PROSIDING SEMINAR

PENYELIDIKAN JABATAN TAMAN LAUT MALAYSIA 2018

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Kandungan

Perutusan Ketua Pengarah JTLM

Alhamdulillah, bersyukur ke hadrat Allah SWT kerana dengan izin-Nya Seminar Penyelidikan Jabatan Taman Laut Malaysia (JTLM) 2018 dapat dianjurkan pada kali ini dengan tema *'Conserving Malaysia's National Treasure'*. Tema ini adalah bersempena dengan sambutan *International Year of Reef* (IYOR), 2018 yang disambut oleh semua negara anggota *International Coral Reef Initiative* (ICRI) termasuklah Malaysia.

Seminar tahunan yang diadakan ini adalah bertujuan untuk memberi ruang kepada penyelidik-penyelidik membentangkan hasilan penyelidikan yang telah dijalankan secara kolaborasi antara JTLM dengan penyelidik universiti tempatan. Untuk tahun 2017, sebanyak 8 projek dan 2 ekspedisi penyelidikan telah dijalankan di beberapa pulau Taman Laut yang merangkumi pelbagai bidang penyelidikan. Projek penyelidikan ini telah berjaya dilaksanakan dengan penglibatan hampir 100 orang penyelidik daripada universiti tempatan, Institusi Penyelidikan, Agensi Kerajaan dan Pertubuhan Bukan Kerajaan (NGOs). Dana bagi projek penyelidikan ini adalah daripada peruntukan Pembangunan RMK-11 dan Tabung Amanah Taman Laut dan Rizab Laut.

Saya bagi mewakili Jabatan ingin mengambil kesempatan ini mengucapkan setinggi penghargaan kepada pasukan penyelidik. Saya yakin hasil kajian akan dapat membantu JTLM dalam menguruskan biodiversiti marin di Taman Laut dengan lebih berkesan dan membantu pihak pembuat dasar membuat keputusan-keputusan yang penting. Selain itu, maklumat ini akan dapat membantu Jabatan dan negara dalam penyediaan laporan bagi memenuhi tuntutan dan obligasi di peringkat antarabangsa seperti di peringkat *Convention on Biological Diversity* (CBD), *Sustainable Development Goals* (SDG), *Coral Triangle Initiative* (CTI) dan lain-lain.

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Ab. Rahim bin Gor Yaman
Ketua Pengarah
Jabatan Taman Laut Malaysia

Assessing the Vulnerability of Coral Reefs Towards Climate Change Impacts with the IUCN Reef Resilience Factors: A Tool for Prioritize Management Resources

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Abstract: Establish of marine park as a total no-take zone aim to protect and conserve the marine resources. Conflict of interest commonly occurs include disagreement with the local stakeholders such as islanders that harvest the marine resources for their livelihood. Consequently, many locals ventured into tourism industry as the permitted alternative within the marine park that later became one of the major threats to the marine environment. This study aimed to examine the resilience of coral reefs in the marinepark and to further support the potential of zonal management within the no-take Marine

Protected Areas (MPA). Pulau Payar Marine Park, the only MPA located on the west coast of Peninsular Malaysia was selected as the study site. No tourist operator was allowed to station on Pulau Payar Marine Park, and all day-trip tourism activities (e.g., snorkeling and SCUBA diving) were operated from a pontoon. The resilience of 16 selected reefs within the Pulau Payar Marine Park were examined according to IUCN Resilience Index. Nearly half (43.8%) of the reefs were categorized as good resilience site. High and moderate resilience sites each constituted a quarter (25%) of surveyed reefs. Only one site was found to be in poor resilience level. Moreover, the nutrients (nitrate: 0.04 – 0.13ppm; phosphate: 0.004 – 0.015 ppm) and faecal coliform (1.8 – 16,000 MPN/100 mL) concentration tested in most of the sites were not compliance to Class I of Marine Water Quality Criteria and Standard. This was empirical evidence of anthropogenic impact resulting from tourism activities which affecting the resilience of coral reefs at Pulau Payar Marine Park. To reduce the anthropogenic impacts, tourism activities should be limited at general zone to enable close monitor by the management authority. Then, selected good resilience sites could be the buffer zone served as alternative site during peak tourist season. Lastly, high resilience sites are recommended as conservation zone where no human activity is allowed.

Keywords: coral reef, resilience, climate change, marine park

INTRODUCTION

“*Ecosystem Resilience*” refers to the ability of an ecosystem to resist change when it experienced stressful event (Mumby et al. 2007). Furthermore, resilience also refers to how soon an ecosystem is able to bounce back or recover to the state before the change after experiencing a stressful event (Obura & Grimsditch, 2009). Such events, for instance pollution, over-exploitation, andclimate-change-related threats, are some of the major causes of ecosystems degradation worldwide (Jackson et al., 2014). As one of most the diverse ecosystems on the planet, coral reef is facing severe threats and coral cover has decreased greatly throughout the tropical region in recent decades. In 2016, abnormally elevated sea temperatures caused mass coral bleaching and northern Australian Great Barrier Reef lost almost 100% of their shallow reefs after the bleaching (Hughes et al., 2017). Similarly, reefs in Malaysia bleached as well in the 2016 mass bleaching. However, the impact of bleaching was minimal and almost unknown. With the increased intensity and frequency of mass coral bleaching events, together with other climate change-related impacts such as ocean acidification, coral reef managers are required to design innovative strategies to protect the coral reefs (Maynard et al., 2017). It is increasingly recognised that these approaches should build coral reef survivability based on patterns of resistance and resilience. To build resilience, managers must first identify the resilient reef. Then, one can focus on protecting those areas by reducing the most pervasive local threats to reefs. These include land-based sources of pollution and sedimentation, overfishingand tourism development. In this way, the source of new recruits is protected. The general aim of this study was to understand the resilience of coral reefs in Pulau Payar Marine Park. Specifically, this study first identified the suitable resilience factors to be used in assessing the resilience of coral reefs in Pulau Payar Marine Park. Then, by using the selected resilience factors, this study examined the resilience level of coral reefs in Pulau Payar Marine Park. Lastly, high resilience reefs in Pulau Payar Marine Park were identified. To achieve these objectives, this study applied the guidelines following the IUCN Resilience Assessment handbook (Obura & Grimsditch, 2009). Of the total 61 resilience factors, empirical data of the selected factors (e.g., benthic abundance, coral diversity, fish abundance and et.c.) were collected. On the other hands, data from publication (report, journal, and thesis) that related to Pulau Payar Marine Park were also compiled for the resilience analysis. This study would provide fundamental yet crucial information for Department of Marine Park Malaysia in resource management as well as decision-making processes.

METHODS

The feasible resilience factors for Pulau Payar Marine Park will first be identified and selected based on the published literatures (e.g., *IUCN Resilience Assessment handbook* and *Coral Reef Resilience. Rapid Assessment of the Coral Reefs)*. Only empirical data of the selected factors will then be collected following the methods below.

1. *In-situ* underwater survey

At least four surveyors were involved in this in situ study, which covers the six out of nine IUCN reef resilience factor (Benthic, Coral conditions, Coral populations, Coral Associates, Fish groups, and Physical). A 100 m line transect was placed on the reef parallel to the shoreline at a constant depth (± 1.0 m). The surveys were conducted within an area of 2.5 m x 2.5 m belt, with the line transect as the middle guideline. Coral Video Transect (CVT) was used to assess the benthic community cover. Three categories were recorded with six subcategories; Coral- hard coral, soft coral, algae-fleshy algae, turf algae, crustose coralline algae (CCA), and substrate- rubbles. The number of hard coral colonies and genera found within the area of the belt transect were counted and recorded. In addition, the rate of dead corals observed along the transect line were recorded based on current stress (bleached coral, recently died coral, diseased coral) and historical (old dead coral) footprint.

The number of invertebrates' categories and individuals found within the area of the belt transect were counted and recorded. The invertebrates identified were later separated into six categories based on their feeding habits: competitors of space with corals, external bioeroders of corals, internal bioeroders of corals, corallivores, obligate feeders, and residence on branching corals. The number of fish species and individuals found within the area of the belt transect were counted and recorded. The fish species were grouped later in three categories: corallivores, herbivores, and piscivores. The physical condition of the reefs was assessed by surveyors swam along the transect and observe the following parameters: substrate and morphology, cooling and flushing, shade and screen, substrate, and fishing.

2. Seawater quality and physical parameter

Water quality was conducted for the sites within Pulau Payar, Pulau Lembu and Pulau Kacha only. There were nine sites in total with 2 sub-site each: surface and bottom. Temperature, Salinity and Dissolved Oxygen (DO) was recorded for each sub-site using handheld YSI probe. Seawater (2.5L) was collected using Niskin water sampler and kept in an ice chest to maintain low temperature until further analysis. Parameters such as Total Suspended Solid, Oil and Grease, Ammonia, Nitrate, Phosphate concentrations and Total Faecal Coliform were analysed from the collected water samples. On top of that, HOBO Pendant® Light and Temperature loggers were deployed at Pulau Payar Marine Park since January 2016 to record the seawater temperature continuously.

3. Literature search and data mining

Research of the past records on the parameter and reef conditions as follow were done based on literature reviews: cooling and flushing, extremes and acclimatisation, historic, dispersal, transport, water, connectivity, and management.

4. Data analysis

The results from the surveys were compiled and used as a reference to score the resilience of the sites based on the IUCN reef resilience factors. The scores were then grouped into four major status categories: Excellent, Good, Moderate and Poor. The status was used as a reference to draw zone lines within the Pulau Payar Marine Park as a proposed zonal management.

FINDINGS AND ARGUMENT

A total of 16 reefs around Pulau Payar Marine Park were examined in this study (Table 1). For the three main resilience sections: benthic, fish and physical parameter *in-situ* data were collected at all four main islands: Pulau Payar, Pulau Lembu (Besar and Kecil), Pulau Kacha and Pulau Segantang (Fig. 1). However, no sample was collected at Pulau Segantang for water quality analysis because of logistic constraint. In general, nearly half (43.8%) reefs were categorized as excellent resilience site. Good and moderate resilience sites each constituted a quarter (25%) of surveyed reefs. Only one site was found to be in poor resilience level.

For benthic category (Fig. 1a & b), Pulau Payar reef community was generally in ‘Good’ status except for the north-west of Pulau Payar which scored ‘Moderate’. Pulau Kacha had two distinct benthic community statuses, the northern part was in ‘Excellent’ state, but the southern part was ‘Moderate’. Pulau Lembu Besar had the lowest benthic resilience score. In contrast, reefs in Pulau Lembu Kecil were at “Good” categories. The benthic community of Pulau Segantang was in ‘Excellent’ condition. High life coral cover, with diverse coral species and growth forms are some of the positive characteristics contributed to the “Excellent” and “Good” sites. These are the fundamental biological features that need to be maintained for high resilience reefs (Obura & Grimditch 2007).

TABLE 1: Name of the 16 survey sites in this study

Code/ Number	Site	Code/ Number	Site
A	Pulau Payar Jetty	1	Pulau Kecil Northwest
B	Pulau Payar Mid	2	Pulau Kacha West
C	Coral Garden	3	Pulau Payar North
D	Pulau Payar Exposed	4	Lobster Garden
E	Lobster Garden	5	Coral Garden
F	Pulau Payar North	6	Pulau Payar Mid
G	Pulau Kacha Sheltered	7	Pulau Payar Jetty
H	Pulau Kacha Exposed	8	Platform Front
I	Pulau Lembu West	9	Platform Side
J	Pulau Lembu Kecil Sheltered		
K	Pulau Lembu Kecil Exposed		
M	Pulau Lembu South		
N	Pulau Segantang South		
O	Pulau Segantang West		
P	Pulau Segantang North		

The coral reef fish community at Pulau Payar Marine Park documented with lesser resilience score, with 62.5% of the study sites were in ‘Moderate’ categories (Fig. 1c & d). The lower resilience scores attributed to low numbers of herbivorous fish groups (e.g., Scaridae and Siganidae). Herbivorous fish served as an important biological control on the algae community. Without these fish groups, there is higher possibility for a reef to change from coral-dominated to algal-dominated reef, especially during catastrophic event (e.g., mass coral bleaching). Therefore, the Department of Marine Park Malaysia needs to ensure no illegal fishing activity in the marine park areas, in order to protect the fish communities in the MPA.

The exposed and sheltered natural environment shaped the physical conditions of the reefs. These include the micro- and macro topography, current, wave, visibility etc. Consequently, reefs located on the northwest and southwest of islands are in “Good”

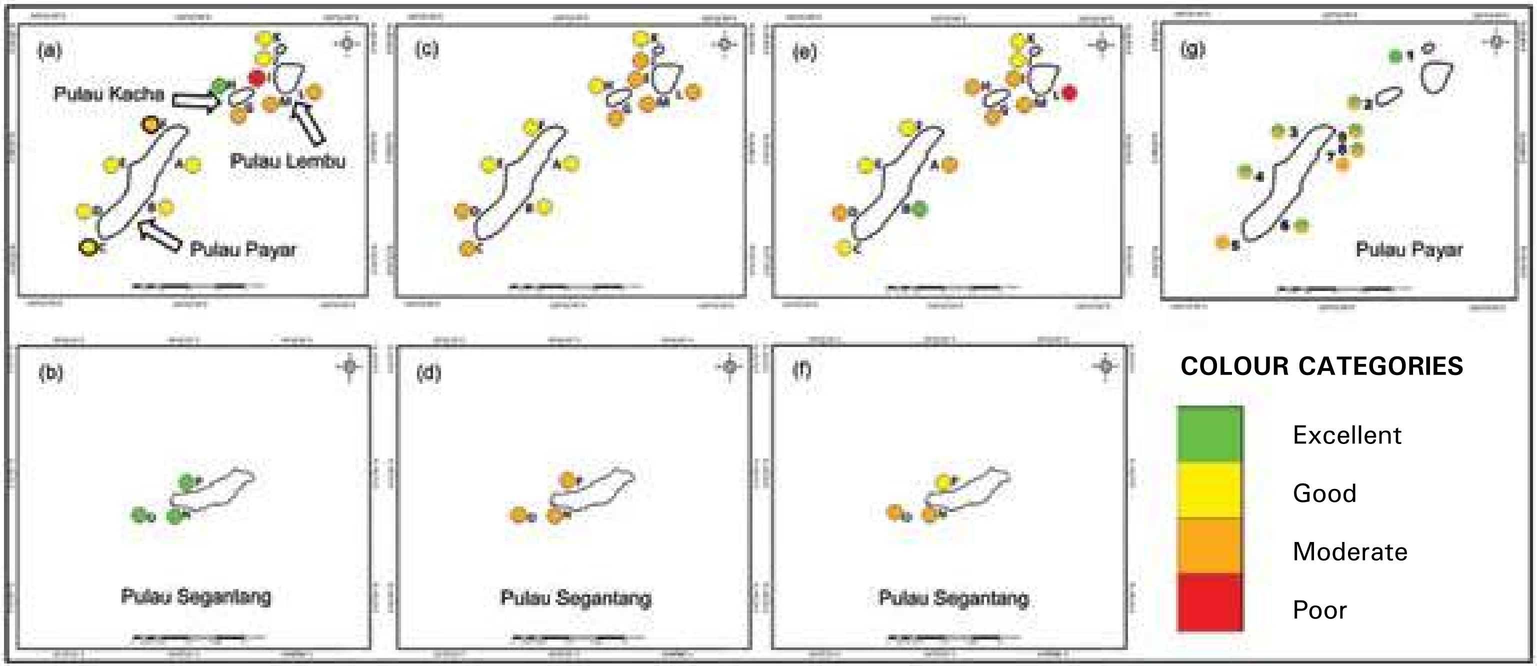

FIGURE 1: Coral reef resilience categories around Pulau Payar Marine Park according to different sections: (a) & (b) Benthic abundance and diversity; (c) & (d) Fish Abundance and diversity; (e) & (f): Physical parameters, and (g): Water qualities according to Marine Water Quality Index. Top and bottom semi-circles in (g) shows surface and bottom water quality, respectively. Alphabets (in Fig. a-f) and numbers (in Fig. g) in the maps represent sites that were surveyed (refer to Table 1).

categories (Fig. 1e & f). In contrary, reefs on the southeast areas were in lower physical resilience. However, Pulau Payar Mid (Code B) and Coral Garden (Code C) were found to be in "Excellent" and "Good" categories, respectively. Southern Pulau Payar was found to be deeper (depth > 50 m) compare the other near-shore (~300 m) areas (Bachok et al., 2017). An upwelling of cold and high flow water may have affected physical conditions for the southern Pulau Payar reefs. The diverse coral community recorded at Coral Garden (when compared to other sites) further enhanced the suggestion of physical heterogeneity in southern Pulau Payar.

The water quality results showed that generally the surface waters had better quality as compared to the bottom waters (Fig. 1g). All the surface water quality was in 'Excellent' state, except Coral Garden and the waters around Langkawi Coral Platform. On the other hand, all the bottom water scored 'Moderate' categories except for Site No. 1 at Pulau Lembu Kecil (Fig. 1g). Moreover, the nutrients (nitrate: 0.04 – 0.13 ppm; phosphate: 0.004 – 0.015 ppm) and faecal coliform (1.8 – 16,000 MPN/100 mL) concentration tested in most of the sites were not compliance to Class I of MWQI. The results indicated strong anthropogenic impact on the marine environment that require immediate attention.

CONCLUSION

In summary, Pulau Payar Marine Park consists large proportion of highly resilient reefs. These reefs are mainly located on the exposed side of the islands with complex physical parameters and diverse benthic as well as fish community. However, the high resilient reefs may be threatened by human activities due to low water qualities near and around the only tourism facility inside the marine park.

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Benthic Invertebrates in Coral Reefs of Pulau Payar Marine Park: A Quantitative Survey

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Abstract: Invertebrate fauna are considered indicators of ecological change and an important component of coral reef ecosystems. Possible disturbance to the reef can be estimated through monitoring of invertebrates' community structure, abundance, biomass and productivity of the benthic. In the course of our study the abundance of coral associated invertebrates was investigated among five islands of Payar archipelago using the common benthic validation exercise such as quadrat and CVT. Numbers of invertebrates are presented herein according to each island, Pulau Payar (34 taxa), Pulau Lembu (21 taxa), Pulau Lembu Kecil (19 taxa), Pulau Segantang (19 taxa) and Pulau Kacha (10 taxa). Invertebrates communities (in term of diversity) differed significantly among islands, however in term of abundance, several taxa dominated in all islands such as *Pedum* sp. (flame scallop), *Lopha* sp. (Cock's comb oyster), *Diadema* sp. (sea urchin), and *Spondylus* sp. (thorny oyster). Likewise, the least abundance was also represented by similar taxa such as *Tridacna* sp. (giant clam), *Cypraea* sp. (Cowrie snail), and *Cassis* sp. (helmet shell). Most of the dominated taxa were filter feeders, detritivorous, suspended feeders, and a herbivorous. As such, in term of abundance, the coral resilience is suggested to be very low, as herbivorous invertebrate presented low in the studied areas. Nevertheless, taking into consideration of scrapers, grazers, excavators, browsers and generalist, their density range between 9 – 34 ind/100m^{-2}. This study extends the known community structure and abundance of associated invertebrates to Pulau Payar and their minimal relation to it resilience.

Keywords: Coral invertebrates, abundance, coral resilience

INTRODUCTION

Coral reefs are complex ecosystem that harbour abundant and diverse marine invertebrates that perform various ecosystem functions such as: nutrient recycling, the removal of detritus material, consumption of invading algae, calcification, bioerosion, consolidation and benthic-pelagic coupling (Hutchings, 2003; Glynn and Enochs, 2011). Hence the health and resilience of a reef are greatly linked to the abundance and diversity of marine invertebrates, and disturbance towards associated invertebrates can result in negative ecological impacts upon the reef, that lead to a reduction in coral cover (Dumas et al., 2007, Hutchings, 1986). Motile invertebrates are one of the richest groups, containing about 168 000 valid species described on coral reefs, surpassing their fish counterpart with around 5000 species (Ruppert et al., 2004; Stella et al., 2011; Bellwood et al., 2012). To assess the diversity, community structure and abundance of reef invertebrates of Pulau Payar Marine Park, the common benthic validation exercise such as quadrat and CVT were conducted. Data recorded were then transferred into a spreadsheet where the results from each survey sites were compared and analyzed. Allthough *Pedum* sp. (*flame scallop*), *Lopha* sp. (*Cock's comb oyster*), *and Spondylus* sp. (*thorny oyster*) were more commonly retrieved in the sampling sites, species of indicative interest such as Diademasp.(sea urchin), *Echinothrix* sp. (sea urchin), and synaptids sea cucumber were found low, ranged between 9 – 34 individuals per 100m^{-2} at each island. In this paper herein, we discussed the abundance and the relation of found species to coral reef resilience.

METHODOLOGY

The surveys of this study were conducted as part of the '*Pulau Payar Marine Park Reef Resilience'* research framework that aims to investigate indicative parameters for the resilience of this archipelago. Invertebrates were surveyed in June and July 2017 from a total of sixteen sites across the islands such as, Pulau Payar (6 sites), Pulau Lembu (3 sites), Pulau Lembu Kecil (2 sites), Pulau Segantang (3 sites) and Pulau Kacha (2 sites). Overall, a total of 8000 m^2 area of coral reefs were surveyed in this study. In general, this study utilized Coral Video Transect (CVT) and quadrat technique for the rapid assessment of the benthic community cover. Specifically, a 100 m line transect was placed on the reef parallel to the shoreline at a constant depth (± 1.0 m). The surveys were conducted in buddy pairs with one person recording coral and the other soft corals, invertebrates and algae, within an area of 2.5 m x 2.5 m belt, with the line transect as the middle guideline. The number of invertebrates' taxa and individuals found within the area of the belt transect were counted, recorded and further identified on in-silico basis. The feasible resilience factors of recorded invertebrate were also studied via literature search (Obura & Grimsditch, 2009) and relating such information towards their density (individuals/100 m^2) at each island. No invertebrates were taken during the study.

FINDINGS AND ARGUMENT

Most of the taxa were identified down to genus, with some were only identified in common name unit. Some invertebrates could not be identified due to their small size and distinctive characteristics, but it is worth pointing out their presence in the studied area. Of the five islands surveyed, Pulau Payar harbor the most diverse invertebrates with 34 taxa, followed by Pulau Lembu, with 21 taxa, Pulau Lembu Kecil and Pulau Segantang with 19 taxa each, and lastly Pulau Kacha with 10 taxa. The health of a reef is greatly influenced by the abundance and diversity of marine invertebrates and disturbance of marine invertebrates can result in negative ecological impacts upon the reef, such as algae blooms and invertebrate plagues (Dumas et al., 2007). During this study, a weak correlation was found between invertebrates' diversity towards benthic cover (coral cover) condition among the islands. For example, when the reef community were generally 'Excellent' and 'Moderate' in Pulau Payar, the diversity of invertebrates was rather low (10 taxa). The diversity of coral associated invertebrates may give an indication of community structure because any species groups would serve a function in the community.

