Marine Habitat Distribution and Substrate Composition of Dangli Group of Islands, Langkawi UNESCO Global Geopark, Kedah, Malaysia

Jamil Tajam¹² & Mazlin Mokhtar¹,*

¹Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia.
²Marine Research and Excellence Center (MAREC), Faculty of Applied Science, Universiti Teknologi MARA (UiTM) Perlis, 02600, Arau, Perlis, Malaysia.

*Corresponding Author

Abstract

There are recurring problems facing the mapping of marine habitats using satellite remote sensing due to poor water quality resulting from high levels of suspended particles. This study was carried out to investigate the pattern of benthic features in the turbid water at Dangli group islands of Pulau Langkawi, Kedah using Acoustic Ground Discrimination System (AGDS). AGDS signals are capable of determining the distribution of coral habitats as well as categories within the coral reef areas by measuring roughness (E1) and hardness (E2) of the substrate. Eight clusters were identified during the survey, among them are live coral cover (Cluster I), rough surface covered by live substrate and fine particles (Cluster II), bedrock (Cluster III), sand, shell fragments and rubble (Cluster IV), Gorgonians sp. (Cluster V), fine sand and silt/clay (Cluster VI), sand (Cluster VII) and Clay/Silt (Cluster VIII). Observations revealed that the study location with the most abundant live coral cover was Pulau Dangli (10,782m²), followed by Pulau Pasir (10,633m²) and Pulau Gasing (7,593m²). Overall, the distribution of substrate on these three islands is according to the following sequence: Cluster VII > VI > I > II > VIII > IV > III > V. The outcome of the digital thematic map produced will then play a significant role in the process of managing the marine resources in Langkawi UNESCO Global Geopark. Apart from that, this approach will help the policy makers improve their understanding for informed decisions pertaining to environmental management and developing guidelines for utilizing this unique coastal ecosystem in a sustainable manner.

Keywords: Marine Habitat, Mapping, Discriminate Analysis, Marine Protected Area, Coastal Conservation
1. INTRODUCTION

Generally, clear water conditions are considered crucial for determining the health of an ecosystem and the effectiveness of environmental management. However, in recent years, there is a clear evidence showing that an ecosystem with turbid water conditions may also provide an environment for healthy coral reefs. The turbid water condition can prevent or reduce the amount of light influxes into the marine ecosystem while acting as a buffer for the coral reef communities when faced effects of climate change. This has been supported by the discovery of some reefs growing in turbid water conditions. For example, in the Seychelles archipelago where, after the 1998 El Niño caused high coral mortality, only large colonies of coral species resistant to increased temperatures were found in the area near the lagoon with turbid water conditions (Iluz, Vago, Chadwick, Hoffman, & Dubinsky, 2008). This is an area that requires more investigations.

In Malaysia, the Dangli group of islands is a good study location, because of the presence of most of coral colonies in turbid water conditions. This archipelago consists of three small islands, namely Pulau Dangli, Gasing and Pasir. Generally, this area is located at the northern part of Pulau Langkawi, 30km west of the northern end of Peninsular Malaysia where it is at the border between Malaysia and Thailand. The reefs here are distinctively exposed to the influence of Andaman Sea in the Indian Ocean. Although the water condition was poor, there were still some coral species being able to survive. There is a paucity of data on the resilience of coral reefs that live in turbid water, and there was no specific research conducted on this island to investigate this matter. There could be unique mechanisms never explored before, which if investigated will reveal interesting information, hitherto unknown to scientists. The present study will be helpful in providing data for use in sustainable management of this area.

A problem often highlighted is the limitation of satellite imagery when sea water is not clear or when information is needed deep water. According to Foster et al (2013), the accuracy of information obtained through aerial and satellite imagery is limited to temperate waters and coastal areas, while deep waters are a definite challenge to map. There has been a case in Florida, where over 55% of Florida Keys National Marine Sanctuary (about 1,540 square nautical miles) could not be mapped because of the water depth or clarity limitations (Gleason et al., 2008). Therefore, this study was aimed at investigating the pattern of benthic features in the turbid water using hydroacoustic signals.

