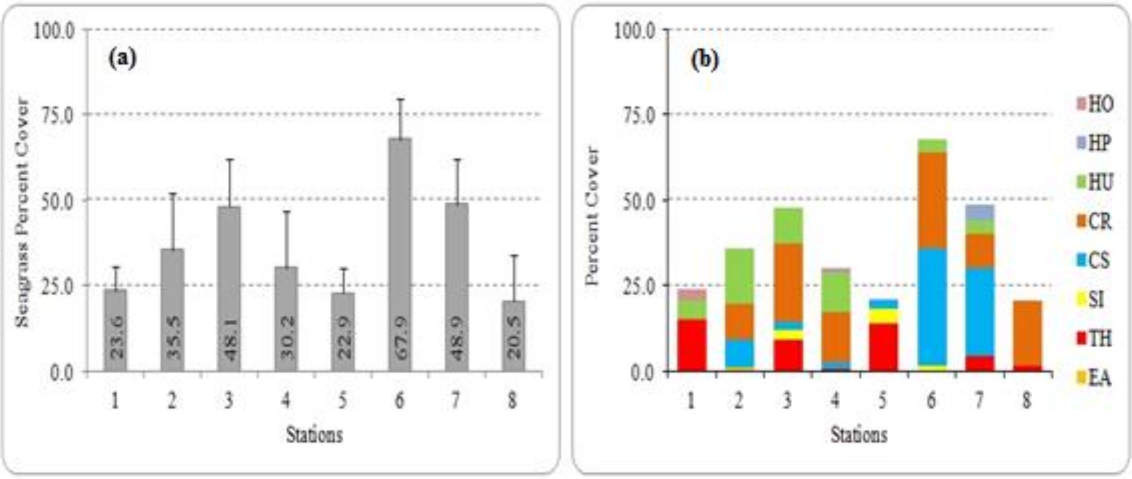

Figure 5. The Seagrass Cover (a) and Composition (b) at Bontosua Sampling Stations

Spatial Composition of Benthic Substrate

Spatial composition of benthic substrate is a comparison of distribution length of each benthic class on reef flat area. This study had profile 10 (ten) line cross section reef flat and five classes of benthic substrate presented in the form of spreading map (Table 3). The class benthic of dom.livc and dom.sg were containing unique and specific substrate, while benthic class of mix.sa.sg, mix.rb.sg.al and mix.rb.al were actually contain several substrates or not dominated by certain substrates. Therefore, the length distribution values for these three classes can be unified to form a new class called the mixed class. Furthermore the ratio between benthic classes can be calculated based on the longest segment distance (i.e segment A). The calculation results of spatial benthic substrate ratios for the Western and Eastern sides of Bontosua island are presented in Table 4

Table 3. The Length Segment of Benthic Substrate Distribution along Reef Flat (unit in meters)

Benthic Classes	Segment of Cross line											
	A	B	C	D	E	F	G	H	I	J	K	L
dom.livc	31.5	6.2	3.6	5.7	7.2	7.8	0.0	0.0	5.4	6.8	3.7	8.2
dom.sg	266.9	80.3	126.2	31.1	82.9	74.8	81.9	14.5	22.4	72.8	54.9	43.3
mix.sa.sg	75.4	34.5	0.0	116.3	64.6	162.3	0.0	8.3	15.0	0.0	0.0	88.7
mix.rb.sg.al	150.2	277.2	74.7	170.9	50.4	133.0	16.0	11.9	7.3	9.7	31.7	44.0
mix.rb.al	34.5	36.2	8.3	17.6	221.8	0.0	44.1	7.0	13.4	0.0	0.0	18.7
Sum	558.4	434.4	212.8	341.6	427.0	377.9	141.9	41.7	63.6	89.3	90.2	202.8

Table 4. The Spatial Benthic Substrate Ratios

Benthic Classes	Spatial Ratio	
	West	East
dom.livc	2	1
dom.sg	20	9
mixed	49	9

The spatial ratios of these benthic substrates are able to show us that the reef flats on the western side of Bontosua island are generally dominated by a mixed substrate. The seagrass may found more on the West side than on the East side. Furthermore, this value can also indicate us that the distribution of benthic substrates on the West side is much wider than on the East side based on the magnitude of values for each benthic class.

This spatial based valuation approach is potentially applied to neighbour islands in order to compare their benthic substrate composition variation in context long term and large scale area monitoring. This index also potential to deploy in the study of environmental services that benthic substrate provided. As well as how much this spatial ratio may indicate the shifting shapes of small islands.

CONCLUSION

In order to monitor the benthic substrate composition variation it is important first to develop a simple index value. This study had produced benthic substrate distribution map for 54.2 hectares of Bontosua reef flat. There were five benthic substrate classes with thematic accuracy 76%. Most of reef flat area (43%) were cover by mixture of coral rubble, seagrass and algae. Only 8% substrate were cover by live coral. Of the 16% substrate dominated by seagrass there were eight seagrass species found with average percent cover about 37.2 ± 12.5 percent. The benthic spatial composition or may stated as a spatial benthic substrate ratio index is actually a comparison of live coral, seagrass and mixed substrate line segment for the reef flat at area of study. In this study the spatial benthic substrate ratio shows that the distribution of mixed substrate was much higher at West side than East side of Bontosua reef flat. It is also shows that West side reef flat much more wider than East side.Further study that employ this approach to monitor long term of benthic substrate composition variation is needed in order to see its relationship with small island coastline change.

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