Even though it is clear to see that Pulau Payar harbour the highest number or invertebrates taxa, the density of dominance invertebrates group were much higher in other reefs area and relatively differed between the islands. The number of selected dominance taxa surveyed and recorded can be seen in Table 1. Among them, *Pedum* sp.(flame scallop), were mostly densed in Pulau Kacha with 88 ind. 100^{m-2}, followed by Pulau Payar with 62 ind. 100^{m-2}, while Pulau Lembu Kecil recorded the lowest density of this taxa with only 11 ind. 100^{m-2}. *Lopha* sp. (*Cock's comb oyster*) were found in highest density at Pulau Segantang with 118 ind. 100^{m-2}, while the least dense population were found in Pulau Lembu with 20 ind. 100^{m-2}. In term of taxa of indicative interest such as *Diadema* sp.(sea urchin) and *Echinothrix calamaris* (sea urchin), both presented in

TABLE 1: Coral associated invertebrates comparison in term of percentage (%) abundance, density, and feeding behaviour between five islands of Payar Island Marine Park archipelago

Localities	No. of Individuals	% Abundance	Density (ind. 100^{m-2})	Feeding Behavior
Pulau Payar				
Pedum sp. (Flame Scallop)	1871	33.8	62	Filter feeders
Lopha sp. (Cock's Comb Oyster)	1611	29.1	54	Suspension feeders
Spondylus sp. (Thorny Oyster)	417	7.5	14	Suspension feeders
Synaptid (sea cucumber)	350	6.3	12	Detritivorous
Diadema sp. (Sea Urchin)	337	6.1	11	Herbivorous
Pinna sp. (Pen Shell)	234	4.2	8	Suspension feeders
Oyster (not id)	192	3.5	6	Suspension feeders
Synaptula lamperti (Sea cucumber)	190	3.4	6	Detritivorous
Pulau Kacha				
Lopha sp. (Cock's Comb Oyster)	973	44.9	97	Suspension feeders
Pedum sp. (Flame Scallop)	881	40.7	88	Filter feeders
Diadema sp. (Sea Urchin)	171	7.9	17	Herbivorous
Spirobranchus sp. (Christmas Tree)	42	1.9	4	Filter feeders
Echinothrix calamaris (sea urchin)	40	1.8	4	Herbivorous
Holothuria (Sea cucumber)	40	1.8	4	Detritivorous
Pulau Lembu Kecil				
Lopha sp. (Cock's Comb Oyster)	969	74.1	97	Suspension feeders
Pedum sp. (Flame Scallop)	113	8.6	11	Filter feeders
Synaptula lamperti (Sea cucumber)	60	4.6	6	Detritivorous
Spondylus sp. (Thorny Oyster)	49	3.7	5	Suspension feeders
Pulau Lembu				
Pedum sp. (Flame Scallop)	348	27.5	23	Filter feeders
Lopha sp. (Cock's Comb Oyster)	297	23.5	20	Suspension feeders
Diadema sp. (Sea Urchin)	143	11.3	10	Herbivorous
Spondylus sp. (Thorny Oyster)	131	10.4	9	Suspension feeders
Synaptula lamperti (Sea cucumber)	129	10.2	9	Detritivorous
Pulau Segantang				
Lopha sp. (Cock's Comb Oyster)	1774	61.8	118	Suspension feeders
Diadema sp. (Sea Urchin)	443	15.4	30	Herbivorous
Spondylus sp. (Thorny Oyster)	299	10.4	20	Suspension feeders
Pedum sp. (Flame Scallop)	174	6.1	12	Filter feeders
Pinna sp. (Pen Shell)	53	1.8	4	Suspension feeders
Echinothrix calamaris (sea urchin)	49	1.7	3	Herbivorous

low density at all islands particularly the latter taxa. *Diadema* sp. were found in highest density at Pulau Segantang with 30 ind. 100^{m-2} while lowest at Pulau Lembu Kecil with only 2 individuals recorded. Density of *Echinothrix calamaris* were 3 and 4 ind. 100^{m-2} for Pulau Segantang and Pulau Kacha respectively, with individuals recorded only between 6 to 13 on the other islands. Monitoring abundances enables us to quantify the extent of the reef condition and therefore the mere observation of an indicator species can tell a story (Vandermeulen, 1998).

Certain invertebrates can be used as indicators towards marine environmental condition and serve as an early warnings cue. From this perspecitve, coral health and resilience has been linked towards to various indicators that include invertebrates. Specifically, the invertebrates of indicative interest are selected on the feeding behavioural basis, with more attention given to herbivorous species and related group such as scrapers, grazers, excavators, browsers and generalist. On the course of this study, several other taxa potentially serve as an indicator such as the holothurids (sea cucumber) – generalist/ detritivorous, *Cassis* sp. (helmet shells) – grazers, nudibranchs – generalist grazers and *Cypraea* sp. (cowrie) – grazers, just to name a few. However, their density is so low separatively, but range between 9 – 34 individual 100 m^{-2} cummulatively at each island. Indicator species can have added value over raw data as they represent the broader significance or implications of the data. Future research on invertebrates should include weight per unit area of herbivorous invertebrates and one could consider a taxon to be exclusively studied as indicator or otherwise the study could be inclusive of all major herbivore functional groups.

Overall, this study reported the diversity, abundance and density of associated marine invertebrates in coral reefs area of Pulau Payar Marine Park. The overall findings derived from this study are mitigated however by the lack of other analysis such as biomass and productivity of the benthic community and the conclusion may be well improvised in the future.

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Taburan, Kelimpahan dan Struktur Genetik Populasi Dua Spesies Kima (Cardiidae: *Tridacna*) dari Taman Laut Pulau Perhentian

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Abstrak: '*Giant clam*' atau lebih dikenali tempatan sebagai kima adalah spesies terumbu utama yang menyumbang kepada kepelbagaian spesies dan fungsi ekologi. Nic ekologi kima adalah sangat penting khususnya peranan sebagai penyumbang kalsium karbonat kepada terumbu karang, penghasilan jaringan makanan, serta sebagai perumah kepada hidupan marin yang lain atau *holobiont*. Malangnya, ancaman pemanasan global dan aktiviti manusia telah menpercepatkan kemerosotan populasi kima di lautan Indo-Pasifik. Tindakan segera dalam usaha pemuliharaan adalah sangat diperlukan. Kajian ini dijalankan untuk menilai kepelbagaian dan taburan kima di Taman Laut Pulau Perhentian. Maklumat kajian ini akan mengisikan jurang maklumat antara populasi *Tridacna* di Pulau Perhentian dan hubungkait dengan populasi yang lain di perairan yang lain di Laut China Selatan. Dalam kajian ini, dua spesies *Tridacna* telah dijumpai di Pulau Perhentian iaitu *T. maxima* and *T. squamosa*. Jumlah individu *T. maxima* (401 individu) yang dijumpai di semua lokasi adalah sekali ganda berbanding dengan *T. squamosa* (195 individu). Kelimpahan tertinggi adalah sebanyak 17.4 individu per 100 m^2. Juvana kima *T. squamosa*

(< 5 cm in panjang cengkerang) adalah jarang dijumpai berbanding dengan juvana *T. maxima*, dengan 67 individu telah direkodkan dalam kajian ini. Ini adalah tanda penghad kepada pengambilan baru populasi *T. squamosa* yang kurang diperhatikan pada populasi *T. maxima*. Pemerhatian ini juga menunjukkan *T. squamosa* di Perhentian menunjukkan kehomogenan genetik bersama populasi yang lain di Laut China Selatan. Sebaliknya, *T. maxima* telah menunjukkan keheterogenan genetik yang berkemungkinan akibat aliran gen yang terhad. Kehadiran juvana adalah tanda pengambilan baru populasi *T. maxima,* juga menunjukkan populasi yang sihat dan berkembang di Taman Laut Pulau Perhentian. Kajian ini telah menyumbang kepada data inventori taburan dan kelimpahan dua spesies kima di Pulau Perhentian, dan maklumat lanjut hubungan populasi genetik kedua-dua species *Tridacna* di Malaysia

Kata Kunci: Kima, gen mitokondrial sitokrom c oxidase I, Pulau Perhentian, *Tridacna maxima*, *Tridacna squamosa*

Abstract: Giant clams are one of the key reef species contributing to overall reef biodiversity and functionality. Their ecological niche is significant where they act as caches of calcium carbonate for coral reef, contribute productivity to overall marine food webs and excellent holobiont host. Unfortunately, global warming and human-mediated threats have accelerated the loss of giant clams across the Indo-Pacific while they are in pressing need of conservation action. This study aims to evaluate the diversity and distribution of giant clams of Perhentian Islands Marine Park, Terengganu, and to determine the population genetic connectivity between two species of *Tridacna* (*T. maxima* and *T. squamosa*) of Perhentian Islands. Field surveys were undertaken at 13 sites of the park. The number of individuals of *T. maxima* (401 individuals) was higher than that of *T. squamosa* (195 individuals); Teluk Gadung was found with the highest clam density of 17.4 individuals per 100 m^2. For juvenile clams (< 5 cm in shell length), *T. squamosa* recruits were rare, while *T. maxima* juveniles were more abundant with 67 individuals recorded. This observation may clue in on the recruitment constraints in *T. squamosa* populations, but lesser for *T. maxima*. Molecular characterization of the samples revealed that Perhentian populations of *T. squamosa* shared a degree of genetic homogeneity with other populations from the South China Sea. On the contrary, Perhentian populations of *T. maxima* showed some degree of genetic heterogeneity and were likely to exhibit limited gene flow. Evidence of recent recruitment of giant clams in the survey sites was reassuring, as it stands for healthy and replenishing tridacnine populations in Perhentian Islands Marine Park. This study provides an update data inventory on the distribution and abundance of two giant clams in Perhentian Islands Marine Park, as well insights into the population genetic connectivity of the two species of Tridacna of Malaysia.

Keywords: Giant Clams, mitochondrial cytochrome c oxidase I gene, Pulau Perhentian, *Tridacna maxima*, *Tridacna squamosa*,

PENGENALAN

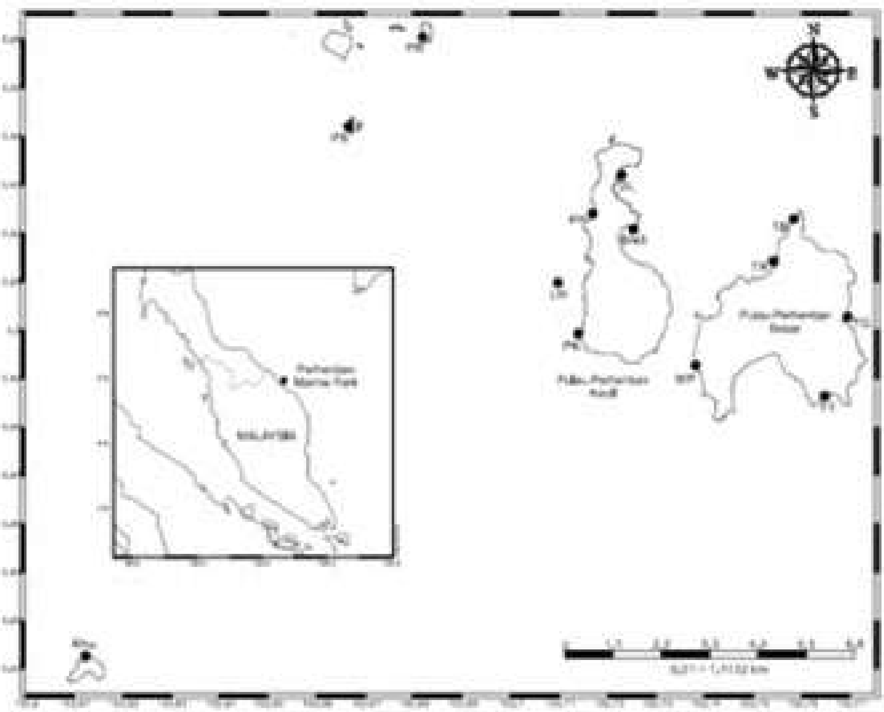
Kima adalah spesies yang penting di ekosistem terumbu karang dengan sumbangan kepada fungsi dan kepelbagaian spesies. Molluska bersaiz besar dan menarik ini memainkan pelbagai peranan termasuk menyumbang kepada kalsium karbonat, sebagai sumber makanan kepada pelbagai pemangsa dan meningkatkan kompleksiti topografi terumbu. Malangnya, ancaman akibat aktiviti manusia telah membawa kepada kemerosotan mendadak populasi kima di lautan Indo-Pasifik. Populasi kimia telah berkurang akibat kesan pencemaran, degradasi persekitaran dan pengambilan kima untuk tujuan makanan (Hviding, 1993) dan pengambilan cengkerang untuk pelbagai kegunaan (Brown & Muskanofola, 1985; Dawson & Philipson, 1989). Pengambilan kima di kawasan terumbu karang akan menyebabkan kitar pembiakannya terganggu dan seterusnya menyebabkan pengurangan size populasi (Munro, 1992). Kini, populasi kima telah berada di tahap yang memerlukan tindakan pemuliharaan yang mendesak.

Populasi kima di Malaysia telah diselidik dan dinilai dalam beberapa kajian terdahulu, di antaranya: Pulau Redang (Mohamed-Pauzi et al., 1994), Pulau Tioman (Tan et al., 1998), Pulau-pulau di Perairan Johor (Zulfigar and Tan 2000; Tan and Zulfigar, 2001) dan Pantai timur Perairan Sabah (Montague et al., 2013). Sekurang-kurangnya tujuh spesies kima telah direkodkan di Perairan Malaysia. Semua spesies kima adalah terlindung di bawah Akta Perikanan Malaysia 1985. Walau bagaimanapun, maklumat taburan dan populasi kima tidak dikemaskini, dan tiada maklumat genetik dilaporkan setakat ini untuk populasi tersebut. Oleh yang demikian, kajian ini telah dijalankan dengan tujuan untuk:

1. Menentukan taburan dan kelimpahan kima di Taman Laut Pulau Perhentian, Malaysia.
2. Menentukan struktur populasi dua spesies *Tridacna*, iaitu *T. maxima* dan *T. squamosa*.
3. Menenyelidik hubungan genetic antara populasi Tridacna dengan pendekatan molekular.

KAEDAH

Kajian lapangan ini telah dijalankan di Taman Laut Pulau Perhentian, Terengganu, Malaysia. Kehadiran dan kelimpahan kima telah diselidik di 13 lokasi kajian di Taman Laut tersebut dari Mac hingga Jun 2017 (Rajah 1). Kaedah transek jaluran (*belt transect*) dengan ukuran 100 m × 8 m atau 50 m × 10 m telah digunakan selari dengan garis pantai pada kedalaman 5 m sehingga 10 m pada setiap lokasi. Setiap individu kima akan digambar, diidentifikasi dan ukuran panjang cengkerang ditentukur. Data kedalaman juga dicerap untuk setiap individu.



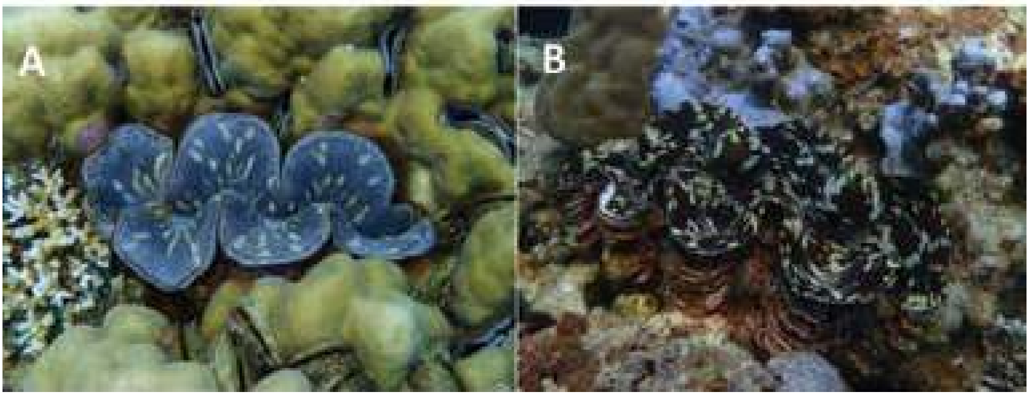
RAJAH 1: Taman Laut Pulau Perhentian, Terengganu menunjuk 13 lokasi persampelan

Pengambilan tisu kima (*biopsy*) untuk kajian genetik juga dijalankan untuk individu terpilih di setiap lokasi. Semua tisu yang diambil dilabel dan disejukbekukan pada suhu –80°C sebelum analisa selanjut dijalankan. Sampel tisu juga disejukkeringkan (*lyophilized*) untuk simpanan jangka panjang.

DNA genomik dalam tisu diekstrak dengan menggunakan kit DNeasy® Blood & Tissue (QIAGEN, Hilden, Germany). Gen mitochondrial cytochrome c oxidase I (*COI*) telah diamplifikasi dengan tindakbalas berantai polymerase (PCR). Hasil produk PCR ditulenkan sebelum dihantar untuk tujuan penjujukan di syarikat pembekal perkhidmatan penjujukan dengan menggunakan mesin penjujukan ABI 3700XL automated DNA sequencer (Applied Biosystems, USA).

HASIL KAJIAN DAN PERBINCANGAN

Dua spesies kima telah dicerap di Taman Laut Pulau Perhentian, iaitu: *Tridacna maxima* (juga dikenali sebagai kima kecil) and *T. squamosa* (dikenali sebagai kima seruling) (Rajah 1). Jumlah individu yang direkod untuk *T. maxima* adalah lebih tinggi daripada *T. squamosa*; dengan 195 individu untuk *T. squamosa* berbanding dengan 401 individu *T. maxima* pada 13 lokasi persampelan yang dikaji.

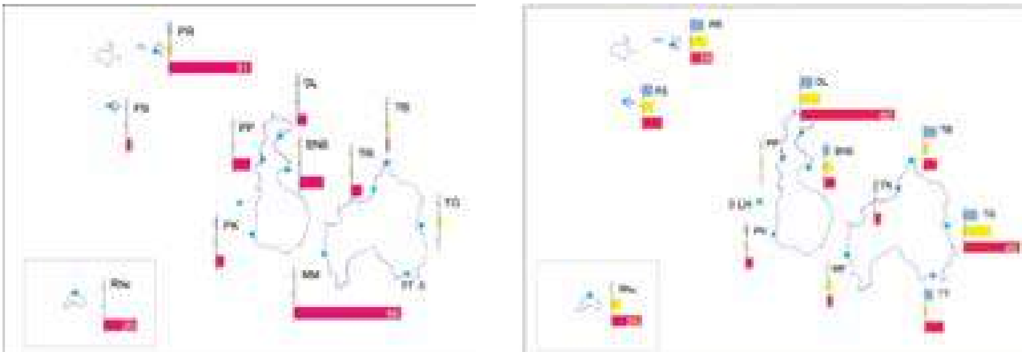


RAJAH 2: Dua spesies kima di Taman Laut Pulau Perhentian, Terengganu. (A) *Tridacna maxima* dan (B) *T. squamosa*

Kelimpahan kedua-dua spesies *T. maxima* and *T. squamosa* adalah seperti yang disenaraikan dalam Jadual 1. Kelimpahan tertinggi *T. maxima* (17 ind. 100 m^{-2}) telah dicerap di Tanjong Gedong (TD) manakala *T. squamosa* mempunyai kelimphan tertinggi di Jeti MP (8.25 ind. 100 m^{-2}). Untuk juvena (< 5 cm panjang cengkerang),*T. squamosa* adalah jarang dijumpai berbanding dengan juvana *T. maxima*. Sebanyak 67 individu *T. maxima* telah direkodkan dalam kajian ini (Rajah 3). Pemerhatian ini juga menunjukkan tanda penghad kepada pengambilan baru populasi *T. squamosa* tetapi kurang berlaku pada populasi *T. maxima*.

JADUAL 1: Kelimpahan *Tridacna maxima* dan *T. squamosa* (unit: individu/100 m^2) di 13 lokasi persampelan di Taman Laut Pulau Perhentian

Site	Kod	Kordinat	Kawasan persampelan (m^2)	*T. squamosa*	*T. maxima*
D.Lagoon	DL	5°55’55.49”N 102°43’22.45”E	800	0.75	13.63
Batu Nisan	BNS	5°55’15.00”N 102°43’31.03”E	800	1.88	2.38
Pasir Pengalau	PP	5°55’26.68”N 102°43’0.95”E	800	1.38	0.13
Lighthouse	LH	5°54’35.22”N 102°42’35.22”E	800	0	0
Pasir Keranji	PK	5°53’57.24”N 102°42’50.23”E	800	0.75	1.25
Tanjung Basi	TB	5°55’22.84”N 102°45’30.40”E	800	0.25	3.25
Jeti Marine Park	MP	5°53’33.67”N 102°44’17.41”E	800	8.25	0.88
Tanjung Tukas	TT	5°53’10.89”N 102°45’53.19”E	500	0	4.80
Teluk Gadung	TG	5°54’9.90”N 102°46’10.14”E	500	0.40	17.00
Tiga Ruang	TR	5°54’51.25”N 102°45’15.10”E	500	1.60	1.40
Rawa Island	PR	5°57’37.83”N 102°40’54.72”E	2400	2.33	1.83
Seringgih Island	PS	5°56’31.47”N 102°40’0.08”E	800	0.38	4.63
Pulau Rhu	Rhu	5°49’57.62”N 102°36’44.72”E	800	2.50	4.00



RAJAH 3: Taburan kima *Tridacna maxima* (A) dan *T. squamosa* (B) di Taman Laut Perhentian dan Pulau Rhu dalam tiga kelas, juvenile (biru), sub-dewasa (kuning) dan dewasa (merah)

Sebanyak 185 tisu kima telah diambil dari 11 lokasi di Pulau Perhentian, dengan 78 tisu *T. squamosal* dan 107 tisu *T. maxima*. Jujukan gen mitochondrial COI dengan panjang 580 bp untuk 41 sampel *T. maxima* and 39 sampel *T. squamosa*. Penjajaran jujukan COI menunjukkan kehadiran 73 haplotaip *T. squamosa* and 138 haplotaip *T. maxima*. Kedua-dua spesies menunjukkan darjah polimofisma dengan pencapahan intraspesifik yang tinggi antara, iaitu 8.3% dan 8.1% untuk *T. maxima* dan *T. squamosa* masing-masing. Pencapahan jujukan interspesifik antara kedua species adalah 12.9 – 17.2%.

Populasi *T. squamosa* dari Pulau Perhentian berkongsi kehomogenan genetik bersama populasi-populasi di zon kepulauan Melayu Indo-Pacifik (IMPA) (Philippines, Singapore and Indonesia). Data juga menunjukkan darjah pertukaran genetik yang tinggi, manakala darjah keheterogenan genetik adalah jelas pada populasi *T.maxima*. Ini juga menunjukkan takungan gen tempatan adalah disokong dengan kelimpahan juvena kima di Pulau Perhentian.

KESIMPULAN DAN CADANGAN

Hasil keputusan kajian ini menunjukkan populasi dua spesies *Tridacna* yang sihat di Taman Laut Pulau Perhentian, dengan kehadiran juvena dan pengembangan saiz populasi. Kelimpahan kima di Pulau Rhu adalah sederhana, walaupun pulau ini adalah di luar kawasan Taman Laut dan berdekatan dengan muara Sg. Besut. Pulau Rhu berpotensi dipertimbangkan sebagai sebahagian dari Taman Laut. Kajian adaptasi dan ketahanan populasi kima di Pulau Rhu adalah penting dalam usaha memahami populasi kima di bawah tekanan perubahan iklim dan aktiviti manusia. Operasi dan aktiviti pelancongan yang minima di Pulau Perhentian semasa musim tengkujuh timur laut (selama lima bulan) juga didapati memberi peluang untuk ekosistem terumbu karang dan organisma penghuni yang lain berpulih daripada tertekan oleh aktiviti aktiviti manusia.

Kehadiran ektoparasit dan kesan pemutihan seperti yang diperhatikan dalam kajian ini didapati adalah tanda yang berguna dalam memantau status kesihatan kima. Populasi kima dan status kesihatan di Perhentian harus dipantau secara berkala melalui program pemantauan Taman Laut yang diwujudkan dengan pihak-pihak yang berkepentingan (termasuk pengusaha pelancongan). Pemantauan populasi juga disarankan diserapkan dalam elemen program pemantauan status terumbu karang – "Reef check".