It is based on the understanding that the hydroacoustic signals as a remote sensing tool can help in determining the distribution of coral habitats and categories within a coral reef by measuring different levels of hardness and roughness of the substrate. There is a paucity of data on this aspect in the tropical regions. Elsewhere, Hamilton et al. (1999) made a comparative study between the two different acoustic classification systems in the Great Barrier Reef, and Murphy et al. (1995) carried out a wide-scale mapping off the coast of Florida. Acoustic remote sensing has been used successfully in temperate waters in mapping of sublittoral habitats and biota (Sotheran...
et al., 1997; Foster-Smith et al., 1998;), mapping of kelp bed distribution (Foster-Smith et al., 2000) and occurrence of horse mussel beds (Magorrian et al., 1995). However, in Malaysia, the benefits of this system have not been fully utilized for the mapping of marine habitats although the knowledge of spatial patterns of marine physical, biological and geographical landscapes generates worthwhile information on habitat-species linkage (Jordan et al., 2005; Poulos et al., 2015).

Marine habitat maps can provide information on species diversity patterns, marine habitat types and spawning aggregation sites, and this data can be used for conserving biodiversity and aid the selection of marine protected areas, thus allowing managers to meet the country’s commitments towards the Convention on Biological Diversity (Cogan et al., 2009; Foley et al., 2010; Copeland et al., 2013), and fisheries management and coastal development planning (Edinger and Risk, 2000). Specifically, this investigation will map the seabed and other features of the marine ecosystem of Dangli Group of Islands and examine the changes in the diversity of different substrate classes as a way to measure habitat heterogeneity. It is expected that the implications of this research will manifest in future planning, designing, protection and management of the ecosystem of the islands and the livelihoods of local fishermen.

2.0 MATERIALS & METHODS

2.1 Description of study area

Islands forming the Dangli group (Figure 1) include Pulau Dangli, Pulau Pasir and Pulau Gasing, which measure 0.06km$^2$, 0.03km$^2$ and 0.05km$^2$, respectively. Located at the northern part of Pulau Langkawi. These uninhabited islands are clearly visible from the Tanjung Rhu beach. Geologically, these islands have rocky surface, with only 40% cover of tropical forest. The natural features of this island group are icons of Langkawi UNESCO Global Geopark (LUGG).

2.2 Acoustic Ground Discriminating System – RoxAnn

RoxAnn is a state-of-the-art product of Acoustic Ground Discriminating System (AGDS) that is commonly used as a remote sensing tool for marine surveys. According to Foster-Smith and Sotheran (2003), this system operates on the basis of a single beam echosounder, which integrates the components of the returned echo to give detailed information on the seabed features. Apart from the characteristics of ocean depth, the seabed roughness (E1) and hardness (E2), can also be measured by this system. The signals of E1 and E2 are derived from the tail of the first echo, and the entire second echo, respectively. On the other hand, White et al. (2003) stated that the second echo refers to the echoes that are reflected twice before returning to the transducer as seen in Figure 2. Furthermore, the basic data processing and discrimination of habitat are strongly dependent on the strength of the returning echoes, and the accuracy of seabed habitat information is subject to the features or characteristics of the sea floor.
Figure 1: Study area of Dangli Group of Islands

Figure 2. A diagram describing the acoustic variables recorded by a *RoxAnn* acoustic ground discrimination system (Hume et al., 2005).

E1 and E2 value are determined from the reflection of first and second echoes. E1 represents the seabed roughness and computed from the decay tail of the first return echo. While, E2 represents the seabed hardness and computed from second echo, which is reflected twice before returning to the transducer.
2.3 **RoxAnn AGDS survey setting and procedure**

The equipment used for the survey consisted of a RoxAnn signal processor combined with a Furuno single beam echo-sounder. A Garmin GPS (without differential correction) was interfaced with the system and the recorded data were plotted using the microplot where they were then exported as raw text file data. For accurate positioning, the GPS aerial was fixed at the highest point of the vessel on a scaffold pole above the echo-sounder’s transducer (fixed to the starboard side of the boat). The vessel ran at an average speed of 3 to 4 knots forming a continuous ‘U’ transect at 5 to 10 meter surface interval, perpendicular to each island. This allows the seabed ranging in depths between 3 to 25 meters (±2 meters tidal variations), where most live corals and other important habitats were found, to be surveyed. Meanwhile, for waters around smaller islands (Pulau Dangli, Pulau Gasing and Pulau Pasir), it was sufficient to make just several rounds around the islands with the survey lines spacing between 5 to 10 meters. During the survey, the output signals (position, depth, E1 and E2) were monitored and areas of interest (with high E1 and E2 values and variable depths) were noted, along with any potential erroneous data points. All of the data collected in the ASCII form were processed using the Surfer 13.0 software for thematic maps.

