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 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 ISocluuster 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 seagrass 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).

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 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, Luikang 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

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

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 mapsourse 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 unsupervised 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).
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 Northwest side of the island. Seagrass beds are commonly found at West coast of the island and distribute sparsely around the reef flat.
Table 2. The Matrix Accuracy for Bontosua Substrat Benthic Image Classification

<table>
<thead>
<tr>
<th></th>
<th>dom.sg</th>
<th>mix.sa.sg</th>
<th>mix.rb.sg.al</th>
<th>dom.livc</th>
<th>mix.rb.al</th>
<th>Total</th>
<th>Error</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>dom.sg</td>
<td>24</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>30</td>
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<td>mix.sa.sg</td>
<td>9</td>
<td>11</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>22</td>
<td>0.50</td>
<td></td>
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<tr>
<td>mix.rb.sg.al</td>
<td>7</td>
<td>1</td>
<td>100</td>
<td>8</td>
<td>5</td>
<td>121</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>dom.livc</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>34</td>
<td>0</td>
<td>36</td>
<td>0.06</td>
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<tr>
<td>mix.rb.al</td>
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<td>4</td>
<td>2</td>
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<td>111</td>
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<td>14</td>
<td>230</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>0.49</td>
<td>0.21</td>
<td>0.10</td>
<td>0.23</td>
<td>0.57</td>
<td>0.24</td>
<td></td>
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</tr>
</tbody>
</table>

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.

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.
The substrates are able to support further mapping of tropical seagrass habitats. A. 2014. The assessment of study that employ this approach to monitor long term reef flat Bontosua reef flat. The spatial ratio of the mixed substrate is actually a comparison of live coral, 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 indicate 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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