Berdasarkan kedekatan geografi, kima yang berada di Pulau Perhentian berpotensi digunakan untuk tujuan *restocking* di Taman Laut lain di Pantai timur Semenanjung Malaysia demi memulihara kepelbagai genetik dan mengelakkan pengurangan populasi kima di rantau ini. Maklumat genetik yang diperolehi juga penting dalam pembangunan strategi pengurusan trans-sempadan (transboundary) serantau di bawah pengurusan sumber Biodiversity *Beyond National Jurisdiction (BBNJ)*.

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Reviewing and Documenting the Functions of the No-Take Zone in Marine Parks Malaysia of Pulau Redang and Pulau Tioman

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Abstract: As one of the fisheries management tools, the No-Take Zone (NTZ) concept prohibits any direct human disturbance of all forms in the protected area. Together with the conventional fisheries conservation management measures NTZs will enhance protection of marine wildlife and heritage and safeguarding or improving local fish stocks. This study examines the effects of using the No-Take Zone (NTZ) concept in MPAs on the marine resource enhancement as well as socio-economic conditions of local communities and stakeholders in Pulau Redang and Pulau Tioman. Data have been obtained from a survey involving 212 stakeholders who are directly or indirectly affected by the establishment of the MPAs and the NTZs. The assessment of the impacts is in terms of the perception of the stakeholders on the benefits of the development of NTZ on their livelihoods and other economic conditions and as a means in conserving and enhancing fisheries resources. The results of the analyses indicate that the stakeholders believe that the establishment of the 2 nautical-mile NTZ has complemented the benefits obtainable from the MPA.The communities perceive that more benefits can be obtained if the government and local community manage the MPAs together. The stakeholders realize that MPAs produce impacts beyond the monetary returns; the contingent valuation (WTP and WTA) analyses prove that the stakeholders place values on the resources and are willing to help in the protection and conservation of the resources including the decision to establish the NTZ.

Keywords: management tool, artisanal fishers, tourism operators, benefits, conservation values

INTRODUCTION

The No-Take Zone (NTZ) concept is a limited prohibition technique of management which prohibits any form of extractive activities in the protected area. Marine Protected Area (MPAs) withNTZ concept also permanently set aside from direct human disturbance where all methods of fishing and extraction of natural materials, dumping, and dredging or construction activities are prohibited, from which the removal of any resources, living or dead is prohibited. The establishment of the NTZs will ensure a long-term sustainable supplies of fish. NTZ if used alongside conventional fisheries and wildlife and heritage management processes will enable to safeguard or improve local fish stocks for future generations to enjoy. The establishment of NTZ may be done in isolation surrounded by normal fishing grounds, or form part of a larger marine reserve, or enclosed by managed buffer zones around the NTZ in order to manage the nature conservation.

Problem Statement

The lack of understanding of the concept of MPA and the NTZ has created apprehension among various stakeholders who are affected directly or indirectly of the usefulness of the establishment of the MPAs and Marine Park (MPs). After more than 20 years of establishment, the functions of MPAs and NTZ as a management tool in increasing the economic, social and ecology benefits of coastal water and stakeholders need to be reassessed. Stakeholders in Pulau Tioman, especially the small fishers feel that they are at the losing end of the development of the MPAs; unequal distribution of the impacts of the MPAs is one of the unsatisfactory situations often cited among the small traditional fishers. Whereas fishers of the Pulau Payar MPs are more concerned with the losses due to the illegal encroachment of fishers from outside the areas. The tourism operators are concerned with the management of the utilization of the marine parks in terms of impacts on congestion and pollution. The stakeholder's views of the benefits of the establishment of the NTZs are skewed towards the short-term tangible effects due to their limited knowledge, understanding and awareness of the long-term consequences of conservation of the marine resources.

Objectives

The overall objective of this project is to evaluate the impact of MPAs with NTZ concept in Malaysia for the effective and sustainable natural resource management in increasing the economic, social, and ecological benefits of the Tioman Island, Pahang and Redang Island in Terengganu. More specific objective was:

1. To examine the effects of the establishment of the NTZ in MPAs on the marine resource enhancement and on the wellbeing of socio-economic conditions of local communities in Pulau Redang and Pulau Tioman;

2. To establish the level of agreement of the stakeholders on the functions of the NTZ as an alternative tool for the management of the marine resources to enrich their livelihoods and economic conditions.

Relevant Past Studies

Past studies on the impacts of the establishment of MPAs and NTZs have proven the effectiveness of MPAs in the conservation of the marine resources and on the benefits produced to the local communities (Vaso (2013), Pollnac et al., 2001; Appeldoorn& Lindeman, 2003). Other studies by Salmand Clark, 2000 and. Mangubhai, et al., (2015) have stressed the importance of collaborative management between the government and coastal communities. Ban et al., (2009) and Chan et al., (2007) have pointed out that in the developing countries the differences in the way's people/ communities interact with are directly dependent on nature for their basic life functions; these interactions will have a significant influence on the planning for conservation. Any deliberation on the management of the MPAs must assure that conservation of the natural resources does not severely affect the basic needs and survival of the communities.

METHODS

The data were obtained from a survey involving 212 stakeholders who have direct and indirect interests with the establishment of the MPAs of Pulau Tioman and Pulau Redang. The study will be conducted at various stakeholder groups i.e. resource users (tourists, fishers, tourist workers, boatmen, tourist guide), operators (traders, chalet managers, diving operators, boat maintenance) and experts (officials, managers, researchers, local leaders, NGOs). Survey will be conducted to assess the factors important for the effective management of the MPAs as NTZ. The data was obtained from various stakeholders will be help to develop indicators for MPAs planning and management. MPA management strategy developed based on the local views will be accepted by various stakeholders will improve the habitat conservation, fisheries and other marine resources. The sampling was selected using the judgmental method from local information and statistics data on the all stakeholders for both Islands by types of economic activities.

The perceptions of the respondents who have been conveniently selected from both islands are used as the main variable to review the justifications of the functions for the MPA establishment. The Exploratory Factor Analysis (EFA) is utilized to determine the main factorial elements agreed by stakeholders for the establishment of 2 nautical miles NTZ; also, on their perception on whether the NTZ would help to conserve and enhance the fisheries resources. The various factors of the management will be analyzed to determine the important factors in the NTZ contribution. An overview from the previous studies also will be carried out to aid in identifying the important indicators to establish the effective MPA as NTZ.

The other analysis was the Willingness to Accept (WTA) and Willingness to Pay (WTP) analyses are carried out to determine the values of the protection and conservation of the resources and the decision to establish the NTZ concept from the stakeholder's perspectives. This implementation may adversely affect local people who have been practicing their normal socio-economic activities. To measure the readiness of local fishers in accepting the establishment of MPAs, WTA can be considered as the opportunity cost of foregoing their existing are of fishing and doing other social economic activities.

FINDINGS AND ARGUMENTS

The study collects around 212 sample size from various stakeholders and from the survey most of the respondent was represent by tourism operator with 52% (110 respondent), fishers with 30% (64 respondent) and others with 18% (38 respondent). The average age of respondent was 42 years old mostly age category is within 20 to 35 years old (37%) and more than 50 years old (36%) which may imply that the younger generation may be have some interested in working in MPs as their livelihood. 69% of the respondents was male with only 31% is a female. Malay is the majority ethnic with 193 respondents (91.5%) and others was represented by Chinese 13 respondents (6%) and only 2% (5 respondents) was others. Religious of the respondent represent by 93% was Muslims and others were Buddha (4% and Christian (3%). The sample reveals that most of respondents have finish their schooling, at least at primary or religious or non-formal school levels with 28% (60 respondents). However due to age category trend, the education of the respondent was representing majority for 51% (109 respondents) of them was finished high school levels (SPM) levels or certificate or Diploma or University. The origin of the respondent shown only 81 respondents (38%) was local communities and the others was representing for 62% (131 respondents) that migrate to both Islands.

Among the total sampled of respondent, the average years of experience for fishers was 28 years old and only 9 years old experience was record for tourism activities as a main occupation. The second occupation experience for respondent was around 7 years old for fishers and 8 years old for tourism activities. Most fishers working for around 10 months a year compare to only 8 months a year by tourism operator. Sampan or boat A was the main vessel for fishers in both islands with 97% (68 fishers from 70 fishers) with using hook and line (62%); fish trap (15.9%) and drift net (22.1%).

TABLE 1: Perceptions of functions and roles of NTZ and MPAs

Factor	No of variable	% var	% cumvar
F1. Judicious conception of protected zone	10	11.2	11.19
F2. Enforcement of protective actions	4	7.2	18.4
F3. Acceptance of rules and regulations	3	5.7	29.2
F4. Empowerment of local communities	4	17.8	41.6

The perceptions of the communities on the roles and functions of the NTZ within the MPAs in Pulau Tioman and Pulau Redang are summarized in Table 1.

The factor implies that the communities believe that the process of conservation benefits them in terms of increase in fish stocks, quality of fish found in the enlarged areas of the coral gardens, regeneration of the fish resources near the boundaries of the MPAs, the potential spill over effects and the economic benefits from the shifts to the more stable tourism sector.The communities have pleaded to the relevant authorities that some flexibilities be afforded to them to carry out the fishing activities within the NTZ of the marine parks during the monsoon season.

Communities believe that this technique for the management of the MPAs allows the marine resources and corals within the protected areas to be replenished. The management technique thus resulting in the restocking of not only the quantity but also the quality of the fishes within the protected areas.Fishers have voiced out their dissatisfaction to the relevant agencies when trawlers have encroached into the fishing zones of the small fishers as the spill over effects have increased the fish resources both in quantity and quality which have lured fishers to illegally catch fish near and within the marine park boundary.

The communities still hold strongly that the participation of communities is essential to ensure that the conservation of the marine resources will help to sustain the tourism industry which has become the main source of their livelihood. Yet they feel that some flexibility could be afforded to them to carry out the fishing activities within the marine parks during the monsoon season and if the tools used are non-destructive to the marine resources, for example, use of line for fishing.

The development of the tourism sector is a direct benefit of the establishment of the marine park in both locations; it is youths who get the most gains from the tourism development. Also the communities feel that the tourism development as a result of the establishment of the marine has helped to further sustain the conservation of the marine resources.

Estimation of the values of the marine resources as perceived by the local communities. The values of marine resources conserved in the NTZ and MPA are depicted in Table 2.

TABLE 2: The values of marine resources conserved in the NTZ and MPA

Island	Mean WTP		Mean WTA	
Pulau Redang	19.67/month	236.00/year	3,070.48/month	3,6845.71/year
Pulau Tioman	26.75/month	320.97/year	2,063.42/month	2,4761.05/year

The establishment of the MPAs provides a wide range of goods and services that are essential for the maintenance of the social and economic well-being of our society which are supported by marine biodiversity. The establishment of the marine park and the use of NTZ as one of the management tools to conserve and protect the marine lives are generally accepted by the communities. The values expressed could be viewed as the level of appreciation, demand and satisfaction among local communities towards the consumption of the marine resources

CONCLUSION AND RECOMMENDATIONS

There is a need to understand clearly the impact of MPAs with No-Take Zone (NTZ) concept on the marine resources in the enhancement of resources as well as the socio-economic condition of local communities. Implementation of MPA generally affects resources, socio-economic and environment conditions of local stakeholders, including fishers, tourism workers, and businesses. Effective management of MPA can contribute positively to both the fisheries and tourism sectors. However, regular monitoring and evaluation of the NTZ concept are needed to ensure the impacts on the economic and social conditions of the stakeholders and ecological environments of coastal waters are enhanced.

The communities realize the task of protecting the marine resources in the MP is not a straightforward matter, given the limited resources and assets the relevant authorities are facing. Many are apprehensive of the effectiveness of the relevant agencies to enforce the rules and regulations to control the destructive activities especially by the trawlers. In that matter, they have voiced their opinions for the needs to share the burden of protecting the resources together with the authorities. The communities are determined that the task should be shared between locals and the relevant agencies by having the local representatives in the management committee and giving some form of empowerment to the communities. Fisher communities as well as tourism business operators believe that cooperation with the relevant agencies will enhance the protection of the marine resources. Several members of the communities have taken the initiatives to do some form of conservation activities like beach cleaning, sea bed cleaning, recycling and awareness education to local communities and tourists.

Representation by the communities in the MPA management committee is seen as a significant issue in order to foster the sense of ownerships of the resources among the communities. Without the community representation in the management of the MPAs, supports for conservation of the resources would be more difficult to be acquired because the community feels the conservation programs become the sole responsibility of the relevant government agencies; the communities have nothing to do with it. Various stakeholders ought to be included in the management committee of the MPAs; the community representatives in the committee could be accomplished by top down appointment or by democratic election supervised by the relevant agencies.

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Measurement of the Success of the No-Take Zones in Malaysia in Fish Population Perspective

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Abstract: The No-Take Zone in Malaysia has been adopted and implemented for more than 20 years and in order to evaluate the success of the implementation, a scientific study on the fish population in this area should be conducted. This study is proposed to investigate the success of the No-Take Zone implementation in Malaysia by conducting a research in Redang Island in Terengganu, representing No-Take Zone and Bidong Island to represent non-protected zone. In this study, the biomass and diversity of fish population was determined through video-census underwater observation and the use of single beam echo-sounder. There are 15 family of fishes occur in Bidong Island and Redang Island. Family Pomacentridae or damselfish dominated the occurrence of fish in both Bidong Island and Redang Island with 36 and 27 species, respectively. Second most dominance family in both islands is Labridae or wrasse, comprise of 17 species in Bidong Island and 15 species in Redang Island. Other most dominant families are Chaetodontidae (Butterflyfish), Siganidae (Rabbitfish), Scaridae (Parrotfish) and Serranidae (Grouper). For the diversity of fish, the Shannon-Wiener Index was slightly higher in Redang Island which showed that the relation between the number of species and the number of individuals in the protected area is slightly better than in the non-protected area. The Pielo's Evennes Index also higher in Redang Island which showing that the individuals in the protected area are more evenly distributed. For Margalef's Richness Index, Bidong Island recorded slightly higher value, showing higher number of fish species occurs in non-protected zone compared to protected zone. In terms of biomass from echosounder experiment, Redang Island recorded higher biomass of fish at more than 2800 tonnes compared to Bidong Island of more than 1500 tonnes of fish. The findings from this study will greatly contribute to the database on fish population in the Marine Park, as well as helping in the future management practice of No-Take

Zone in Malaysia. The finding from this study calls for more extensive research on fish population to be conducted and also to the other marine parks in Malaysia.

Keywords: No-take zone, fish population, fish abundance, diversity

INTRODUCTION

Fishing contributed significantly to the economy of a nation, but the negative impacts of fishing also were widely documented. Fish population depletion, community structure alteration, destructive fishing practices resulted in degrading habitat and ecosystem modification are some of the effects of fishing (Jennings & Kaiser, 1998). In order to effectively manage fishing activity, No-take marine reserves or No-take zone was introduced where the activities in the areas are regulated and all fishing activities are prohibited. The introduction of no-take marine reserves are aims to restore the natural community structure and ecosystem of the area (Shears & Babcock, 2002) and support the adjacent fisheries by adult emigration of target species and movement of larvae to support other part of the population (Russ & Alcala, 2011). Gell and Roberts (2003), reported that the areas where fishing is prohibited will allow the exploited population to recover and habitats that affected by fishing can regenerate. Dahlgren (2014) reported that the No-take zone may contribute to conserve population of exploited species by increase the density of fish, increase biomass per unit area, increase individual sizes of various species, increase reproductive success and fish also will survive to the older ages which then will influence greater larval survivor, higher growth rate, greater probability of reaching juvenile stages.

The marine parks in Malaysia was gazette in 1994 which aimed to protect and conserve various marine habitat and aquatic life, adopted the concept of No-Take Zone where only recreational activities or any activities not involving the extraction of aquatic life was permitted. Marine Park is an area of the sea zoned two nautical miles from the shore at the lowest tide, except Pulau Kapas in Terengganu and Pulau Kuraman, Pulau Rusukan Besar dan Pulau Rusukan Kecil in Labuan which are zoned one nautical mile from the shore at the lowest tide and currently, there are 42 islands have been gazetted as Marine Park in Malaysia (Department of Marine Park Malaysia, 2017). After more than 20 years of the marine park was introduced in Malaysia, the effectiveness of the implementation has not yet been investigated. This study is proposed to investigate the success of the No-Take Zone implementation in Malaysia by conducting the scientific research on fish population characteristics and comparing the data between the No-Take Zone and non-protected zonewhere Redang Island represented the No-Take Zone and Bidong Island represent non-protected Zone.

Redang Island is located off Terengganu coast where the marine waters surrounding the island up to two nautical miles from the low water mark of the shore have been designated as Marine Parks to manage and conserve its marine resources (Department of Marine Park Malaysia, 2017). Bidong Island is also located off Terengganu coast but not listed as a marine park, hence received various activities including fishing. A university research centre was built on this island, attracting frequent boat visits and variety of leisure activities by university student and staff. Other part of the island that was formerly occupied by Vietnamese refugees also received frequent tourist visits as well as fish farming activities. Hence, this study aims to investigate the fish abundance and diversity of fish in both islands which represent the No-Take Zone and non-protected zone to see the effectiveness of marine park implementation in Malaysia.

METHODS

Sampling Area

In this study, the observation was conducted at Redang Island, representing No-Take Zone and Bidong Island, represent unprotected zone. The study was carried out at 5 selected stations in Redang Island and 5 selected stations in Bidong Island. These stations extensively covered all parts of the respective island.

Research Activity

Two main research activities were conducted in order to determine the fish population in Bidong Island and Redang Island which are; 1) Underwater survey at selected stations, and 2) the use of single beam echosounder to determine biomass of fish.

Monthly video-census underwater survey for fish occurrencewas conducted in April, May, July and August 2017 for four days a month. In shallow waters within the limits of safe SCUBA diving, 100 m transect underwater video-census survey aided by the Go-Pro and SJ Cam cameras was carried out. Fish biomass was determined by acoustic survey by using Echo-sounder equipment (SIMRAD EK-15). The experiment was conducted in August to October 2017. The acoustic survey was designed for parallel transect boat. Target Strength (TS) was determined by a calibrated copper ball before estimating fish biomass for the target fish schools. Finally, the acoustic data was tested using statistical measures.

Data Analysis

Fish Abundance and Diversity Estimation

Fish observed from each section of Bidong Island and Redang Island was identified to the species level based on Mohsin & Ambak (1996), Matsunuma et al., (2011) and Ambak et al., (2012). The number of fishes of each species was recorded. The abundance of fish was expressed in percentages of occurrence for family and species. The data then was analysed for various diversity indices commonly used in fish population study which were:

- Fish species diversity was analysed using Shannon-Wiener Index (Shannon & Weaver (1963).
- The species evenness was calculated using Pielou's Evennes Index (1969)
- Fish species richness was calculated using the Margalef's Index (1958).

Fish Biomass Estimation

To estimate biomass of fish, the average of area backscattering strength (S_a) and TS of the dominant fish school was determined using acoustic backscatters acquired by a SIMRAD EK-15 echo sounder. The fish density (ρa) per unit of area is shown in Equation (1) is derived from integrating acoustic echoes along the predetermined acoustic track (Fabi and Sala, 2002; MacLennan et al., 2002; Parker-Stetter et al., 2009; Rudstam et al., 2009; Toresen, et al., 1998). Next, the backscattering coefficient and cross-section was converted to decibel units. Finally, the total density per ESSR, representing fish biomass, was calculated using Equation (2) by Parker-Stetter et al., (2009).

$$\rho a = 10^6 x \frac{sa}{\sigma bs} x \frac{w}{1000000}\left(\frac{t}{km^2}\right) \quad (1)$$

$$N = \rho a \; x \; A(t) \quad (2)$$

where S_a is the area backscattering coefficient, σ_{bs} is the average backscattering cross-section, *w* is the average fish weight in ESSR (g), TS is fish target strength, 1,000,000 is the constant to convert grams to tonnes, N is the total population (biomass) and ρa is the average density per unit area and A is the total area.

RESULTS

Fish Abundance

In this study, 15 family of fishes was observed in Bidong Island and Redang Island with most family can be found in both island except for Diodontidae which occurs only in Bidong Island, and Zanclidae that can be found only in Redang Island (Table 1). Family Pomacentridae or damselfish dominated the occurrence of fish in both Bidong Island and Redang Island with 36 and 27 species, respectively. Second most dominance family in both islands is Labridae or wrasse, comprise of 17 species in Bidong Island and 15 species in Redang Island. Other most dominant families are Chaetodontidae (Butterflyfish), Siganidae (Rabbitfish), Scaridae (Parrotfish) and Serranidae (Grouper).

In terms of the percentage of occurrence of the most dominant species in Bidong Island and Redang Island, the top ten fish species found in Bidong Island are belongs to the Family Pomecentridae with *Chromis viridis* contributed to more than 14 percent from 22 065 fish observed during this study period. On the other hand, nine from top ten species occur in Redang Island is also belongs to family Pomacentridae and one from family Lutjanidae. In Redang Island, *Pomacentrus moluccensis* occur the most, comprised of just over 10 percent from the total of 9 655 fish.

TABLE 1: The number of species for each family of fish observed in Redang Island and Bidong Island

Family	Number of species	
	Redang Island	Bidong Island
Pomacentridae	27	36
Scaridae	5	6
Serranidae	6	6
Labridae	15	17
Chaetodontidae	5	3
Lutjanidae	1	2
Nemipteridae	4	5
Caesionidae	2	6
Apogonidae	5	5
Holocentridae	1	1
Diodontidae	0	1
Siganidae	2	2
Carangidae	1	2
Pempheridae	1	1
Gerredae	1	2
Zanclidae	1	0

Fish Diversity

Fish diversity was described by three indices mostly used in fish population study and presented in Table 2. The first index, Shannon-Wiener diversity index was used to describe the relation between the number of species and the number of individuals (Spellerberg, 1991). In this study, we found that the Shannon-Wiener Index was slightly higher in Redang Island at 3.30 compared to Bidong Island at 3.10.

The second index used was Pielo's Evennes Index to expresses on how evenly the individuals in the community are distributed over the different species (Heip et al., 1998). This study found that the Redang Island recorded the higher index at 0.76 compared to Bidong Island. The third index is the Margalef's Richness Index which is a measure of the total number of the species in the community (Heip et al., 1998) where Bidong Island recorded slightly higher index at 21.64.

TABLE 2: Fish diversity indices in Bidong Island and Redang Island

Site	Number of species	Number of individuals	Shannon-Wiener Index	Pielo's Evennes Index	Margalef's Richness Index
Bidong Island	95	22 065	3.10	0.68	21.64
Redang Island	77	9 655	3.30	0.76	19.07

Fish Biomass

The biomass of 4 species which are *Epinephelus fasciatus*, *Cephalopholis cyanostigma*, *Chephalopholis boenak* and *Chephalopholis microprion* was estimated. The biomass of these species in Redang Island was more than 2800 tonnes while Bidong Island recorded the biomass of more than 1500 tonnes of fish (Table 3).

TABLE 3: The fish density and biomass, expressed in term of average, standard deviation (SD), range (minimum and maximum), variance, standard error of density and biomass (SE) estimates calculated for Redang Island and Bidong Island

Statistical measures	Redang Island		Bidong Island	
	Density (t/km^2)	Biomass (t)	Density (t/km^2)	Biomass (t)
Average	0.571	460.374	0.873	702.672
SD	0.124	232.521	0.241	203.413
Minimum	1.232	357.282	1.257	1032.579
Maximum	0.329	321.321	0.216	251.355
Variance	0.497		0.752	
SE (density)		178.641	0.6285	
SE (biomass)		214.321		121.542
Total biomass		2821.320		1599.980

DISCUSSION

Marine Park in Malaysia has been implemented more than 20 years ago, adopting the concept of the no-take zone where no exploitation of its resources was permitted aims to conserve its aquatic population and marine environment. The concept of the no-take zone contributed by increase the diversity and abundance of aquatic species (Dahlgren, 2014; McClanahan & Arthur, 2001; Sweke et al., 2013). McClanahan & Arthur (2001) has investigate the effect of marine reserves in the Mombasa Marine National Park where they found that the biomass of fish increases after the enforcement of fishing ban, and population of some important target species started to increase.