AGDS is more likely to differentiate between seabed habitats due to the fact that some of the substrate features give different acoustic reflections. Generally, the coral substrate has its own values of roughness (E1) and hardness (E2). Substrates of rock and gravel, on the other hand, generate high values of E1 and E2. Unlike rock and gravel, the muddy substrate absorbs the sound from the transducer and, therefore, will determine very low hardness (E2), and roughness (E1) values due to its flatness. Prior to the survey, the system was calibrated against the initially identified seabed substrate. Table 1 displays the substrates that were divided into eight (8) clusters.

<table>
<thead>
<tr>
<th>CLUSTER</th>
<th>SUBSTRATE DESCRIPTION</th>
<th>SUBSTRATE</th>
<th>ROUGHNESS (E1)</th>
<th>HARDNESS (E2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster I</td>
<td>Live Coral</td>
<td><img src="image1.png" alt="Image" /></td>
<td>0.015 - 1.209</td>
<td>0.067-0.928</td>
</tr>
<tr>
<td>Cluster II</td>
<td>Rough Surface Covered by Live Substrate + Fine Particles</td>
<td><img src="image2.png" alt="Image" /></td>
<td>1.115 - 2.837</td>
<td>0.067-2.347</td>
</tr>
</tbody>
</table>

Table 1 The seabed substrates identified and calibrated during the survey.
<table>
<thead>
<tr>
<th>CLUSTER</th>
<th>SUBSTRATE DESCRIPTION</th>
<th>SUBSTRATE</th>
<th>ROUGHNESS (E1)</th>
<th>HARDNESS (E2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster III</td>
<td>Bedrock</td>
<td></td>
<td>1.091 - 3.187</td>
<td>0.926 - 2.969</td>
</tr>
<tr>
<td>Cluster IV</td>
<td>Sand + Shell Fragments + Rubble</td>
<td></td>
<td>0.601 - 1.243</td>
<td>1.214 - 2.844</td>
</tr>
<tr>
<td>Cluster V</td>
<td>Gorgonians Sp.</td>
<td></td>
<td>0.151 - 1.802</td>
<td>0.000 - 0.354</td>
</tr>
<tr>
<td>Cluster VI</td>
<td>Fine Sand + Silt/Clay</td>
<td></td>
<td>0.002 - 0.616</td>
<td>0.057 - 0.432</td>
</tr>
<tr>
<td>Cluster VII</td>
<td>Sand</td>
<td></td>
<td>0.014 - 2.101</td>
<td>0.068 - 2.848</td>
</tr>
<tr>
<td>Cluster VIII</td>
<td>Clay/Silt</td>
<td></td>
<td>0.001 - 0.582</td>
<td>0.000 - 3.434</td>
</tr>
</tbody>
</table>
2.4 Map accuracy assessment

In order to determine the precision of this map, the accuracy assessment is carried out. It is considered essential for obtaining a precise map (Roelfsema et al., 2006). The assessment is based on the error matrix, where it is accomplished by comparing clusters on the map with the actual cluster type at field studies (Foody, 2010). Moreover, Kappa and Tau coefficients are applied to provide extensive information on both overall accuracy (OA) and the user and producer's accuracy of individual classes. According to the scheme of Fleiss (1981), the Kappa coefficient can be categorized as ‘K< 0.4: poor’, ‘0.4 < K < 0.75: good’, and ‘K > 0.75: excellent’.

3.0 RESULTS AND DISCUSSION

3.1 Interrelation among roughness, hardness and depth

A total of 14,543 points were successfully recorded using AGDS at Dangli Group of the islands during the survey period. The survey transects consisted of lines both parallel and perpendicular to each island as an effort to obtain accurate results. The number of individual recorded points of Pulau Dangli, Pulau Gasing and Pulau Pasir were 6,103, 3,411 and 5,029, respectively. The survey covered a total area of approximately 735,895m$^2$. According to Figure 3a, the average depth recorded during the survey was 8.73 ±4.26 meters and the deepest area was located at the northern part of each island. From the observation, the west coast of most islands shows a more sloping formation against depth. However, the east coast of the island has a gentle slope except for Pulau Pasir. Most of the coral colonies on these three islands were found living within the slope area.

![Figure 3a. Bathymetry map generated from the surveys. Data are interpolated according to ‘nearest neighbour’ method using the program Surfer 13.0.](image-url)
Figure 3b Roughness (E1) and Hardness (E2) profile of study areas.
Initially, the usage of the acoustic signal has enabled the identification of properties of the seabed entropy, namely the roughness and hardness of the seabed surface. According to Serpetti et al., (2011) the combination of roughness (E1) and hardness (E2) is able to provide an indication of the topography and distribution profile of the seabed features, respectively. For observations along the depth, the values of E1 and E2 varied and showed differences depending on signal strength, being either weak or strong. It is evident from Figure 4 that the values of the roughness and hardness differed in trend (linearly and inversely related) against depth. Pearson correlations for both roughness and hardness in this study gave ‘r-values’ of 0.092 and -0.378, respectively. The difference in correlation values was probably related to the depth factor, effect of water column characteristics and also the seabed topography. Serpetti et al. (2011) stated that the positive Pearson correlation values for roughness are particular to shallow water substrate distribution. On the other hand, the differences between the bottom types cannot be explained only by looking at the depth value (Voulgaris and Collins, 1990; Kloser et al., 2001; Brown et al., 2005). In agreement with previous studies, instead of the depth criteria, we defined that the acoustic response during the surveys in this shallow water as a response to a different survey track orientation and vessel speed (Wilding et al., 2003) and high heterogeneity of the seabed (Brown et al., 2005).

3.2 Accuracy assessment

The accuracy test of the marine habitat map classification conducted by using the confusion matrix will generate the Producer’s and User’s Accuracy of each class, Overall Accuracy (OA), and Kappa and Tau Coefficient, as shown in Table 2. A total of 450 accuracy assessment points were collected to obtain the accuracy of each map. Overall, the accuracy assessment of the classification of marine habitat mapping for all of these islands indicated an OA reading of 61.11%. The Tau coefficient suggested that 57.20% of the clusters were classified correctly. However, Kappa analysis has implied a lower value of coefficient which indicated that only 54.35% of the clusters were correctly classified. It indicates that the marine habitat classification scheme of the eight clusters with the maximum likelihood approach gives good results. This is based on the strength of Kappa analysis that vis in agreement with the scheme proposed by Fleiss (1981). The cluster of ‘Gorgonians on Sand’ (Table 2) shows lower accuracy compared to other types of habitats. Nevertheless, ‘Live Coral Cover’ and ‘Sand’ clusters have relatively high Producer’s Accuracy with values of 71% and 70%, respectively, while the User’s Accuracy displays a high percentage on ‘Sand’ (77%) compared to ‘Live Coral Cover’ (73%). Furthermore, the error matrix in Table 2 shows an extensive confusion between ‘Rock’, ’Gorgonians on Sand’, ‘Fine Sand and Silt/Clay’ and ‘Clay/Silt’.
Figure 4: Scatter plot visually showing roughness-E1 (a) and hardness-E2 (b) indices with depth.
Table 2: Error matrices representing accuracy assessment of supervised map