This study was conducted to determine the abundance and diversity of fish in Redang Island represented the No-Take Zone and Bidong Island, represented non-protected zone. Pomacentridae (Damselfish), Labridae (Wrasse) and Serranidae (Grouper) are the most dominant family of fish observed in both islands, similar with the finding by Yusuf et al., (2001). This study found that there are more than 20,000 individuals of 95 species from 15 family was recorded in Bidong Island and 77 species from 15 family with less than 10 000 individual fish in Redang Island. Yusuf et al., (2001) reported that 191 species from 41 family was observed in Redang Island, which is far higher than the number of fish species observed in this study. However, their observations are conducted at 10 sampling sites compared to 5 sampling sites in this study.

For the diversity of fish, the Shannon-Wiener Index is slightly higher in Redang Island which showed that the relation between the number of species and the number of individuals in the protected area is slightly better than in the non-protected area. The Pielo's Evennes Index also higher in Redang Island which showing that the individuals in the protected area are more evenly distributed. For Margalef's Richness Index, Bidong Island recorded slightly higher value, showing higher number of the fish species occurs in non-protected zone compared to protected zone. In terms of biomass, Redang Island represented No-Take Zone recorded higher biomass of fish at more than 2800 tones compared to the biomass in Bidong Island of more than 1500 tonnes of fish

Our findings showed that the species occurence in Redang island which represented the No-Take Zone is lower than the fish the non-protected area, however, the high number of fishes in Bidong Island is contributed by the high number of small coral reef fishes in Family Pomacentridae such as *Pomacentrus mollucensis, Chromis viridis* and *Pristotis obtusirostris*. The biomass and diversity of fish the No-Take Zone is just slightly higher than the non-protected zone which probably due to the nature of the activity that occur in both islands. Although Redang Island is gazetted as a marine park where fishing is prohibited, there are about 200 families living in the fishing village on the island and the agriculture activity also was carried out at the flat land (Department of Marine Park, 2017). Besides, one of the main economic activity in Redang Island is tourism, which attracting high number of visitors each year mostly for scuba diving and snorkeling activity contributed to the high traffic of boat trips every day. Davenport & Davenport (2006) reported that coastal tourism may cause marine pollution and disturbance to the aquatic life due to the fuel, chemicals and litter release from tourist yatch, excursion boat and car ferries. But they also added that the greatest ecological threats is from the infrastucture and transport arrangements required to support it, particularly where there are little control on the numbers of tourists.

Unlike Redang Island, even though Bidong Island is not legally protected, there are minimal activities carried out in this island. Other than occasional fishing activity, the island is mostly used for research and recreational activities with the limited number of occupants. This resulted in minimal damage to the aquatic environment in this island hence the difference on the diversity indices and abundance are not much differences between these two islands.

Advani *et al*., (2015) proposed that the long-term monitoring in the no-take marine reserves in crucial to assess the effectiveness of marine reserves in fulfilling the objectives to conservation and management. McClanahan & Arthur (2001) also suggested that a good monitoring program is essential to tract the trends in fish catches at different distances from the closed area.

CONCLUSION AND RECOMMENDATIONS

The finding from this current study showed that the performance of the No-Take Zone in order to conserve and increase the abundance and diversity of fish with the case study in Bidong Island and Redang Island is not as expected with the variation in the species occurrence, diversity and biomass of fish. Other aspects other than prohibition of fishing activity in the No Take Zone may greatly influence the population characteristics of fish.

The finding from this study call for more extensive study to be conducted on fish population and also can be expanded to the other marine parks in Malaysia such as Perhentian Island for better database and understanding on fish population. A long-term monitoring program can be created to determine the changes of fish catches at different distances from the closed area. In terms of the management of the marine protected area where fishing was prohibited, other regulations can be implemented such as limiting the number of visitors each year or designated closed area/s particularly at the area with high fish diversity. These added measures may help to achieve the objective of the marine park implementation.

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Lesson Learned from Pulau Tioman Marine Park (PTMP)

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Abstract: The performance of a Marine Protected Areas (MPAs) can be assessed from three main dimensions, namely (1) biophysical, (2) governance, and (3) economic and social cultural. This particular study has investigated the performance of Pulau Tioman Marine Park (PTMP) from these comprehensive dimensions in aiming to gain knowledge on lessons learned from this 24 year old marine park. The PTMP is also chosen due to its progressive development and worldwide popularity as a tourist destination, which has a significant economic as well as social impact to the local community of the island. The study integrates qualitative and quantitative approaches in achieving its objectives and to enhance the rigorousness of the study. The respondents include the communities in Kg Juara, Kg Tekek, Kg Air Batang, Kg Salang, Kg Mukut, and Kg Genting/ Paya. The findings of the study reveal the lessons learned from the three dimensions of performance. First, in terms of biophysical dimension, there is an urgent need for developing a focal species database, hiring qualified research officers at the island, and strictly enforcing the marine park plan, particularly on the development areas, water and sewage system. Second, from the perspective of the governance, three lessons learned has been identified. Good cooperation in monitoring and surveillance by both the JTLM and the local community, effective information dissemination, particularly on the rules and regulations, and adequacy of available resources to manage the island are considered as the key requirements. Finally, in terms of economic and social cultural dimension, the study identifies another three lessons learned. For continuous improvement efforts, the establishment of one-stop centre for development of the island, development of historical/ attraction sites, and integration of local values, beliefs, and opinion into the management plan are deemed to be beneficial to the island in the long-run. These lessons learned are hoped can be a lesson to other marine parks in managing the marine life and not to forget the people life as well for achieving sustainability development.

Keywords: Lesson Learned, Best Practices, Pulau Tioman Marine Park

INTRODUCTION

Marine Protected Area (MPA) is an area of intertidal or subtidal terrain (include overlying waters and associated flora, fauna, historical and cultural features) which has been reserved by law to protect part or all of the enclosed environment. MPA is critical for the world sustainable development efforts. The ocean is the source of food for human beings, and hence should be conserved in the long run. This effort, however, is a continually challenging goal due to various reasons. It could be due to financial, political as well as social factors. Despite these challenges, MPA needs to be effectively managed with scientific information over time. MPA should be the place for protecting marine species and habitats, conserving marine biodiversity, and restoring fisheries stocks. It is also an area for improving the economy of the local communities through the eco-tourism activities in the surrounding areas. Hence, in order to achieve these goals of MPA establishment, managing an MPA will require continuous, iterative adaptive and participatory processes from all angles to ensure it remains relevant to the community as well as other stakeholders. The management process will usually include planning, design, implementation, monitoring, evaluation, communication and adaptation.

Pulau Tioman Marine Park (PTMP) is home to tropical rainforests, habitats and coral reefs which house a variety of critically endangered species. This ecosystem has to be sustained for future generations and its success story needs to be shared to other MPAs. Furthermore, PTMP had achieved category Level 4 for Regional Flagship Sites in ratings Coral Triangle Marine Protected Areas (CTMPAS) in 2016. This category represents the highest level of evaluation leading to regional interest involved three components namely ecological, social and governance criteria in addition to the highest level for effective management. This paper discussed the insight of three (3) dimensions from The International Union for Conservation of Nature (IUCN) published guidebook of natural and social indicators for assessing the effectiveness of management of MPA entitled “How your MPA is doing”. The guidebook, as a matter of fact, has highlighted three main dimensions that need to be seriously taken into consideration by the MPA manager. Those three dimensions include the biophysical indicators, the social-economic indicators, and the governance indicators. The biophysical indicators measure the biophysical conditions of the ocean and costs, which include the biotic, abiotic and aerial dimensions. The socio-economic indicators, on the other hand, concern with the social, cultural, economic and political factors. Meanwhile, the governance indicators are related to the management of the park. They measure how effective the available resources (input) used by the park managers. Resource governance would involve local, state, national and international stakeholders. These indicators measure how the MPAs affect and affected by the people or stakeholders of the marine park.

Biophysical Dimension

MPAs are considered as a main tool for conserving the bio-physical conditions of our oceans and coast. Therefore, there should be an indicator to measure these conditions. IUCN has listed ten (10) biophysical indicators which include biotic, abiotic and aerial. Among the ten (10) indicators, six (6) indicators are (B1, B2, B3, B4, B6, and B8) used to measure how much 'inventory' is reserved and available, while the other four (4) indicators (B5, B7, B9, and B10) are used to examine the level of 'income' that may be affected the MPA. IUCN has defined the 10 indicators in biophysical as:

- B1: Focal species abundance
- B2: Focal species population structure
- B3: Habitat distribution and complexity
- B4: Composition and structure of the community
- B5: Recruitment success within the community
- B6: Food web integrity
- B7: Type, level and return on fishing effort
- B8: Water quality
- B9: Area showing sign of recovery
- B10: Area under no or reduced human impact

Governance Dimension

The management effectiveness refers to as the assessment of how well a protected area is being managed by the MPA manager, primarily the extent to which it is protecting values and achieving goals and objectives. IUCN has developed a framework for assessing management effectiveness, which has been widely applied around the world to develop specific assessment systems designed to meet the need to evaluate management effectiveness in different circumstances. The IUCN framework which used by this study has 16 indicators. These 16 indicators, in fact, can be grouped in those nine (9) dimensions of Management Effectiveness Assessment Tool (MEAT). Table 1 shows the integration of the two frameworks.

Socio-economic Dimension

The establishment of MPAs always put forward the conserving and protecting ecosystems and biodiversity for future generations' benefits. Beside biophysical and governance perspective in managing the MPAs, the key factors that will shape the development and management are related with the economic, politics and socio-cultural in the surrounding area. Thus, MPAs with inhabitants as PTMP will affect the people and also affected by them. IUCN through Pomeroy, Parks & Watson (2004) has listed 16 socio-economic indicators to allow MPA managers to incorporate and monitor stakeholder group concerns and interest into the management process, determine the impacts of management decisions

TABLE 1: Integration of the IUCN framework and MEAT

G1	Level of resource conflict	NA
G2	Existence of a decision-making and management body	Management Body
G3	Existence and adoption of a management plan	Management Plan
G4	Local understanding of MPA rules and regulations	Community Participation, Legal Instrument and CEPA
G5	Existence and adequacy of enabling legislation	Legal Instrument
G6	Availability and allocation of MPA administrative resources	Financing
G7	Existence and application of scientific research and input	Monitoring & Evaluation
G8	Existence and activity level of community organization	Community Participation
G11	Level of training provided to stakeholders in participation	CEPA and Community Participation
G12	Level of stakeholders participation and satisfaction in management process and activities	Community Participation
G13	Level of stakeholder involvement in surveillance, monitoring, and enforcement	Community Participation
G14	Clearly defined enforcement procedures	Enforcement
G15	Enforcement coverage	Enforcement
G16	Degree of information dissemination to encourage stakeholder compliance	CEPA

on the stakeholders, and demonstrate the value of the MPA to the public and decision makers. This study employed socio-economic indicators that been designed as a guideline to evaluate the performance of PTMP and further identified the lesson could be learned by other MPAs particularly in Malaysia. The 16 socio-economic indicators are listed as in Table 2.

TABLE 2: List of possible socio-economic indicators related to MPA goals

Socio-Economic Indicators	
S1	Local marine resource use patterns
S2	Local values and beliefs about marine resources
S3	Level of understanding of human impacts on resources
S4	Perceptions of seafood availability
S5	Perceptions of local resource harvest
S6	Perceptions of non-market and non-use value
S7	Material style of life
S8	Quality of human health
S9	Household income distribution by source
S10	Household occupational structure
S11	Community infrastructure and business
S12	Number and nature of markets
S13	Stakeholder knowledge of natural history
S14	Distribution of formal knowledge to community
S15	Percentage of stakeholder group in leadership positions
S16	Changes in conditions of ancestral and historical sites/ features/ monuments

(*Source:* Pomeroy, Parks &Watson, 2004)

METHODOLOGY

Research Process

This study employed three phases (phase 1: idea generation and instrument development, phase 2: data collection, phase 3: data analysis and report writing) in completing the research process for PTMP lesson learned study starting from May 2017 until December 2017. We used hybrid approach which integrates qualitative and quantitative methods in gathering the insight information from relevant stakeholders using a well design interview questions, primary data through field survey with structured questionnaire and comparative analysis with other marine parks. The quantitative and qualitative methods, as almost all data-collection methods have some biases. Collecting data through the multi-method approach and from multiple sources lends breadth and rigor to the present study. In addition, literature review was conducted on previous studies in PTMP and other MPAs.

There are four (4) instruments developed for this study, as follow:

1. A designed comparative instrument based on a set of good practices from several well-known marine parks.
2. Structured interview question for JTLM:
   i. JTLM Pulau Tioman
   ii. JTLM Putrajaya
3. Structured interview question for six group of stakeholders:
   i. Police
   ii. School
   iii. Clinic
   iv. Ketua Kampung
   v. Association Representative
   vi Tioman Development Authority (TDA)
4. Survey questions distributed to local community at six villages:
   i. Kampung Tekek
   ii. Kampung Air Batang
   iii. Kampung Salang
   iv. Kampung Juara
   v. Kampung Mukut
   vi. Kampung Genting

The items contain for survey questionnaires are mostly related to socio-economic perspective and a few captured on the perspective of biophysical and governance. Meanwhile, structured interview questions focused mainly on biophysical and governance issues. In order to develop this instrument, three workshops have been set up from the beginning of this study. The research process for this study is illustrated in Figure 1.

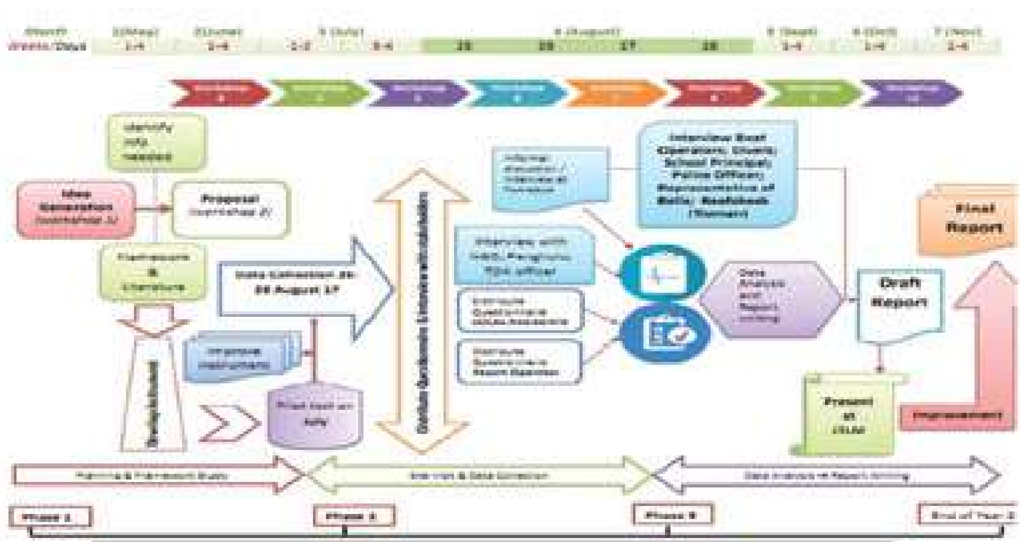

FIGURE 1: Research Process

Data Collection Process

An on-site data collection on PTMP was conducted during school holiday in August 2017. There are three approaches carried out in getting the insightful information; which are through:

1. Structural interview
   Within four days, this study manages to conduct few interviews as in Table 3.
2. Survey
   The second approach is a survey through a set of questionnaires that has been distributed to the local community of PTMP which scattered around six main villages. These villages are Kampung Tekek, Kampung Air Batang, Kampung Paya & Genting, Kampung Juara, Kampung Salang and Kampung Mukut. Total number of PTMP local community is 3,314 residents (TDA, 2015). There is no increasing in terms of number of the population since 2012. A total of 400 set of questionnaires were distributed to the list of the population obtained from TDA which been stratified according to six villages. Table 4 listed the survey respond according to these six villages.
3. Observations
   Observations have been done on PTMP during the visit from 25th August 2017 until 28th August 2017.

FINDINGS

Below are finding for lesson learned according to three dimensions:

Lesson Learned from Biophysical Dimensions

i. *The development of focal species database in PTMP*

A database that keeps all the information regarding the focal species in PTMP is much needed for fulfilling the purpose of PTMP. Seven different focal species types that have been identified in Section 2.1 can be used as a guideline for producing a list of potential focal species in PTMP. By having a list of focal species many efforts can be done in order to fully utilized PTMP especially in serving as part of food security function for local and surrounding communities. Any corrective measures and restoration efforts also can be made by having this database of focal species. These measures and efforts have been addressed in Introduction under indicators B1 to B6.

ii. *Qualified research officers stationed in PTMP*

Qualified research officers are believed to be important for monitoring and controlling researches by the private parties and any other agencies that will be conduct in PTMP. The officers also functioning for analyzing findings from the researches and reporting them to management of PTMP for further actions. At the same time, these officers are responsible for focal species database mentioned above.

iii. *Plan for development areas, water and sewage system*

PTMP has significant areas of permanent forest that are still no or reduced human impact. A proper plan for development should have in place for maintaining the flora and fauna in PTMP. It is also important for areas that have damaged due to human or natural effects to recovery. In term of water and sewage system, much more work needed to be done in order to protect organisms in the sea since all the sewage systems are connected to the rivers.

Lesson Learned from Governance Dimensions

iv. *Good monitoring and surveillance by JTLM and community*

From the perspective of the JTLM, the stakeholders are encouraged to participate in managing the PTMP. In general, user participation in surveillance, monitoring and enforcement of coastal areas is improved in PTMP. For example, the involvement of local community are considerably high in observing and investigating activities such as commercial fishing, recreational fishing, traditional fishing methods, tourism, boating and any other activities in zoning areas.

v. *Excellent in information dissemination on rules and regulations*

The best action of management plan in term of laws and regulations can bring together all level of shareholders or authorities needs to be implemented. In PTMP, there are various available authorities to govern the island such as Tioman Development Authority (TDA), Jabatan Alam Sekitar (JAS), Jabatan Perairan dan

TABLE 3: List of conducted interview

Day	Stakeholders	Topic/Issue	Place
1 - morning	JTLM staff 1) En Anuar	 1) Biophysical	Tanjung Gemuk Jetty Tioman Island Marine
2 - morning	JTLM staff 1) 2) 3) 4)	2) Governance	Park Office
2 - morning	1) Nazri 2) Boat Operator -Fatin 3) Hafaz – PIBG , PPK		Air Batang Village
2 - morning	1) Tok Wan – pengurus 2) Diver 3) nelayan		Tekek Village
2 - evening	1) TDA officer 2) Salang ex-village head	 Authority Office	Tioman Development
3 - morning until evening	Juara Village representative 1) Ketua Kg 2)Tok Imam Salang Village representative 1) bekas ketua kampung 2)Imam surau 3) Pakcik Maulana – old citizen Genting Village representative 1) Hj Azman - KK 2) Imam Masjid Mukut Village representative 1) SU JKKK 2) Imam		Juara Village Salang Village Genting Village Mukut Village
4 - morning until Mukut Village	Government agencies 1) Police - Sarjan 2) Clinic - MO 3) School - Cikgu Community representative 1) Ketua Belia Kg Mukut Selatan 1) Pengusaha Scuba 1) Penghulu assistance (jawatan sambilan) 2) TDA officer	 Secondary data gathering	Tekek Village Tekek Village Air Batang Village 1) Penghulu Office 2) TDA Office

TABLE 4: Survey Responds According to Tioman Six Main Villages

Area (name of village)	Total House	Total residents	Disproportionate Stratified Sampling	Sample size respond
Kampung Tekek	421	1866	100	69
Kampung Air Batang	34	226	100	39
Kampung Salang	40	279	50	17
Kampung Paya & Genting	86	435	50	15
Kampung Mukut	46	225	50	43
Kampung Juara	70	283	50	30
TOTAL	705	3314	400	213

Saliran (JPS_ and etc. From the perspective of local community, they are satisfied in terms of information dissemination on the rules and regulations of the marine park by the authority specifically by TDA. Moreover, the existence of rules and regulations of PTMP are generally adequate and well in place scattered around the Tioman Island.

vi. *Inadequate resources in term of staff, financial and equipment*
Human and financial resources are obligatory and required to carry out the management plan effectively particularly in terms of its enforcement in PTMP. Enforcement also requires a significant fund such as fuel and other maintenance costs of the ships and equipment. Consequently, increasing enforcement activities needs extra allocation for overtime payment while additional staff at the island will incur higher cost in terms of compensation. Thus, in order for realizing the effectiveness of management plan, it's important to JTLM to enhance and optimize their resources specifically staff and equipment.

Lesson Learned from Socio-Economic Dimensions

vii. *The establishment of centered development authority specifically for PTMP.*
Pulau Tioman as a marine park is managed by JTLM. However, the management in terms of physical development in the island and socio-economic growth of the local community is administered and govern by Tioman Development Auhority (TDA). TDA plays a main role in implementing local government functional. Therefore, PTMP is under a proper and systematic planning. The existence of TDA is an opportunity for MPA management to be more focused in their main task in conserving the biodiversity. However, to increase the local community understanding on how the natural ecosystem works, and take action to protect the MPA, a synergy approach between JTLM and TDA is indeed important to boost the growth and development in Tioman Island.

viii. *The sustainable heritage development of historical / attractions site*
It is seems that PTMP attraction is not only dependent on its oceanic inventories but the island itself. The historical site in PTMP is in a decent attention by the villagers

and responsible authorities. For instance, the five (5) kilometers Dragon Horn Trail, a trail for hikers to Gunung Semukut at Kampung Semukut had been preserved and in a good condition had attracted many local and foreign tourists to visit PTMP. Not only physical trail is in good maintenance but along the side walk the natural beauty of flora and fauna is preserved. Besides this many other walking trails either the old trail or newly made that connecting many villages will also becoming new attraction to PTMP. The local community gains benefit by serving as tourist guides and incidentally from a variety of tourism activities.

ix. *Local values, beliefs and opinion are integrated in the action management plan.* The best action management plans if it can bring together all level of stakeholders needs to be developed and implemented. To the local community, consideration of their cultural values, beliefs and their opinion are an important part of PTMP management plan. The actions took by the authorities reflecting their voices are heard. Majority of the local community are Malay and Muslim. For example, the old folk are worried that the young generations are openly expose to the consumption of liquor and cannot prevent themselves for its addiction after PTMP imposed liquor duty free. However, school education is very vital in supporting any conflicting issues including conservation of ecosystems and biodiversity. At the moment, Sekolah Kebangsaan Tekek is the best platform in educating young generations to be responsible to their homeland. It can be seen when they inform their own parents to protect the coral and marine species of PTMP. Thus, this is an opportunity to MPA management specifically JTLM to work with teachers and students by doing a series of well-designed programs regularly in educating them to become a knowledgeable and responsible community.

CONCLUSIONS

This study review lesson learned from PTMP which are related to National Policy on Biological Diversity 2016-2025 (NPBD 2016-2025). The lessons learned of PTMP in terms of biophysical perspective, governance and socio-economic are found to be aligned with the goals and targets of the NPBD 2016-2025.In other words, in the case of PTMP, the JTLM has successfully taken necessary initiatives to achieve the national biodiversity goals. Lesson learned (vi), however, has been perceived to negatively relate to the national biodiversity goal. In fact, increasing the fund for conservation effort is a challenging goal to be achieved due to availability of limited resources in the JTLM. The goal to increase the protected areas depends heavily on the financial as well as human resources. Hence, further actions should be strengthened to search for alternative sources of funds for conservation effort in the long run.