<table>
<thead>
<tr>
<th>Accuracy Assessment (i)</th>
<th>Live Coral Cover</th>
<th>Rough Surface Covered by Live Substrate</th>
<th>Rock</th>
<th>Sand, Shell Fragments and Rubble</th>
<th>Gorgonians on Sand</th>
<th>Fine Sand and Silt/Clay</th>
<th>Sand</th>
<th>Clay/Silt</th>
<th>Raw Total (nj)</th>
<th>User’s Accuracy (UA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>53</td>
<td>11</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>73</td>
<td>0.73</td>
</tr>
<tr>
<td>II</td>
<td>9</td>
<td>43</td>
<td>8</td>
<td>6</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>69</td>
<td>0.62</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>7</td>
<td>8</td>
<td>29</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>56</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>4</td>
<td>6</td>
<td>40</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>1</td>
<td>69</td>
<td>0.58</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>1</td>
<td>3</td>
<td>8</td>
<td>3</td>
<td>11</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>29</td>
<td>0.10</td>
</tr>
<tr>
<td>VI</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>10</td>
<td>1</td>
<td>33</td>
<td>13</td>
<td>63</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>VII</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>10</td>
<td>61</td>
<td>0</td>
<td>79</td>
<td>0.77</td>
<td></td>
</tr>
<tr>
<td>VIII</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>2</td>
<td>12</td>
<td>0.42</td>
<td></td>
</tr>
<tr>
<td>Column Total (ni)</td>
<td>75</td>
<td>71</td>
<td>58</td>
<td>74</td>
<td>20</td>
<td>55</td>
<td>87</td>
<td>10</td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>Producer’s Accuracy (PA)</td>
<td>0.71</td>
<td>0.61</td>
<td>0.50</td>
<td>0.54</td>
<td>0.55</td>
<td>0.60</td>
<td>0.70</td>
<td>0.50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Coefficient Analysis
a) Overall Accuracy 61.11%
b) Overall Kappa-Coefficient 54.35%
c) Overall Tau-Coefficient 57.20%

3.3 Distribution of marine habitat features

Table 3 showns the substrate composition of Pulau Dangli, Pulau Gasing and Pulau Pasir. Evidently, Cluster VII recorded the highest percentage among all the clusters at Pulau Dangli with the value of 53.81% (151,209 m²), followed by Cluster VI (fine sand and clay/silt) where the value was 37.79% (106,197 m²). Meanwhile, the distribution of corals (Cluster I) occupied third place among these cluster groups, estimated to have a total cover area of about 10,782 m². Most of the live coral cover was found along the southeast and southwest of the islands (Figure 5a). However, the percentage of Cluster II which is a combination of rough surface or dead corals covered with the live substrate (algae and soft coral) and fine particles is slightly lower compared to Cluster I, with a difference of 4,933 m² in total area. Additionally, Cluster VIII (mud/clay/silt) was well distributed throughout the west and southeast of the islands at nine meters depth, posing as the fifth most common substrate with a whole coverage area of 4,260 m². Furthermore, a scattered distribution of a mixed substrate of sand, shell fragments and rubble (Cluster IV) with an entire percentage of 0.45% (1,278 m²) was found at five to eight meters depth, followed by the Gorgonians species on sand with a percentage of 0.41% (1,145 m²). Some rock formations that make up Cluster III were defined and distributed from the shallow waters down to about seven meters.
Pulau Gasing is among these three islands. Cluster VII composed of sand dominated this island with a value of 66.51% (Table 3). Moreover, the mixture of fine sand and silt/clay (Cluster VI) covered 20.82%, recording the second highest among the clusters (Figure 5b). However, Cluster I was seen slightly below Cluster II, with a difference of 622 m$^2$ in total area. The coral reefs (Cluster I) were mostly defined at the east coast of the island. Meanwhile, Cluster VIII, IV, and V recorded percentage values of 2.28%, 2.21% and 0.43%, respectively. Similar to Pulau Dangli, rock formations showed the lowest distribution among the clusters, with a total area of 308 m$^2$ (0.11%).

Figure 5c shows a thematic map with the substrate distribution on Pulau Pasir. Cluster VII dominated all the other clusters, recording a percentage of 66.97% with a total area of 163,337 m$^2$. There are also scattered distributions of coral reefs found in this island with a cover area of 10,633 m$^2$. However, this still remains the third highest value when compared to other substrates. Furthermore, Pulau Pasir is the only island with a fairly stable beach formation. The beach has a gently sloping topography compared to the other two islands. This formation could greatly influence the distribution of corals within this area.

Based on observations of the thematic map (Figure 5), the island with the most abundant live coral cover was Pulau Dangli, followed by Pulau Pasir and Pulau Gasing. This is probably due to the factors of biogeography, topography, size and position of the island that affect the coral reef distribution. In conclusion, the average distribution of substrates on these islands is according to the following sequence: Cluster VII (Sand) > Cluster VI (Fine Sand and Silt/Clay) > Cluster I (Live Coral Cover) > Cluster II (Rough Surface Covered by Live Substrate and Fine Particles) > Cluster VIII (Clay/Silt) > Cluster IV (Sand, Shell Fragments and Rubble) > Cluster III (Bedrock) > Cluster V (Gorgonians sp.)

### Table 3: Substrate composition of Pulau Dangli, Gasing and Pasir.

<table>
<thead>
<tr>
<th>SUBSTRATE CLUSTER</th>
<th>Pulau Dangli</th>
<th>Pulau Gasing</th>
<th>Pulau Pasir</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (m$^2$)</td>
<td>Percentage (%)</td>
<td>Area (m$^2$)</td>
<td>Percentage (%)</td>
</tr>
<tr>
<td>I Live Coral</td>
<td>10,782</td>
<td>3.84%</td>
<td>7,593</td>
<td>3.60%</td>
</tr>
<tr>
<td>II Rough Rock or Dead Coral Covered with Live Substrate</td>
<td>5,849</td>
<td>2.08%</td>
<td>8,215</td>
<td>3.89%</td>
</tr>
<tr>
<td>III Rock</td>
<td>308</td>
<td>0.11%</td>
<td>736</td>
<td>0.35%</td>
</tr>
<tr>
<td>IV Sand + Shell Fragments + Rubble</td>
<td>1,278</td>
<td>0.45%</td>
<td>4,471</td>
<td>2.12%</td>
</tr>
<tr>
<td>V Gorgonians on Sand</td>
<td>1,145</td>
<td>0.41%</td>
<td>900</td>
<td>0.43%</td>
</tr>
<tr>
<td>VI Fine Sand + Silt/Clay</td>
<td>106,197</td>
<td>37.79%</td>
<td>43,918</td>
<td>20.82%</td>
</tr>
<tr>
<td>VII Sand</td>
<td>151,209</td>
<td>53.81%</td>
<td>140,322</td>
<td>66.51%</td>
</tr>
<tr>
<td>VIII Clay/Silt</td>
<td>4,260</td>
<td>1.52%</td>
<td>4,810</td>
<td>2.28%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>281,028</td>
<td>100%</td>
<td>210,965</td>
<td>100%</td>
</tr>
</tbody>
</table>
3.3 Vulnerability to human impacts

Before any mitigation and management efforts towards conservation are to be carried out, knowing the current status of coral reefs in these areas through acoustic approach is highly advisable. There are still quite a limited number of scientific studies on qualitative, quantitative, and bio-geographical aspects of coral reef communities in this area. A comprehensive report on the distribution of coral reefs in Pulau Dangli, Pulau Gasing and Pulau Pasir using Rapid Benthic Survey (RBS) method was completed by Hendry and McWilliams (2002). They stated that Pulau Dangli is less degraded compared to Pulau Gasing and Pulau Pasir, which recorded the coral condition within the area to be ‘Fair to Good’. The percentage of live coral cover found was between 5 to 55% with the dominant genera of hard corals being massive Porites sp. and Diplastrea sp. However, the remaining cover that was between 30 and 95% was composed of dead corals.
The deterioration of coral reefs in these islands might be due to the geographical position of the islands in the northern part of the Malacca Strait. High turbidity due to sedimentation characterizes the environment around the islands there. Most of the coral colonies in the LUGG are greatly influenced by the movement of suspended sediments. Rapid land-based development in the coastal zone have increased the rate of sedimentation that has undermined the coral health. Sedimentation rate is particularly high due to water runoffs due to heavy rainfall during south-west monsoon season (Jamil et al., 2017). Jonsson (2003) noticed that the water conditions around the islands was characterized by high sedimentation and low visibility. Lee and Mohamed (2011) who worked on the sedimentation rates in LUGG reported values of 49.92 mg/cm²/day and 6.64 mg/cm²/day for Telok Yu and Datai, respectively. Meanwhile, according to Abdullah et al. (2011), the sedimentation rate is usually lower during the north-east monsoon compared to the south-west monsoon in the northern part of LUGG. Furnas (2003) and Wolanski et al. (2008) indicated that these fine sediments could have a destructive effect on benthic coral reef assemblages. Thompson et al. (2005) linked the low richness of coral juveniles to the higher ‘clay/silt’ content of the sediments in that region. More studies on the relationship of the benthic organisms with sediment have been reported by Bishop (2007) where they showed a more complex association and believed that the benthic flora and fauna are affected by the re-suspension of fine sediments.