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Feasibility Study of Pulau Sembilan, Perak as a Potential MPA: The Perspective from PGR,TEV and TEI

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Abstract: This paper aims to investigate the potential and feasibility of Pulau Sembilan to be developed as a marine park. The investigation process would identify the main issues and challenges from stakeholders' primary group response (PGR), exploring the prospect of Pulau Sembilan by estimating the Total Economic Value (TEV) for its archipelago and an individual island, which is Pulau Lalang, and further predicting the spillover benefit through Total Economic Impact (TEI) to the surrounding area, particularly Manjung and Bagan Datok District. This study employed hybrid approach by integrating qualitative and quantitative methods in gathering the insight information from relevant stakeholders using a well design interview questions and structured questionnaire survey. The data collection process started from January 2017 until December 2017. Three instruments are developed to ensemble three aggregated stakeholders, which are 1) structured interview for the government agencies, 2) questionnaire survey to the local community, 3) questionnaire survey to the fishermen and the boat operators. Whilst, beside desciptive statistics analysis and transcribing the interview findings, this research employed two models in forward pass the prospect of Pulau Sembilan, namely the cost and benefit analysis (CBA) and System Dynamics (SD) simulation are applied in estimating the TEV and predicting the TEI. It is found that TEV of Pulau Sembilan Archipelago is approximately around RM446.82 million, whilst TEV of Pulau Lalang is RM89.43 million per year. In the next 20 years, if this ecosystem being conserved and preserved, it is estimated to have a value of RM4.25 billion and RM850.82 million for Pulau Sembilan Archipelago and Pulau Lalang respectively. For TEI, it will generate income to the stakeholders including local community around RM25.30 million in 2030. In term of job creations, the entrance of tourists to Pulau Sembilan will create approximately 26,900 jobs in 2020 and will increase to 53,742 in 2030. It shows that job creations for tourism activities such as snorkelling, fishing, diving, accommodation, restaurants and SME business will give a significant economic impact to bounded area spatially from Pulau Sembilan. Commencing the quantitative approach, it seems that Bagan Datuk residents are of a mind towards the establishment of Pulau Sembilan as one of the marine park areas in Malaysia. The local communities are aware about the importance of establishing a new MPA. However, the agreement on establishing a new MPA of Pulau Sembilan is still debatable especially among the fishermen, and fishing boat operators whose incomes reliant on the area of Pulau Sembilan. An idea on proposing only certain islands such as Pulau Lalang to be considered as a marine park area arose in the discourse. In conclusion, the establishment of Pulau Sembilan as a new MPA conceivably influences the socio economic of the residents around the islands. In conveying a new MPA establishment at Pulau Sembilan, the government should take into account the need of the local communities. Therefore, it was suggested that the MPAs in Malaysia alternatively use of a wide range of restrictions in the MPA rules and regulations, from strict no-take areas to areas where resource usage or extraction is only partially restricted.

Keywords: Pulau Sembilan, Primary Group Response (PGR), Total Economic Value (TEV), and Total Economic Impact (TEI)

INTRODUCTION

Pulau Sembilan, Perak is a cluster of nine islands that has high terrestrial and marine biodiversity value. The islands are particularly famous for “blue tears”, the seawater that appear at night due to bioluminescent phytoplankton. This exceptional attraction has made Pulau Sembilan among the top tourism destination in Perak, and Malaysia in general. Scuba diving, snorkeling, camping and jungle trekking are some of the activities associated with its scenic beauty exploration. Besides, the islands are also significantly famous for commercial and recreational fishing activities.

The archipelago of Pulau Sembilan was gazetted as a State Park in 2010, under the management of the Perak State Parks Corporation (PSPC). In 2015, the state government introduced a permit and quota system to restrict the number of visitors, in response to the uncontrolled development and tourism activity on the islands. Nevertheless, the marine protection was not enforced, leaving the harmful activities to the marine life are neither controlled nor monitored. Consequently, the ecological condition of Pulau Sembilan is consistently affected, particularly from the fishing pressure, and also the shipping activity in the Malacca Strait (DMPM, 2015). Furthermore, Pulau Sembilan is considered to be ecologically important, as one of the last major areas of coral reef on Malaysia’s west coast. Hence, if necessary actions are not given a thoughtful attention, there would be a serious implication to the sustainability of the islands’ ecosystems, which in turn threatening their ecological value as well as the economic potential.

Given this issue, marine protected area (MPA) offers a solution to preserve the marine biodiversity of Pulau Sembilan towards sustainable future. Under MPA designation, conservation activities would be more objectively managed, along the structured execution in controlling, monitoring and capacity building of the respective stakeholders. To explore further the feasibility of Pulau Sembilan archipelago as a marine park, this study work on three frameworks, namely 1) Conceptual Framework, 2) Total Economic Value (TEV), and 3) Total Economic Impact (TEI). Thus, the objectives of this paper is to identify the main issues and challenges from stakeholders' primary group response (PGR), exploring the prospect of Pulau Sembilan by estimating the TEV for its archipelago and one individual island, which is Pulau Lalang, and further predicting the TEI to the surrounding area, particularly Manjung and Bagan Datok District.

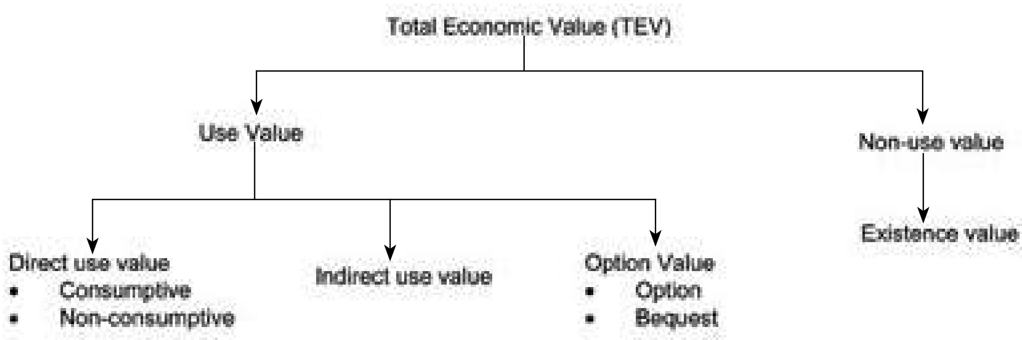
Conceptual Framework

Social, cultural, economic and political factors have significant influence in shaping the development, management and performance of an area (World Bank, 2006). Socio-economic factors directly influence social privilege and levels of financial independence as which explained the lifestyle components and measurement of financial viability and social standing such as income, education, environment and health status. Therefore, in order to develop a new region such as a new marine park area, socio-economic considerations, for example, the compatibility with local culture, food security, livelihood opportunities, monetary and non-monitory benefits, are highly important (Pomeroy, Parks &Watson, 2004). In a formal sense, the behavior that is instituted within the organization is the act done by two or more persons, continuously over time, and exists as part of the organization's daily functions (Goodman & Dean, 1983). Base on the above assertions, a framework of this research has been developed as shown in Figure 1.

Figure 1: Research framework of Pulau Sembilan feasibility study

Total Economic Valuation Model (TEV)

There are two well-differentiated paradigms for valuation: biophysical methods and preference-based methods. The first method constituted by a variety of biophysical approaches while preference-based methods are more commonly used in economics (Pascual & Muradian, 2010). This study deals primarily with preference-based approaches, and the terms total economic value was used. Total economic value (TEV) is a concept in cost benefit analysis that refers to the value derived from a natural resource, a man-made heritage resource or an infrastructure system, compared to not having it. It is most widely used framework to identify and quantify the contribution of ecosystem services to human well-being. According to Pagiola, Von Ritter, and Bishop (2004), economists typically classify ecosystem goods and services according to how they are used. Undeniably, the assessment of total economic value has become pragmatic and popular approach in nature valuation (Admiraal, Wossink, Groot & Snoo, 2013). The main framework used in assessing Total Economic Value (TEV) is developed by Munasinghe & Lutz (1993) (Figure 2).



Source: Adapted from Munasinghe & Lutz (1993)

FIGURE 2: Total economic value and components

Total Economic Impact Dynamic Modeling (TEI)

Based on the concept of Total Economic Value (TEV), this study will select the factors involved for the development of model in evaluating the Total Economic Impact (TEI) in Pulau Sembilan. TEI is an economic impact analysis to analyze the expenditures generated by tourism activities in measuring the accumulated impact on sales revenue, tax revenue, income and employment related activities (Stynes, 1997). According to Carleyolsen, Meyer, Rude, and Scott (2005), from the perspective of public policy and planning, the overview of economic impact analysis is to avoid determining the level of sales or expenses, but it is to evaluate more meaningful effects such as personal income or employment. This study used System Dynamics (SD) simulation to describe the feedback structures of total economic impact in Pulau Sembilan. Before the simulation model is developed, total economic impact dynamic modeling using causal loop diagram is designed (Figure 3).

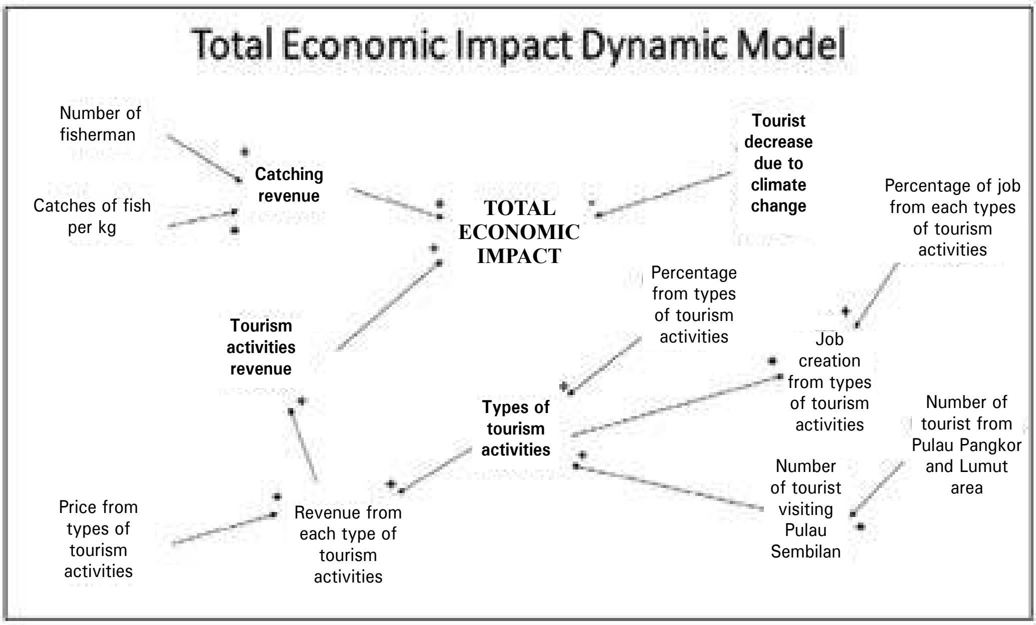


FIGURE 3: Total Economic Impact Dynamic Model

METHODS

Research Process

This study employed hybrid approach by integrating qualitative and quantitative methods in gathering the insight information from relevant stakeholders using a well design interview questions and structured questionnaire survey. The data collection process started from January 2017 until December 2017. Three instruments are developed to ensemble three aggregated stakeholders, which are 1) structured interview for the government agencies, 2) questionnaire survey to the local community, 3) questionnaire survey to the fishermen and the boat operators.

Data Analysis

Beside desciptive statistics analysis and transcribing the interview findings, this research employed two models in looking forward the prospect of Pulau Sembilan if the conseving and preserving it in a certain zoning area are permitted. The cost and benefit analysis (CBA) and System Dynamics (SD) simulation are applied in estimating the TEV and predicting the TEI.

The CBA is reflected by the mathematical equation (1) which took into account, the gross benefits, cost, discount rate and number of years that significantly explained the areas of study. This study utilized three different discount rates ranging from 5% to 15% as suggested by Gustavson (2000) in evaluating the marine resources.

$$NPV = \frac{\sum_{0}^{n} B_n}{[1+i]^n} - \frac{\sum_{0}^{n} C_n}{[1+i]^n} \tag{1}$$

Subject to:

NPV	=	net present value
B	=	gross annual economic benefits, over n years, at a discount rate of *i*
i	=	discount rate
C	=	cost per year
n	=	number of years that we are interested

Whereas the System Dynamics (SD) simulation is used to describes the feedback structures of total economic impact in Pulau Sembilan. Before the simulation model is developed, total economic impact dynamic modeling using causal loop diagram is designed (Figure 3). Causal loop diagram is used as a hypothesis of the real situation in Pulau Sembilan to estimate the total economic impact. A causal loop also referred as a feedback where A affecting B and then, B in turn affecting A through a chain of causes and effects. A causal loop uses an arrow to explain causal influences between variables. It also uses positive or negative signs to show the type of relation that each factor has with the others. A positive sign "+" means the two variables change in the same direction (increase or decrease) and the negative sign "- "means the two variables change in an opposite direction. As in Figure 3.0, in order to estimate the total economic impact, it is assumed that the increment of total economic impact is from tourism activities revenue and catching revenue. Tourism activities revenue is depending on revenue for each type of tourism activities in Pulau Sembilan. To calculate the revenue for each type of tourism activities in Pulau Sembilan, it is depending on types of tourism activities, average charge from types of tourism activities, number of tourists visiting Pulau Sembilan and percentage of tourists from types of tourism activities. Then, from the types of tourism activities, it is assumed that it will create jobs in Pulau Sembilan when number of tourists increased. Finally, it is assumed that the total economic impact will decrease due to the decrement of tourists during climate change in Pulau Sembilan.

FINDINGS AND ARGUMENT

This paper outlined two main findings, 1) finding from stakeholders' primary group response (PGR), and 2) estimation results from TEV and TEI.

Finding 1: PGR

The proposed idea of MPA has invited various arguments from the stakeholders' primary group response (PGR), particularly in Bagan Datuk and nearby areas such as Lumut and Pangkor. Based on the data gathered from series of interviews and survey, several issues and challenges were recognized, which further classified into three broad themes as follows.

Zoning

PGR that represents the fishermen raised a concern regarding the boundary for fishing activity, if MPA is established in Pulau Sembilan. Given that some of the islands are naturally quite close to each other, the existing fishing ground for small boat fishermen is already confined to some distance. They worried that the legitimate area for fishing will be further reduced to a certain extent, hence affecting their source of income. These people are mainly the fishermen from Bagan Datuk, who are constrained by their boat capability (small boat) to fish in anotherplace if the MPA boundary is executed. Moreover, they will be troubled if landing in Pulau Sembilan is restricted, as Pulau Sembilan has traditionally been a shelter for them during bad weather.

Communication

Some PGRs tend to have misleading understanding regarding the concept of MPA. The fishermen in particular are not clear about what are permitted and restricted in MPA regulation. For instance, they perceived that two nautical miles are the only boundary that adopted in MPA law. Besides the rigid and standard rule, they also have a view that MPA will restrict them to land on the islands during bad weather. Consequently, they tend to perceive MPA as a threat, rather than a positive measure to conserve the biodiversity in the long run. Therefore, the concept of MPA needs to be clearly communicated to the PGR and respective society before the proposal of establishment can be taken to a higher extent. A clear briefing and information sharing could have a higher chance to reduce the resistance from PGR for a new MPA in Pulau Sembilan.

Awareness and Education

While the level of awareness on MPA is generally good among the respondents, the attitude towards environmental protection is not yet encouraging. Littering and waste disposal are still the major issues in Pulau Sembilan, particularly among the local tourists. Environmental conscious behavior is indeed important to support the establishment of MPA. Hence, this necessitated for environmental education program to raise the awareness to the public, and eventually change the behavior towards more environmental conscious conduct.

Finding 2: Economic Valuation

This study also predicted the value of Pulau Sembilan Archipelago and an individual island, Pulau Lalang, and its impact through Total Economic Value (TEV) and Total Economic Impact (TEI). These measurements illustrate the prospect of Pulau Sembilan as a conservation island and how much the benefit spillover to the coastal line local community.

TEV for 20-Year Period

The total economic value (TEV) for Pulau Sembilan Archipelago (P9Arch) and Pulau Lalang (PL) is approximately ranging between RM446.82 million and RM89.43 million per year, respectively (Table 1 and Table 2). By next 20-year period, TEV is estimated to amount nearly RM4.251 billion (P9Arch) and RM850.823 million (PL) at 10% discount rate. This study found that the largest portion of TEV is contributed by the aesthetic values (coral reef and coral fish) which are 97-98%, followed by other components for the remaining percentage of total economic value per year.

TABLE 1: Economic values of Pulau Sembilan (P9Arch)

Component of Basic TEV (variables)		Economic Value per Year (RM)	PV (20-year period, i=10%) (RM)
Capture fisheries		7658011	72854975.62
Aesthetic – coral reef		133,315,203.12	1,268,302,679.68
Aesthetic – reef fish		303,881,682.50	2,890,997,749.73
Coastal protection – coral reef		518,186.30	4,929,798.40
Carbon sequestration – coral reef		508,764.73	4,840,165.70
Bequest value	mode		
	WTP	235,792.25	2,243,224.60
	ave WTP	937,038.40	8,914,574.54
	LOWER BOUND	446,117,639.90	4,244,168,593.73
TOTAL	UPPER BOUND	446,818,886.05	4,250,839,943.67

TEI by Year 2030

The total economic impact model of Pulau Sembilan is divided into three sectors, that is, total economic impact sector, tourist inflow sector and job creation sector. In total economic sector, there are two types of inflows for total economic impact in Pulau Sembilan that is catching revenue and tourism activities revenue. In determining tourism activities revenue, there is a positive inflow that contributes to the total economic impact in Pulau Sembilan. The inflow is generated by revenues obtained from the tourist's activities in Pulau Sembilan such as revenue from snorkelling, fishing, accommodation, restaurants, diving as well as revenue from small medium enterprise business. Revenue from each of the activities is calculated by looking at percentage of tourist visited to Pulau Sembilan

TABLE 2: Economic values of Pulau Lalang

Component of Basic TEV (variables)		Economic Value per Year (RM)	PV (20-year period, i = 10%) (RM)
Capture fisheries		1519910.58	14459766.15
Aesthetic - coral reef		26,459,505.96	251,724,195.97
Aesthetic - reef fish		60,312,395.00	573,785,812.92
Coastal protection - coral reef		102,846.14	978,433.27
Carbon sequestration-coral reef		100,976.21	960,643.57
Bequest value	mode WTP	235,792.25	2,243,224.60
	ave WTP	937,038.40	8,914,574.54
TOTAL	LOWER BOUND	88,731,426.14	844,152,076.48
	UPPER BOUND	89,432,672.29	850,823,426.43

multiply by the cost for each activity. The overall simulation model of total economic impact in Pulau Sembilan is shown in Figure 4.

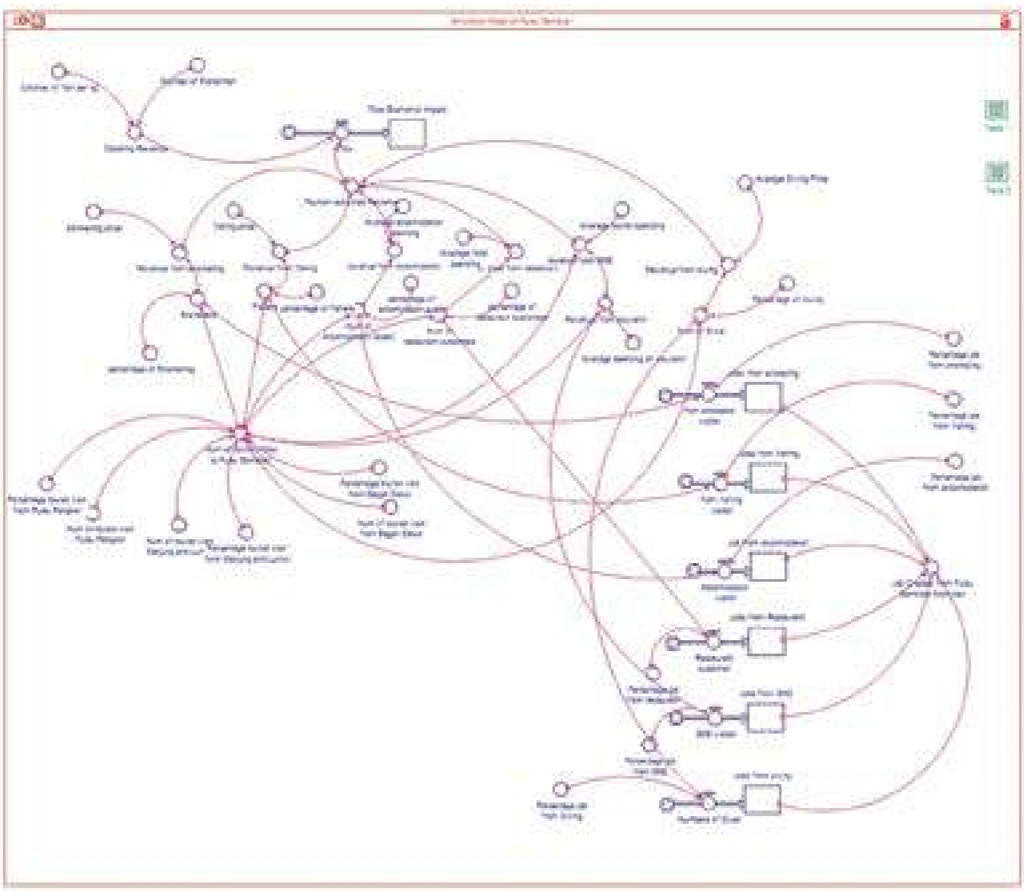


FIGURE 4: Simulation model of total economic impact in Pulau Sembilan

In order to analyse the model, it is assumed that the number of tourist inflow is from Pulau Pangkor and Lumut, (as in Table 3) and one % of tourists from each area will visit Pulau Sembilan.

TABLE 3: Numbers of tourist visited Pulau Sembilan

Years	Pulau Pangkor	Lumut
2010	689,184	339,734
2011	663,078	425,774
2012	984,679	627,791
2013	1,001,415	636,499
2014	835,794	461,721
2015	901,886	686,194
2016	941,407	1,145,634
2017	943,169	857,033

In addition, it is assumed that the tourists who visit Pulau Sembilan will do various tourism activities whereby each of the activities will be charged an average charge as follows (Table 4):

TABLE 4: Types of tourism activities and its average charges

Tourism Activities	Average Charges (RM)
Snorkelling	30
Fishing	20
Accommodation	30
Food	30
Souvenir	10
Diving	150

From each of the tourism activities, total economic impact is calculated from 2011 until 2030 as in Table 5 with the initial value of RM1000. It shows an increment of total economic impact in Pulau Sembilan since the number of tourists is also increased.

For the jobs creation sectors, it is assumed that if the number of tourists increases, it will create 0.1 % of jobs for each tourism activities such as snorkelling, fishing, diving, accommodation, restaurants and SME business. Then, the job creation might also increase as the number of tourists increase as in Table 6.

Currently this study predicted that Total Economic Value (TEV) of Pulau Sembilan Archipelago is approximately around RM446.82 million, whilst TEV of Pulau Lalang is RM89.43 million per year. In the next 20 years, if this ecosystem being conserved and preserved, it is estimated to have a value of RM4.25 billion and RM850.82 million for Pulau Sembilan Archipelago and Pulau Lalang respectively. The spill over benefit from eco-tourism activities at Pulau Sembilan is shown by Total Economic Impact (TEI) that

TABLE 5: Total economic impact

Years	Total Economic Impact (RM)
Initial value	1,000.00
2011	17,296,335.22
2012	22,769,531.24
2013	24,501,284.67
2014	25,049,222.27
2015	25,222,593.16
2016	25,277,448.79
2017	25,294,805.45
2018	25,300,297.21
2019	25,302,034.84
2020	25,302,584.63
2021	25,302,758.59
2022	25,302,813.63
2023	25,302,831.05
2024	25,302,836.56
2025	25,302,838.30
2026	25,302,838.85
2027	25,302,839.03
2028	25,302,839.08
2029	25,302,839.10
2030	25,302,839.11

TABLE 6: Job creations according to each tourism activities

Years	Snorkelling	Fishing	Diving	Accomodation	SME Business	Restaurants
Initial value	10	10	10	10	10	10
2011	100	370	12	370	1,810	82
2012	190	730	14	730	3,610	154
2013	280	1,090	15	1,090	5,411	226
2014	370	1,450	17	1,450	7,211	298
2015	460	1,810	19	1,810	9,011	370
2016	550	2,170	21	2,170	10,811	442
2017	640	2,530	23	2,530	12,611	514
2018	730	2,890	24	2,890	14,412	586
2019	820	3,250	26	3,250	16,212	658
2020	910	3,610	28	3,610	18,012	730
2021	1,000	3,970	30	3,970	19,812	802
2022	1,090	4,330	32	4,330	21,612	874
2023	1,180	4,691	33	4,691	23,413	946
2024	1,270	5,051	35	5,051	25,213	1,018
2025	1,360	5,411	37	5,411	27,013	1,090
2026	1,450	5,771	39	5,771	28,813	1,162
2027	1,540	6,131	41	6,131	30,613	1,234
2028	1,630	6,491	42	6,491	32,414	1,306
2029	1,720	6,851	44	6,851	34,214	1,378
2030	1,810	7,211	46	7,211	36,014	1,450

has been simulated from 2011 until 2030. It shows that, with the entrance of approximately 18,000 tourists every year to Pulau Sembilan, it will generate income to the stakeholders including local community around RM25.30 million in 2030. In term of job creations, the entrance of tourists to Pulau Sembilan will create approximately 26,900 jobs in 2020 and will increase to 53,742 in 2030. It shows that job creations for tourism activities such as snorkelling, fishing, diving, accommodation, restaurants and SME business will give a significant economic impact to bounded area spatially from Pulau Sembilan.

CONCLUSIONS

Commencing the quantitative approach, it can be concluded that Bagan Datuk residents are of a mind towards the establishment of Pulau Sembilan as one of the marine park areas in Malaysia. The local communities are aware about the importance of establishing a new MPA and sustaining the marine resources, however more efforts is required to provide more knowledge and understanding about the role of MPA. Forthrightly, the acceptance levels of the local communities are high and they also thoughtful in participating in the management issue of sustaining the marine resources of Pulau Sembilan. High acceptance level is important to ensure the success of MPA as acceptance can reap a more positive environment, more open communication, greater respect and trust, natural retention of valued people and a better decision making. However, the agreement on establishing a new MPA of Pulau Sembilan is still debatable among the fishermen, and fishing boat operators whose incomes reliant on the area of Pulau Sembilan. There is an idea on proposing only certain islands such as Pulau Lalang to be considered as a marine park area.

In conclusion, the establishment of Pulau Sembilan as a new MPA conceivably influences the socio economic of the residents around the islands. In conveying a new MPA establishment at Pulau Sembilan, the government should take into account the need of the local communities. Therefore, it was suggested that the MPAs in Malaysia make use of a wide range of restrictions in the MPA rules and regulations, from strict no-take areas to areas where resource usage or extraction is only partially restricted. The enforcement on the new marine protection area should choose and adopt suitable good practices that have been implemented in other success MPA. Besides, MPA success is not depend just on the long-term survival and firm institutional status of the protected area, but it is essential to take into account ecological, social, political, and economic outcomes.

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Marine Ecosystem Mapping of Taman Laut Labuan

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Abstract: The first habitat mapping of marine parks in Malaysia were carried out in Taman Laut Labuan (TLL) by integrating acoustic technique, in situ sampling and drone mapping. The objective of this project is to add spatial and ecological context to the benthic habitats in TLL. Few approaches were used to integrate this data that includes; terrain and multivariate statistical analysis for marine landscape mapping, coral video transect for benthic data, supervised classification of drone image and grain size analysis for sediment distribution mapping. 8 marine landscape zones were identified using acoustic data and sediment data, coral video transect showed correlation with the zones and drone mapping came up with three level of classifications. The most detail classification managed to detect the coral growth form within the intertidal area.

Keywords: Taman Laut Labuan, South China Sea, habitat mapping, marine landscape, benthic map.

INTRODUCTION

The three islands of Taman Laut Labuan – Pulau Kuraman, Rusukan Kecil and Rusukan Besar; situated to the south of Pulau Labuan, were designated as a part of Malaysia's marine park (MP) in 1994. Since then, the islands have been well protected and were subjected to only minimal anthropogenic activity under the jurisdiction of Marine Park Department Malaysia. However, with the recent slowdown in the oil and gas sector worldwide, Labuan is economically affected hence the government is steering towards tourism as its economic generator (Bernama, 2016). A large amount of fund is being allocated to improve tourism facilities in these islands such as construction of commercial buildings with modern facilities and yacht, waterfront development, hotel and coastal road. Sea reclamation is also part of the proposal to support the expansion of tourism industry. Such development could lead to a severe stress towards the island ecosystem especially the coastal area that supports a high biodiversity.

The total area of TLL is approximately 158.15 km^2 and is characterized by shallow fringing reef with few submerged shallow reefs. Early study has been conducted by Kushairi (1997) regarding the TLL. However, no published data are available in this study. In 2012, the Department of Marine Park Malaysia have conducted a special marine expedition to acquire the status of living marine resources within TLL. A comprehensive data on marine biodiversity comprising coral, reef fish and marine invertebrates have been recorded during the expedition. In total, 161 species of scleractinian corals, 179 species of reef fishes and 47 species of invertebrates have been identified from eight survey station within TLL (Ransangan et al., 2013). Apart from that, classification of sea bottom in TLL was also reported by Mustajap et al. (2015). Reef Check too conducted coral reef monitoring within TLL with three survey stations (Reef Check, 2013). Throughout both surveys, the coral reef condition was classified as from 'poor' to 'good' condition as outlined by Chou et al., 1994 with a percentage hard coral cover ranging from 21.88% - 60.53% using Reef Check method.

The need for a better understanding of the seafloor condition has never been urgent with more marine parks subjected toward increased anthropogenic activities. Knowledge on the extent geographical range and ecological functioning of benthic habitats is still extremely poor in marine parks in Malaysia due to lack of detailed seafloor information. Consequently, it is difficult to manage marine resources effectively, protect ecologically important areas and set legislation to safeguard the MP. Furthermore, the lack of these baseline data hinders scientific linkage between fields studying the dynamic of the seabed ecosystems which include the biogeochemical cycle, its physical properties and the benthic organism inhabiting the area. In order to address this critical issue, marine ecosystem mapping is much needed to establish their geographical extent and to assess the ecosystem condition. A representation of the marine ecosystem natural zones in marine parks could be made possible using a marine landscape mapping technique as proposed by Verfaille et al. (2009) and Ismail et al. (2015, 2018).

Potentially, the marine ecosystem mapping exercise carried out within this project could aid in establishing a guideline to facilitate a standard practice for efficient marine spatial management in Malaysia. Therefore, overall information on the seabed profile, benthic composition and biological resources within the protected area can be monitored to ensure efficient management of marine parks. Further verification is required to elucidate current status of coral reef and associate marine biodiversity in TLL.

Here, we aim to add spatial and ecological context to the benthic habitats in TLL and it will be addressed through the following objectives:

1. To map the marine habitat within one nautical mile of Kuruman Island, Rusukan Besar and Rusukan Kecil and propose a protocol for marine landscape mapping to be implemented for marine parks in Malaysia.
2. To determine the benthic cover of the study area.

METHODOLOGY

Materials and Data

The project is divided into 3 main components of acoustic mapping, groundtruthing sampling and airborne mapping. Acoustic survey was carried out from 6 – 24 April 2017 to collect multibeam bathymetry, backscatter, singlebeam bathymetry and sidescan sonar. We divided the acquisition into two sectors as the shallow water rocky outcrop (Nazaruddin et al., 2016) in Taman Laut Labuan were a major setback for acoustic boat manoeuvring. The first sector was designated for area less than 10 m of water depth and were surveyed using singlebeam Teledyne Odom Echotrak MK111 and sidescan sonar KLEIN system 3900. Whilst the second sector includes area that area more than 10 m and were surveyed using multibeam echosounder Kongsberg EM2040C.

The in-situ sample taken as groundtruthing materials are sediment sample and coral video transect. These samples were used to create a substrate distribution map. The field sampling was carried out two times from 11- 18 July and 11-17 September 2017.

The third work package of the project were collection of drone images to test the ability to identify coral growth form and coral coverage map within the airborne surveyed area. The drone mapping was involved in 3 field sampling; 11-18 July, 11-17 September and 11-15 October 2017.

Acoustic Data

Sector 1 were surveyed and approximately covers 30km^2 using singlebeam and sidescan sonar. Each survey lines were spaced at the best possible line spacing of 25 meters. Each ping along these lines were recorded and projected in ESRI ArcMap 10.4.1 and interpolated into digital bathymetry model (i.e. DEM) using deterministic technique of Spline with Tension (Ali, 2018). Multibeam bathymetry were processed using Caris HIPS and SIPS by National Hydrographic Centre, Malayisa and were projected into ArcMap to be integrated with the singlebeam data to produce an overall bathymetry map for TLL. Although multibeam data were processed to 0.5 m resolution, due to the coarse grid of singlebeam data at 21 meters, both data had to be averaged to 5 meter. Multibeam backscatter and sidescan sonar were also analysed and was used to predict the sediment distribution in TLL.

A marine landscape map is produced using a method established by Verfaille et al. (2009) and Ismail et al. (2015, 2018). The methods consist of terrain analysis to produce abiotic variables from bathymetry, backscatter, sidescan and grountruthing data. These abiotic variables are then subjected to multivariate statistical analysis comprised of principal component analysis, Calinski-Harabasz criterion and k-means clustering.

In-situ Data

Coral Video Transect

Groundtruthing data on benthic communities was obtained through the Coral Video Transect (CVT) technique (Safuan et al., 2015). There are 17 total dive stations and out of the total, 12 CVT stations were used to analyse its percentage of benthic cover. Each CVT is acquired using 100m transect tape by following the reef contour and parallel to the shoreline. Detail analyses on percentage of benthic cover were carried out using Coral Point Count with Excel Extension (CPCe) software and is outlined in a separate report. The results is used here in the form of percentage cover in four categories: live coral, algae, other invertebrates and dead coral. Coral health status is indicated by percentage of live coral cover following Chou et al. (1994), with the following categories: excellent (> 75%), good (51% – 75%), fair (26% – 50%) and poor (< 25%).

Sediment: Grain size analysis

Sediment samples were collected using Ponar grab in 65 stations. Sampling stations were randomly positioned across Taman Laut Labuan. Each 200 g were sub-sampled from the samples and transferred from estimation of total volume of each grab sample for laboratory particle size analysis. These sub-samples (200 g) were dried in oven, weighed by using electronic balance and sieved through a set of sieve machine. There are 13 different size of sieves that needed to be used for dry sieving process starting from 4, 2.8, 2, 1.4, 1, 0.71, 0.5, 0.355, 0.25, 0.18, 0.125, 0.09- and 0.063-mm. Samples less than 63 μm were analysed using particle size analyser CILAS PSA 1180 LD with bottom detection restriction of 0.02 μm. The outcomes from the fine and coarse data were then consolidated to give the percentage weight per Wentworth (phi) grain size class for each grab sample. The data were included and used for marine landscape mapping of Taman Laut Labuan

Airborne Mapping

DJI Matrice 100 drone was used to obtain 7411 images of Taman Laut Labuan. The drone was flown 500 meters towards the sea from the shoreline. A total of 6795 drone images were successfully obtained from Micasense RedEdge multispectral sensor and 616 images from Zenmuse X3 RGB camera. Pix4D and AgiSoft Photoscan Professional software were used to generate orthomosaic rasters; 8 cm/pixel for Micasense and 5 cm/pixel for RGB camera (Casella et al., 2016; Agisoft LLC, 2018; Pix4D 2018).

Supervised classification (maximum likelihood) was performed to compare the capability of coral reefs mapping using Zenmuse RGB camera and Micasense multispectral sensors. The classification scheme (adapted from NOAA, 2005 and Safuan et al., 2016) for pixel-based classifications was shown in Table 2. A sample of images which representing coral reefs classes appear in Figure 8. Spot check surveys from snorkelling (Roelfsema and Phinn, 2010), SCUBA and georeferenced underwater videos were used as coral mapping verification (201 to 219 verification points depending on area). Three levels of supervised classification were performed (Mumby et al., 1997a). Level 1 classify the TLL into live coral and non-coral. Level 2 categorised the marine park into 5 classes which are live corals, dead corals, algae, sand/rock/silt and others. Level 3 classification is a detailed classification that consists of 10 classes: tabular corals, branching corals, massive corals, aggregated patch reef, dead coral with rubble, dead coral with macroalgae, sun glint/waves, sand, submerged rocks and unidentified.

FINDINGS AND ARGUMENT

Digital Bathymetry Model

A seamless merging of singlebeam and multibeam bathymetry data to produce a continuous surface of sector 1 and sector 2 acoustic mapping were successful. The final bathymetry map produced is shown in Figure 2 with location of groundtruthing samples collected. Based on the map, the deepest area within TLL is 78 meter deep. These can be observed towards the northeast of Pulau Kuruman and southwest of Pulau Rusukan Besar. The latter is a channel where the current is observed to be stronger than most parts of TLL.

Marine Landscape Map

The abiotic variables produced from the bathymetry map and used in the classification are slope, aspect, surface ruggedness, bathymetric position index and curvature. Sediment maps interpolated from sediment samples too were included to produce the marine landscape map. A total of 8 zones (Figure 3) were acoustically identified and were groundtruth qualitatively using visual from dive footage (Table 1). The overall qualitative assessment shows a convincing result to use marine landscape map as level 1 base map. However, the map produced is still a powerful tool that could be improved with more added attributes. These attributes are something that can be incorporated over time and through different repeat surveys.

Coral Coverage Map

Coral coverage map is considered a local scale map of which Classiifcation carried of for both RGB camera and Micasense sensors, however based on accuracy assessment Micasense sensor reported with overall accuracy of 71.23% in comparison to 49.32% by RGB camera. Pulau Kuraman dataset was not processed due to the bad quality of the images obtained. Supervised classification on Micasense sensors for Level 1 map is approximately 25.32% of live coral and 74.68% non-coral in Pulau Rusukan Kecil and 11.66% live coral, and 88.34% of non-coral were detected in Pulau Rusukan Besar (Figure 4).

Further Level 2 supervised classifications on Micasense image resulted in approximately 47% of Pulau Rusukan Besar and 28.71% Rusukan Kecil are dominated by sand/rock/silt class. Level 3 classification shows an interesting result whereby the coral reef forms can be identififed up to growth form level. The overall accuracy of Level 3 classification map for the Micasense sensor in Pulau Rusukan Kecil is 74.63% (Figure 6) and 71.23% for Pulau Rusukan Besar (Figure 7).

CONCLUSION

The spatial extent of benthic properties is a crucial information needed to support effective marine spatial planning in marine parks around Malaysia. As this project is the first comprehensive study on habitat mapping in Malaysia, there are a few conclusions and recommendations that can be outline:

Bathymetry map is an essential information needed in order to support effective marine spatial planning. Integration of multibeam bathymetry and singlebeam bathymetry were successful in providing a base map for TLL. However, whenever possible it is recommended to use the same system all throughout the mapping exercise, preferably multibeam echosounder as much as possible. This is because they have a better coverage and the data are continuous in comparison to singlebeam echosounder.

It is often a challenge faced in habitat mapping is to correlate data of different footprint. For examples, acoustic data will have a bigger pixel (e.g. 2 meters), a medium coverage coral video transect (e.g. 500 cm) and a high-resolution drone image (e.g. 2 cm). Certain details will be lost during data integration and production of a high confidence habitat map. The issue in correlating regional to medium and local scale need a better understanding in order to create a a high confidence habitat map

Groundtruthing materials plays a major role to ensure a high level of confidence in using this map especially for marine spatial management. it is always encouraged to have more groundtruthing materials in habitat mapping for acoustic data and drone mapping. A well distributed coral reefs verification is a way forward for an improved technique to incorporate more biological data into abiotic maps.

Drone mapping demonstrated a bright potential of using the RGB camera and multispectral sensors on board drone platform in mapping coral reefs. Higher accuracy in supervised classification was reported by using multispectral sensors. However, certain limitations are to be considered if using drone for coral mapping. Time limitation of when data can be acquired as it is strongly influenced by the sunlight angle and weather condition. Short flight time requires more field days and the extent constrain limits its ability to map a large area over a short time.

The overall strategy used in this project is potentially could be build up into the recommended operating guideline for the Departments of Marine Parks Malaysia to use as an official guideline in habitat mapping the marine parks as a baseline data.

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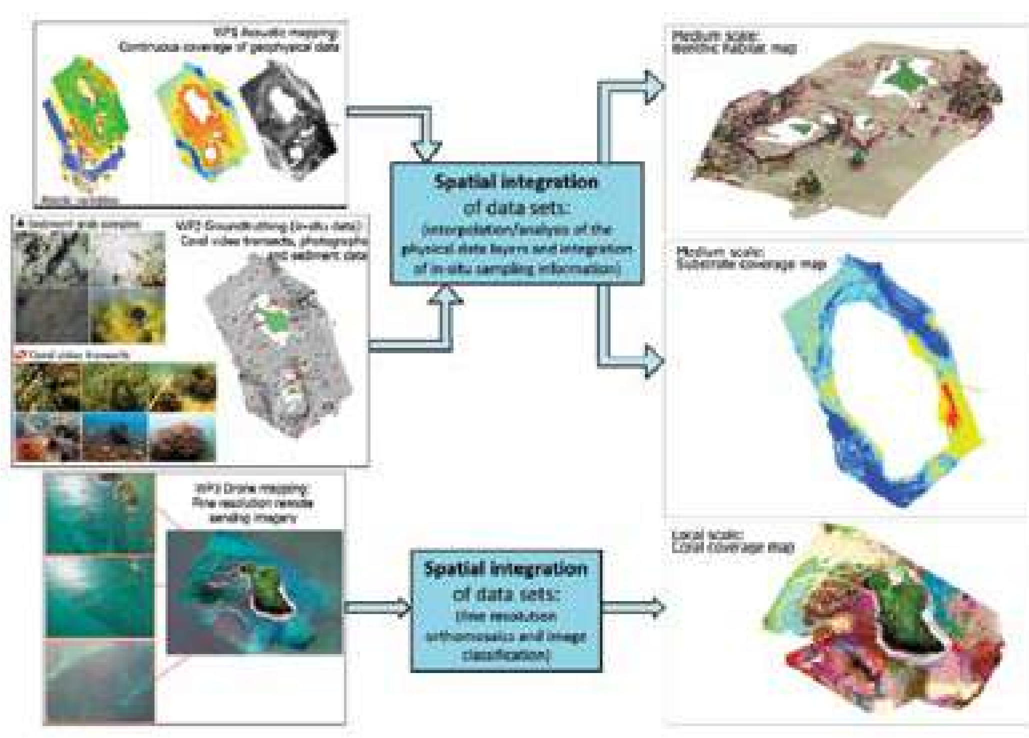


FIGURE 1: A simplified flowchart to correlate between the type of data acquired, the methodology and deliverables by integrating these data sets and presented within the spatial extent of Taman Laut Labuan

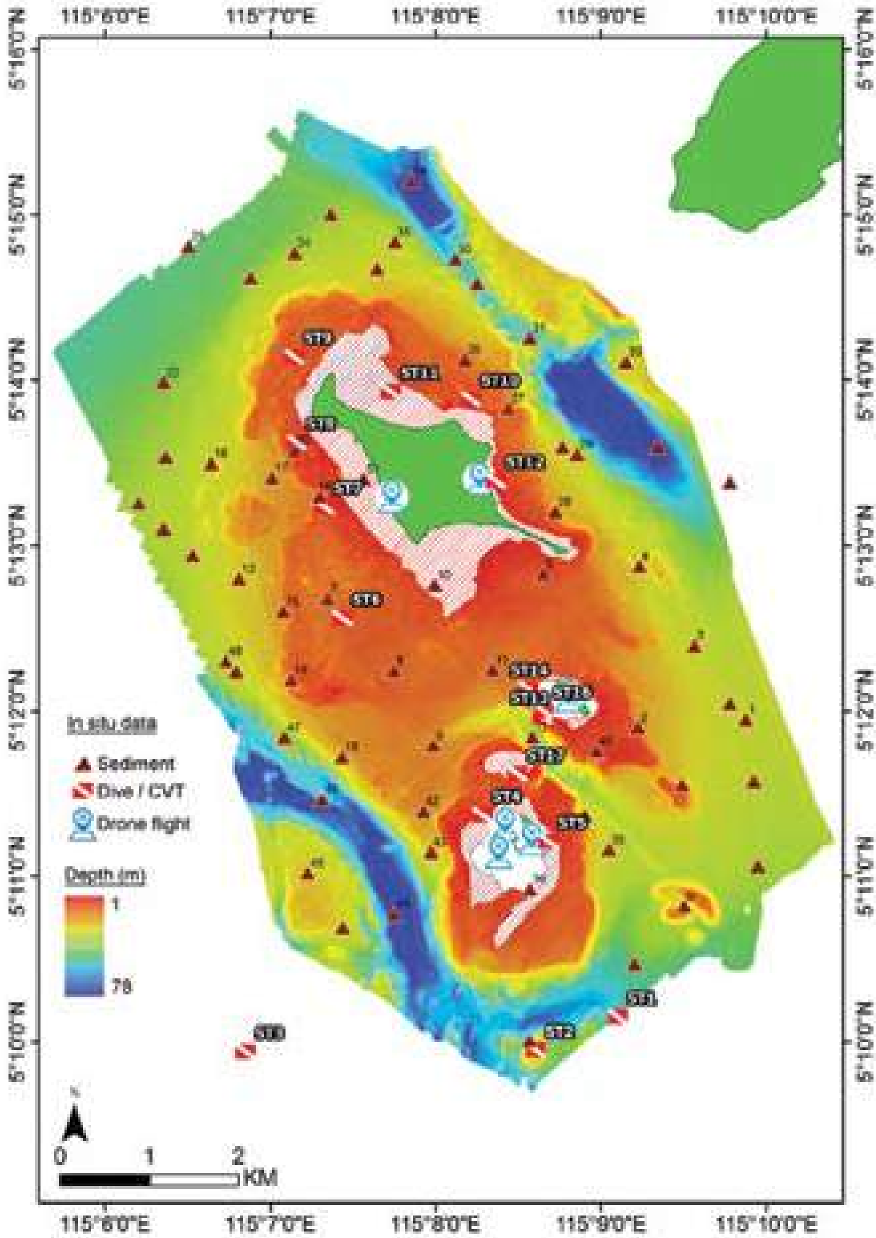


FIGURE 2: All the data acquired for the Marine Ecosystem Mapping of Taman Laut Labuan and the final bathymetry produced for the entire 1 NM of Taman Laut Labuan