Other prominent factors that could have caused the decline of coral distribution in these islands were domestic sewage and industrial pollution. The impact of sewage has also been discussed by Meesters et al. (1998) and Szmant (2002) who explained how the sewage caused eutrophication resulting in an accelerated reef decline, and highlighted the synergistic effect of sedimentation and turbidity on the coral reef ecosystem. Schlacher et al. (2005) also indicated that the discharge of sewage constitutes a significant source of pollution and a powerful stressors for coral reefs.

3.4 Future management and conservation

Remote sensing has become one of the standard methods of determining the effectiveness of measures for management of the coral reef ecosystem (Goodman & Ustin, 2007). Building an inventory of coral reefs is vitally important for monitoring and providing accurate benthic habitat maps (Foster et al., 2013). This information can be helpful in deciding the type and scale of conservation intervention. Habitat mapping not only plays a significant role in the effectiveness of coastal conservation management but also regulating the fisheries operations (Hill et al., 1997). According to Kelleher and Kenchington (1992), the International Union for Conservation of Nature (IUCN) has strongly recommended that proclaiming Marine Protected Area (MPA) is the best way to preserve the existing complexity of the marine habitat, preventing decline or collapse of an ecosystem. Besides, many marine scientists (Poulos et al., 2015; Lundquist et al., 2017) have suggested that MPAs can also serve as limited areas focussing on protecting single species or communities. When MPAs cover large areas focused, they can be an effective tool for habitat connectivity and
biodiversity conservation (Day et al., 2002; Poulos et al., 2015) and recovery of fisheries. Globally, the establishment of MPAs is considered in the strategic plans for implementing the Convention on Biological Diversity (Aichi Biodiversity Targets), which stated that at least 10% of coastal and marine areas should be conserved and equitably managed by the year 2020 (Toonen et al., 2013; Wilhelm et al., 2014; Lundquist et al., 2017). Malaysia currently has 2.3 percent of marine area under protection (World Bank, 2016), indicating that more must be done to meet international targets and standards.

The unique status of the coral habitats in Dangli coastal ecosystem are still surviving in turbid water conditions while experiencing direct anthropogenic threats in the form of sedimentation, nutrient run-off, discharge of raw sewage, coastal developments and overfishing. There are signs that marine habitats in the area are decline and in urgent need for conservation. Health of coral reefs will enhance significantly by measures for improving the water quality around the Dangli islands. A more comprehensive management can be achieved through a community-based habitat management system that reduces anthropogenic effects, and helps in enforcing fishing controls, curbing reckless anchoring and sanctuary zones. Ecosystem Approach to Fisheries Management (EAFM) as a part of the holistic approach for LUGG coastal resource management is step in the right direction. Attwood (2005) has shows the benefits of EAFM on marine conservation. EAFM gives new impetus to the coral reef managers to cooperate with fisheries managers in the conservation of the reef ecosystem (Hiew et al., 2012 Creating a Fisheries Refugia Zone under the Malaysian Fisheries Act 1985 will strengthen the EAFM.

4.0 CONCLUSION

Coral reefs at Pulau Dangli, Pulau Gasing and Pulau Pasir have significantly degraded due to anthropogenic activities. Effective measures are urgently needed to prevent further degradation of the marine ecosystem of the area and for restoration of biodiversity. A management strategy that drastically or entirely prevents non-point source of pollution on coral reefs could see revival of the marine ecosystem services that have traditionally helped the society, especially the indigenous communities of Langkawi. Rehabilitation such as coral planting and propagation are among the steps that can be considered on a priority basis. The acoustic approach described in this paper is suitable for use in waters such as those in Langkawi that have very low visibility. In addition, the data collection using this approach does not depend on the cloud cover, which is known to be a serious problem for satellite imagery. This method will provide detailed information on bathymetry and topography of the area and that will aid in addressing a range of key issues relating to EAFM that will play an important role in preserving and conserving fisheries resources and supporting the local economy.
5.0 ACKNOWLEDGEMENTS

This research was conducted under the funding of Langkawi Development Authority (LADA) through the Field Study Grant. The authors wish to express their gratitude to University Kebangsaan Malaysia for giving full credence during the conduction of this study expedition. The authors also wish to express their gratitude to the Oceanography laboratory members of UiTM Perlis for their invaluable assistance and hospitality throughout the sampling period.

REFERENCES