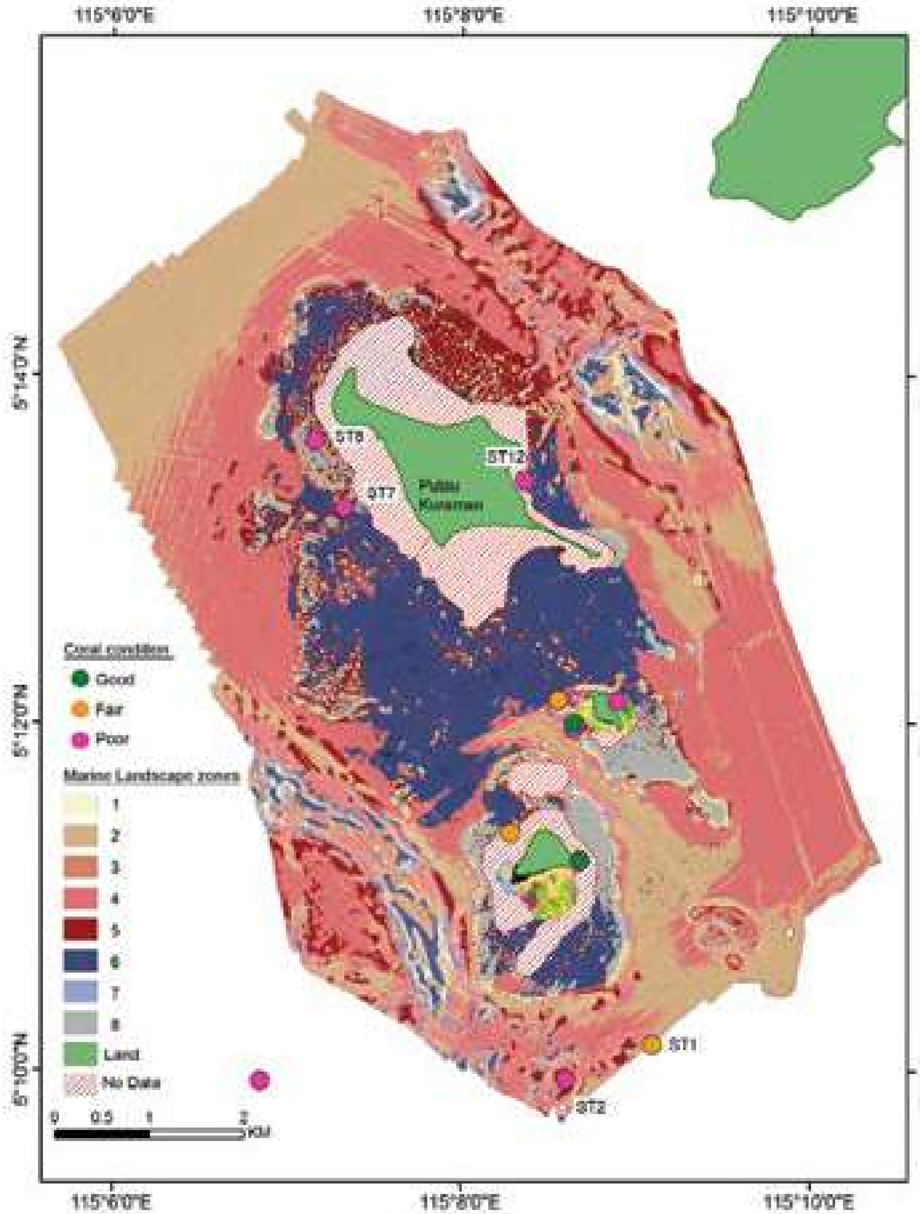


FIGURE 3: The overall habitat map of Taman Laut Labuan expressed as marine landscape zones. Toegther with the zones are the corresponding grountruthing dive sites with its coral reef status indicated via ‘poor’ reef condition with low diversity, green as ‘good’ coral condition and high diversity and ‘fair’ reef condition with high diversity. The interpretation of each zone and the groundtruthing image is shown in Table 1.

TABLE 1: Marine landscape zone with the groundtruthing from dive video footage

Zone	Description	Groundtruthing
1	Patches of coral, dead corals or macro algae. It is scattered all throughout both sectors and can be found associated with most zones.	 (image from Station 6)  (image from Station 9)
2	Broad flat silty or muddy area	No image available, only sediments grab
3	High in surface ruggedness, this could be a potential ground for live coral to be found	 (image from Station 13)
4	Broad flat sandy bottom often in slightly deeper areas (fine to medium sand)	 (the image is most probably a transition between two zones. image from Station 2)

Zone	Description	Groundtruthing
5	High slope and ruggedness. Potentially are coral covered area or even macro algae	 (image from Station 1)  (image from Station 11)  (image from Station 2)
6	Shallow sandy bottom. This area mostly found within the Sector 1 survey area. Often it is associated with patches of coral, dead corals or macro algae.	 (image from Station 6)

Zone	Description	Groundtruthing
7	Moderate open slope with potential coral cover	 (image from Station 1)  (image from Station 11)
8	Relatively flat with potential of encrusting coral coverage	 (image from Station 2)

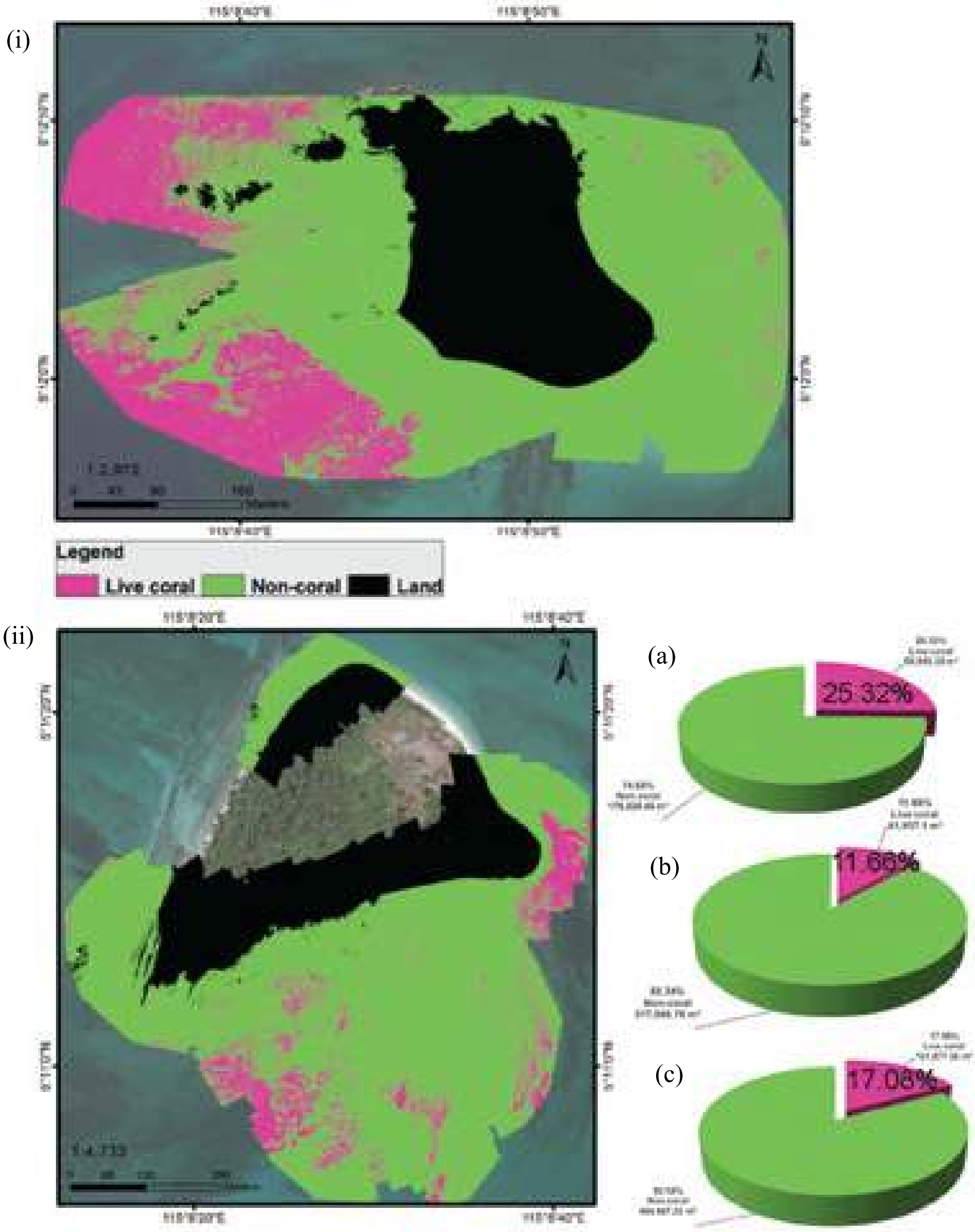


FIGURE 4: Micasense sensors supervised classification Level 1 map in (i) Pulau Rusukan Kecil (ii) Pulau Rusukan Besar with its percentage of coral coverage a) Pulau Rusukan Kecil b) Pulau Rusukan Besar c) combination of both Pulau Rusukan

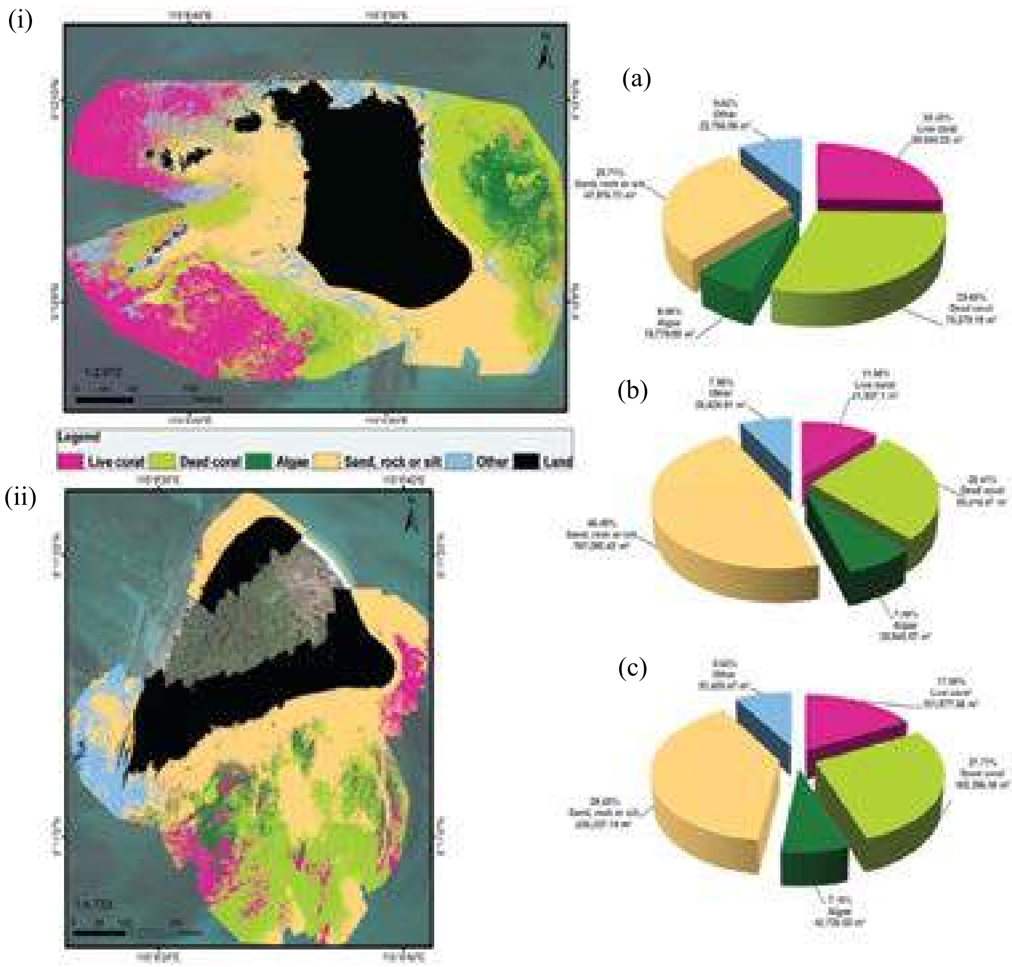
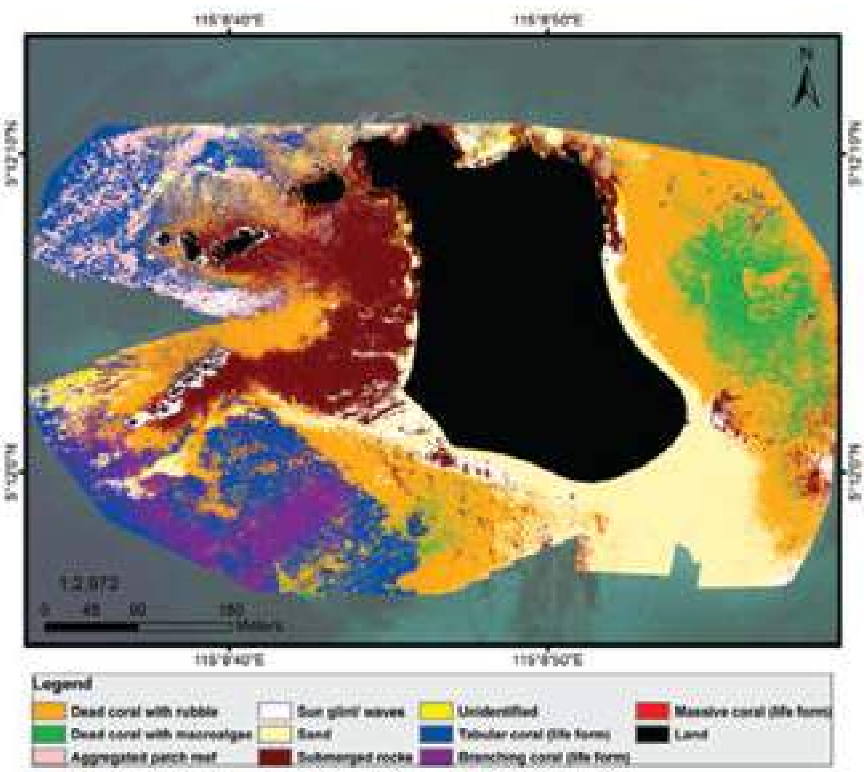


FIGURE 5: Micasense sensors supervised classification Level 2 map in (i) Pulau Rusukan Kecil (ii) Pulau Rusukan Besar with its percentage of coral coverage (a) Pulau Rusukan Kecil (b) Pulau Rusukan Besar (c) combination of both Pulau Rusukan

(a)



(b)

		Reference											
		Dead coral with rubble	Dead coral with macroalgae	Aggregated patch reef	Sun glint/ waves	Sand	Submerged rocks	Unidentified	Tabular coral (life form)	Branching coral (life form)	massive coral (life form)	Total	User's accuracy
Mapped	Dead coral with rubble	17	4	0	2	2	1	1	0	0	5	34	50.00%
	Dead coral with macroalgae	1	15	0	0	1	0	0	0	0	0	17	88.24%
	Aggregated patch reef	0	0	15	0	0	0	0	0	0	0	15	100.00%
	Sun glint/ waves	0	0	0	17	4	2	0	0	0	0	23	73.91%
	Sand	0	0	0	0	15	1	0	0	0	0	16	93.75%
	Submerged rocks	1	0	0	0	2	21	0	0	0	0	24	87.50%
	Unidentified	1	0	0	1	1	1	14	0	0	0	18	77.78%
	Tabular coral (life form)	0	0	2	1	0	0	2	12	2	1	20	60.00%
	Branching coral (life form)	1	0	4	0	0	0	0	4	14	0	23	60.87%
	massive coral (life form)	0	1	0	0	0	0	0	0	0	10	11	90.91%
Total		21	20	21	21	25	26	19	16	16	16	201	
Producer's accuracy		80.95%	75.00%	71.43%	80.95%	60.00%	80.77%	73.68%	75.00%	87.50%	62.50%		
Diagonal sum = 150													
Overall accuracy = 74.63%													

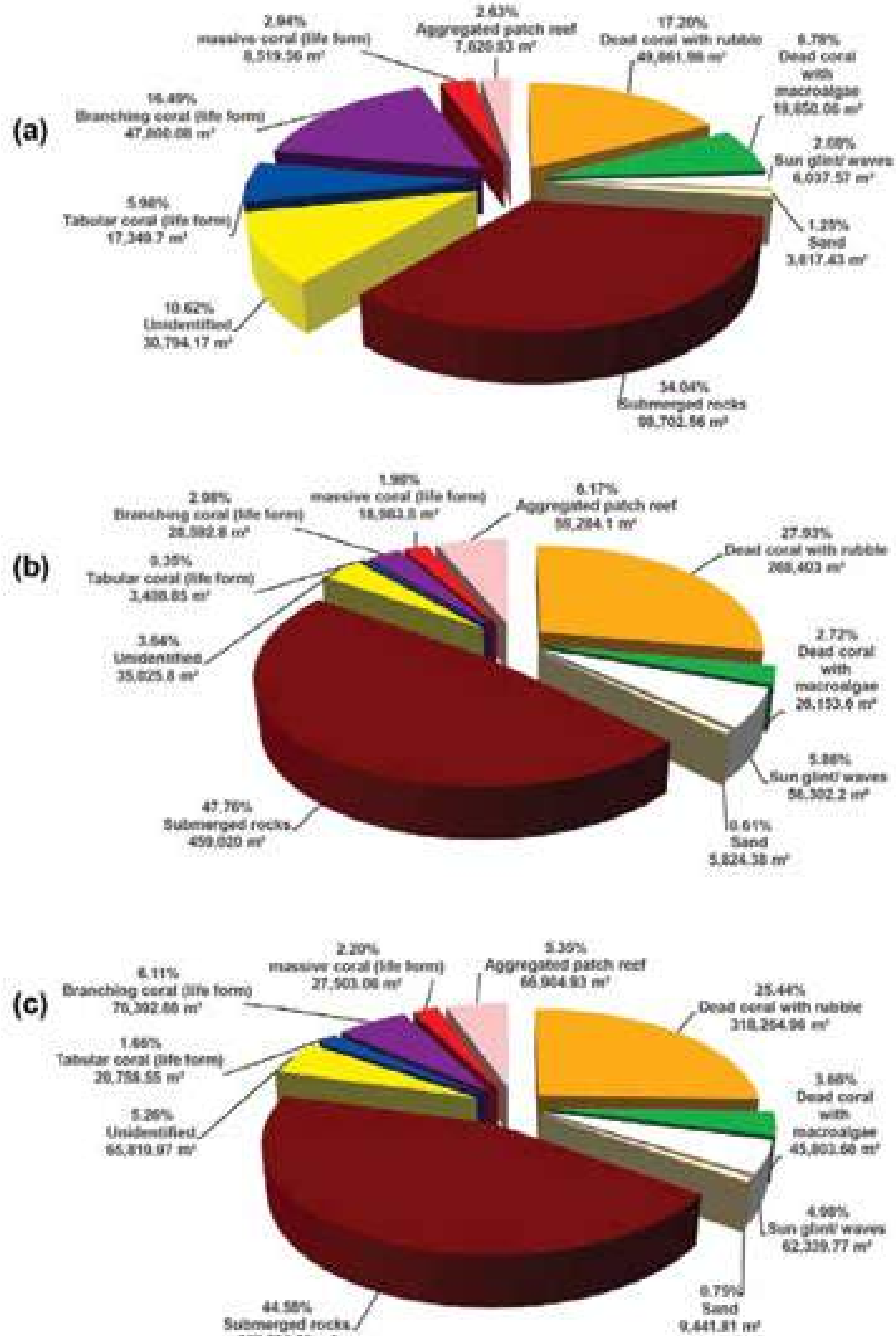
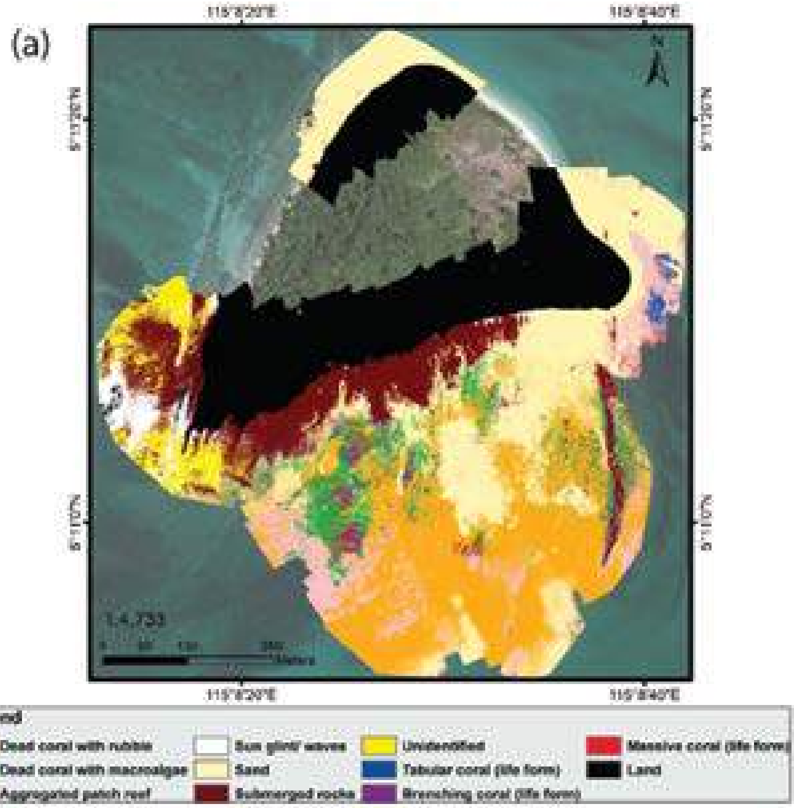


FIGURE 6: (i) Micasense sensors supervised classification Level 3 map in Pulau Rusukan Kecil (ii) the accuracy assessment and its percentage of coral caverage



(b)

		Reference											
		Dead coral with rubble	Dead coral with macroalgae	Aggregated patch reef	Sun glint/ waves	Sand	Submerged rocks	Unidentified	Tabular coral (life form)	Branching coral (life form)	massive coral (life form)	Total	User's accuracy
Mapped	Dead coral with rubble	16	0	1	0	3	0	0	0	0	0	20	80.00%
	Dead coral with macroalgae	0	11	0	0	0	2	0	1	3	5	22	50.00%
	Aggregated patch reef	0	0	20	0	0	0	0	1	0	1	22	90.91%
	Sun glint/ waves	0	0	0	19	0	0	5	0	0	0	24	79.17%
	Sand	5	0	0	0	21	0	0	0	0	0	26	80.77%
	Submerged rocks	0	0	0	3	0	22	0	0	0	0	25	88.00%
	Unidentified	0	0	0	0	1	0	16	0	0	0	17	94.12%
	Tabular coral (life form)	0	0	0	0	0	2	0	6	5	0	13	46.15%
	Branching coral (life form)	0	8	0	0	0	0	0	10	10	0	28	35.71%
	massive coral (life form)	0	1	0	0	0	0	0	4	2	15	22	68.18%
Total		21	20	21	22	25	26	21	22	20	21	219	
Producer's accuracy		76.19%	55.00%	95.24%	86.36%	84.00%	84.62%	76.19%	27.27%	50.00%	71.43%		

Diagonal sum = 156

Overall accuracy =71.23%

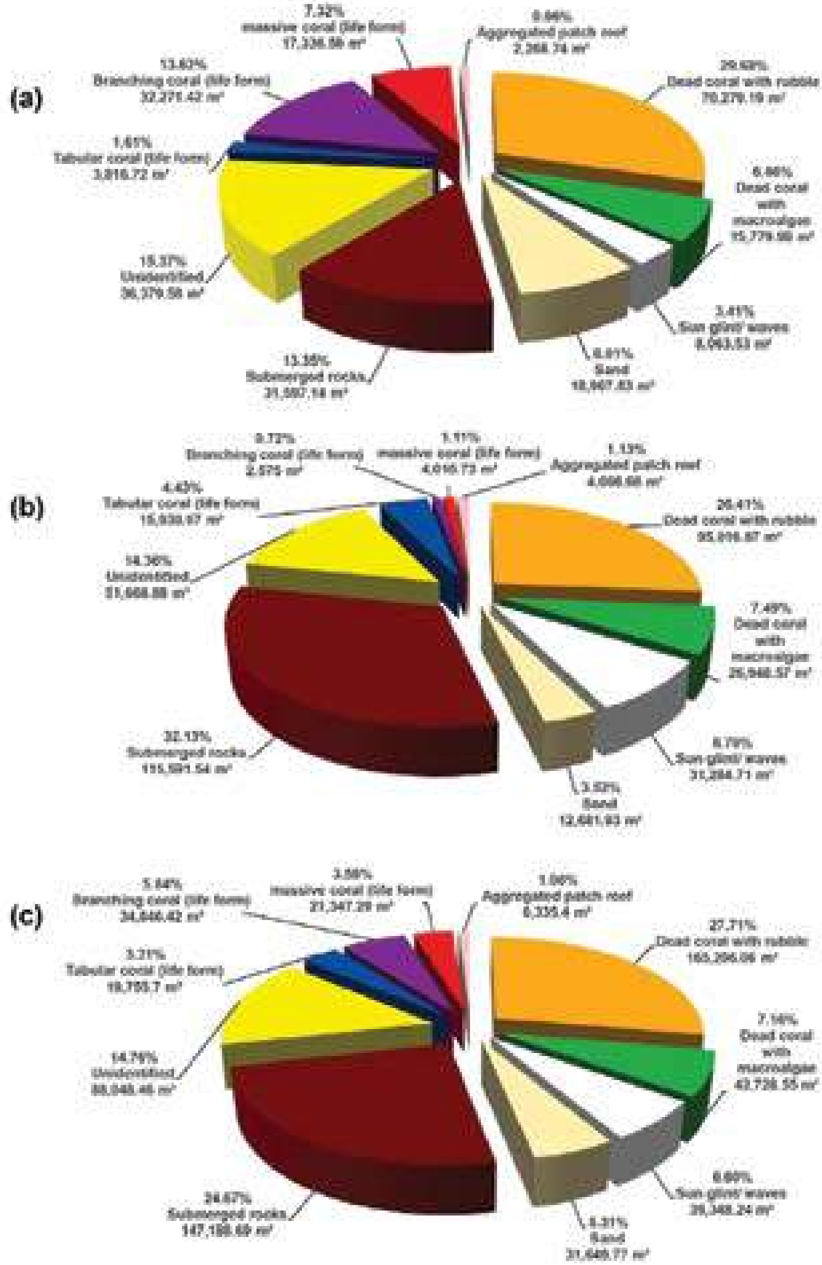


FIGURE 7: i) Micasense sensors supervised classification Level 3 map in Pulau Rusukan Besar
ii) the accuracy assessment and its percentage of coral coverage

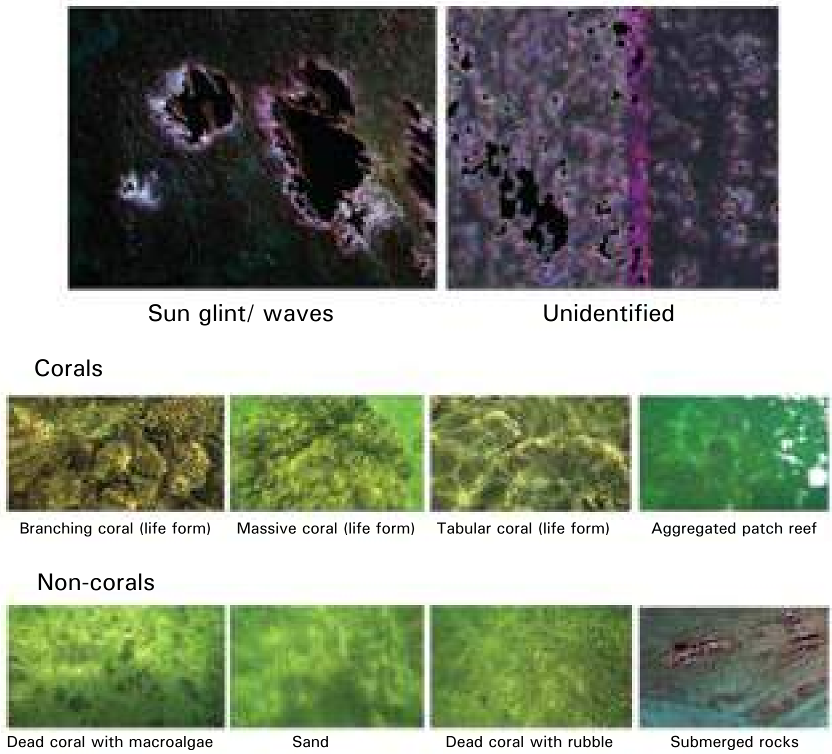


FIGURE 8: Samples of images which representing coral reefs and associated habitat classes

TABLE 2: Supervised classification scheme (adapted from NOAA, 2005 and Safuan et al., 2016)

Classification			Description
Level 1	Level 2	Level 3	
Non-coral	Dead coral	Dead coral with rubble	dead coral, dominated by rubble more than 50%
	Algae	Dead coral with macroalgae	dead coral, dominated by macroalgae (e.g. Sargassum sp.) more than 35% and mixed with rubble
	Sand, rock or silt	Sand	sand, bare substrum surrounded of beach sand and mixed with carbonated segments
		Submerged rocks	non-living, total submerged rocks
	Other	Sun glint/ waves	sun glint casted on water surface, waves movement near shore
		Unidentified	image artefacts formed during mosaicking drone imagery using Pix4D
Live coral	Live coral	Tabular coral (life form)	live coral, dominated by Acropora tabular coral life form more than 50%
		Branching coral (life form)	live coral, dominated by Pocillopora branching and Acropora branching coral life form more than 50%
		Massive coral (life form)	live coral, dominated by Porites massive coral life form more than 50%
		Aggregated patch reef	sparse coral with less than 35% of live and surrounded by dead coral, juvenile coral, and free-living coral

Coral Reef Status and Hard Coral Communities in Labuan Marine Park, Malaysia

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Abstract: A coral assessment was carried out in Labuan Marine Park (LMP), Malaysia utilizing a Coral Video Transect (CVT) method. The goals of the assessment were to seek the variation in benthic components and to describe the pattern of coral community in the LMP. Survey on 17 reefs sites shows that majority of the reefs were in 'poor' condition and the reef floor is predominantly occupied by dead coral. Furthermore, high cover of algae was found mainly in Kuraman Islands which indicated domination of algae in reef area rather than hard coral communities. Coral community in LMP is predominantly by *Acropora*, *Montipora* and *Porites* communities. Among the dominant taxa, *Acropora* recorded the highest coral cover while *Porites* has greater spatial distribution than *Acropora* and *Montipora*. The reefs in LMP might have been damaged by a combination of multiple threats such as destructive fishing practice, nutrient run-off, sedimentation and other land-based pollution from the nearby land.

Keywords: Labuan Marine Park, coral reef status, hard coral communities

INTRODUCTION

Tropical marine environment is a rich and dynamic area consists of different ecosystems. These ecosystems like coral reef, sea grass bed and mangrove provide important ecological as well as economical services to all organisms. Study in Caribbean shows that coral reef, mangrove and seagrass provide an alternative nursery ground to coral reef fishes (Dorenbosch et al., 2004). The South China Sea (SCS) hosting 571 species of hard coral comprising of 83% of total hard coral species in Coral Triangle (Huang et al., 2015). Some of the coral reefs area can be found within the east of SCS. In total, 248 hard corals species have been reported recently as reviewed by Huang et al. (2015). In addition to extensive coral reefs, mangrove forest and seagrass bed can also be found within this area (Shah et al., 2016). However, the biodiversity in this area has received much less scientific and conservation attention.

The importance of reef ecosystem has urged many countries to develop a marine protected area (MPA) subject to conserve the biodiversity offer by the ecosystem. In Malaysia, Department of Marine Park has been established to manage, protect and conserve the MPA to ensure sustainability. However, the marine ecosystems are highly diverse and interconnected. Understanding on all the physical and biological aspects of the MPAs is needed to optimize the management effort. In total, 42 islands in Malaysia have been gazette as Marine Park (MP). Most of the MPs are located at the Peninsular Malaysia. On 1994, a MP was established in east Malaysia at Federal Territory of Labuan, known as Labuan Marine Park (LMP). The LMP is an island located at the west coast of Sabah (5°15'N; 115°07'E), east of SCS. The LMP have approximately 158.15 km^2 size and comprises of three islands namely Kuraman Island, Rusukan Besar and Rusukan Kecil. These three islands were characterized by shallow fringing reef with few submerged shallow reefs.

Early study on coral assessment have been conducted by Kushairi, 1997 regarding the LMP. However, no published data are available in this study. In 2012, the Department of Marine Park Malaysia have conducted a special marine expedition to acquire the status of living marine resources within the MP. A comprehensive data on marine biodiversity comprising coral, reef fish and marine invertebrates have been recorded during the expedition. In total, 161 species of scleractinian corals, 179 species of reef fishes and 47 species of invertebrates have been identified from eight survey station at Kuraman Island, Rusukan Besar and Rusukan Kecil (Ransangan et al., 2013). In a meantime, Reef Check also conducted coral reef monitoring within LMP with three survey stations (Reef Check, 2013,). Throughout both surveys, the coral reef condition was classified as from 'poor' to 'good' condition as outlined by Chou et al., 1994 with a percentage hard coral cover ranging from 21.88% - 60.53% using the Reef Check method. However, previous coral assessment is spatially limited to certain reef around LMP.

This report will highlight the current coral reef status in Labuan Marine Park utilizing Coral Video Transect (CVT) method. The data presented will be useful for Department of Marine Park Malaysia for coral reef management.

METHODOLOGY

Survey Area

Labuan Marine Park (LMP) is represent by three islands; Kuraman Island, Rusukan Besar Island and Rusukan Kecil Island. Most of the reef can be found along the coastal area of the islands extending from 1.0 m to 8.0 m depth respectively. Submerged reef can be found mainly on the western part of LMP at the depth approximately 5.0 m to 18.0 m. The sea condition relatively rough especially during spring tides causing rough sea condition, turbid water and low visibility (± 5 m) during diving.

Sampling was carried out on July and September 2017. In total, 17 reef sites were surveyed around the LMP. Out of 17 survey station, 12 stations were selected for coral assessment utilizing Coral Video Transect (CVT) method. Detailed survey stations are listed in Table 1 and Figure 1.

TABLE 1: Details of survey stations around Labuan Marine Park

No.	Island	Station	Date	Lat.	Long.	Survey Depth
1		ST1	14.7.17	5°10’9.01”N	115° 9’6.05”E	9-10m
2		ST2	14.7.17	5° 9’56.95”N	115° 8’36.20”E	12 m
3	Rusukan Besar	ST3	12.7.17	5° 9’56.40”N	115° 6’51.00”E	6-8m
4		ST4	12.7.17	5°11’22.10”N	115° 8’17.00”E	1m
5		ST5	15.9.17	5°11’12.55”N	115° 8’40.89”E	2m
6		ST6	13.9.17	5°12.560’N	115° 7.437’E	5m
7		ST7	13.9.17	5°13.235’N	115° 7.325’E	4m
8		ST8	13.9.17	5°13.624’N	115° 7.160’E	2m
9	Kuraman	ST9	13.9.17	5°14.142’N	115° 7.144’E	3m
10		ST10	13.9.17	5°13.885’N	115° 8.214’E	3m
11		ST11	13.9.17	5°13.930’N	115° 7.729’E	4m
12		ST12	13.9.17	5°13.393’N	115° 8.363’E	3m
13		ST13	14.7.17	5°11’57.84”N	115° 8’38.65”E	3m
14		ST14	14.9.17	5°12.132’N	115° 8.558’E	5-8m
15	Rusukan Kecil	ST15	14.9.17	5°12.126’N	115° 8.897’E	1-2m
16		ST16	14.9.17	5°11’59.85”N	115° 8’39.04”E	1-2m
17	In between Rusukan	ST17	15.9.17	5°11.618’N	115° 8.492’E	2-3m

Coral Video Transect

Estimation of percentage cover in benthic communities was done using the Coral Video Transect (CVT) technique (Safuan et al., 2015). A 100 m transect tape (divided into 4 segments with 20 m per segment, n = 4) was overlay in each survey transect by following the reef contour and parallel to the shoreline. An underwater video camera (Panasonic LUMIX FT4) protected with an underwater housing (LUMIX 40 m Marine Case) was used to record the benthic substrate communities along the transect lines. A diver swam slowly along the transect line at an approximate speed of 5 m/min and 0.5 m elevation above the substratum, while pointing the camera lens downward during video recording. A reference bar attached to the underwater video housing was used to maintain the vertical elevation during recording, so as to minimize parallax error and maintain focus.

Data Analysis

Videos were analysed using Coral Point Count with Excel Extension (CPCe) software to quantify the percentage benthic cover in the coral reef (Kohler and Gills, 2006). The videos were extracted into non-overlapping frames using Pinnacle Studio HD software

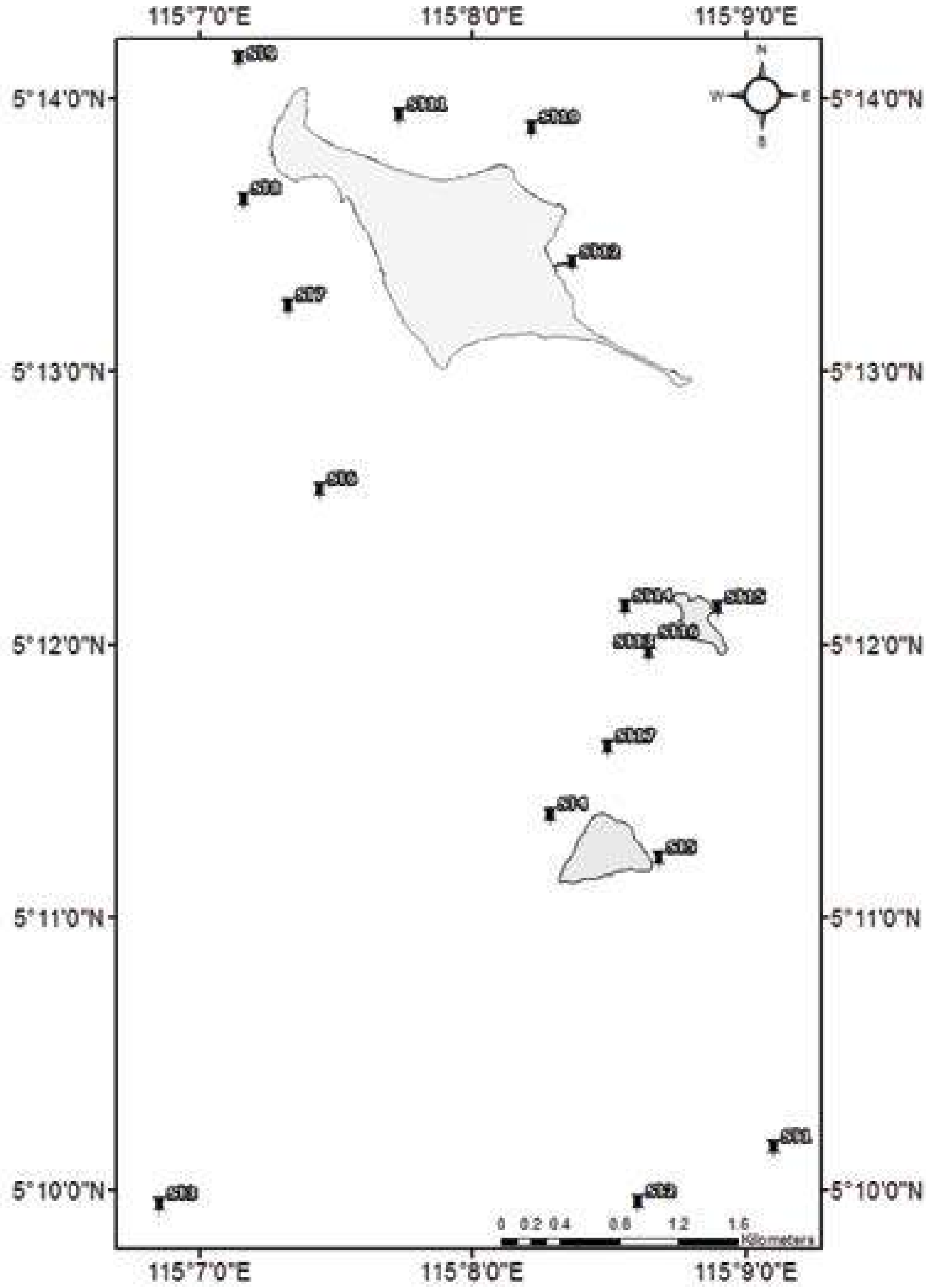

FIGURE 1: Location of survey stations around Labuan Marine Park

and analyzed using CPCe software. Each video frames were analyzed with 50 points per frames (Safuan et al., 2015). Corals were identified up to genus level by following Veron (2000). Numbers of identified coral genera were also counted.

The results obtained were summarized as percentage cover in four categories: live coral, algae, other invertebrates and dead coral. Coral health status was indicated by percentage of live coral cover following Chou et al. (1994), with the following categories: excellent (> 75%), good (51% – 75%), fair (26% – 50%) and poor (< 25%).

FINDINGS AND ARGUMENT

Coral Health Status

Coral assessment in LMP was done in 12 survey stations. Overall, the reefs in LMP can be categorized as 'fair' coral condition with total average coral cover in all stations is 27.04%. Estimation of percentage coral cover by CVT showing that only two reef sites is categorized as having 'good' coral condition, three sites as 'fair' coral conditions and others are under 'poor' coral condition. Percentage coral cover were ranging from 0.97 ± 1.08% - 60.5 ± 6.7% respectively. In comparison with previous studies, it is predicted that there might be a potential decline in coral cover throughout the year (Table 1). However, this comparison can be bias due to different in methodological approach and survey location. Decline in coral cover potentially due to run-off from the nearby main island (Labuan Island) and mainland during low tides. High nutrient output and sedimentation from the nearby sources are release to the ocean, causing reduction in the water quality around LMP.

TABLE 2: A brief comparison of coral reef status in Labuan Marine Park

Study / Report	Marine Biodiversity Expedition Report, DMPM	Reef Check	Reef Check	This Study
Year	2012	2013	2016	2017
No. of Survey Station	8	3	3	12
Overall Coral Cover	46.41%	56.2%	41.67%	27.04%
Coral Condition	Fair	Good	Fair	Fair

Kuraman Island recorded the lowest coral cover with all of the reefs were in 'poor' coral conditions. The reef floor is mainly covered by macroalgae. Macroalgae species such as *Sargassum* sp. can be found dominating the reef in Kuraman Island. In contrast to Rusukan Besar and Kecil, most of the reefs mainly covered by corals and dead corals. High coral cover was recorded in western part of Rusukan Kecil (ST16 and ST14) with percentage coral cover of 52.17 ± 27.29% and 44.84 ± 9.11%. Meanwhile, high coral cover was also recorded in northern and eastern part of Rusukan Besar (ST4 and ST5) with average coral cover of 49.33 ± 22.91% and 60.5 ± 6.7%. Details of benthic cover recorded by CVT is illustrated in Figure 2.

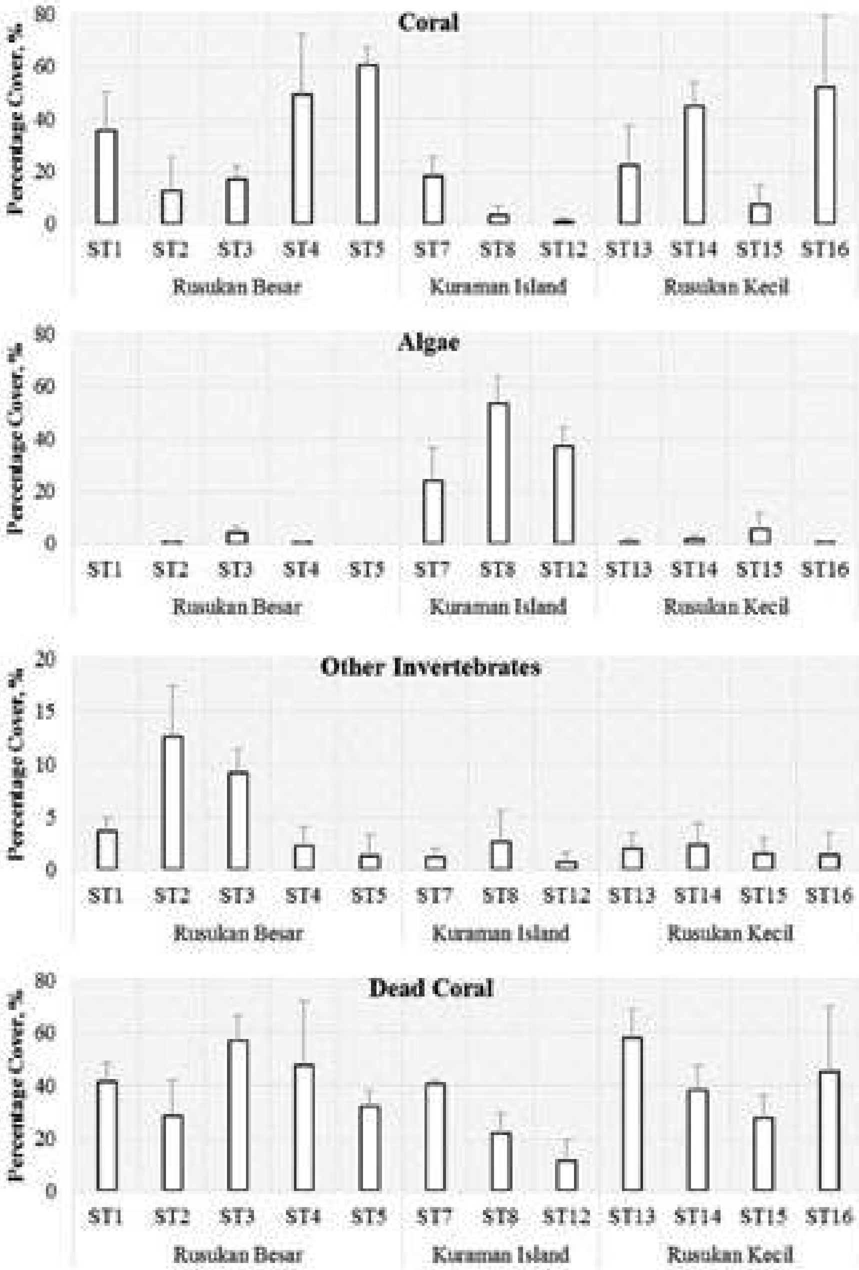

FIGURE 2: Percentage benthic cover of coral, algae, other invertebrates and dead coral in Labuan Marine Park. Values are mean ± SD

Hard Coral Community

The coral fauna in LMP is mainly of hard coral (Scleractinian). In total, 161 species of hard corals comprising of 54 genera were identified previously (Ransangan et al., 2013). In this assessment, a total of 38 coral genera were identified from the video taken through CVT. The distribution of coral genera in LMP is listed in Table 3.

TABLE 3: Generic distribution of hard corals in survey stations. Symbol 'x' denoted as present and '-' as absent

Genera	ST1	ST2	ST3	ST4	ST5	ST7	ST8	ST12	ST13	ST14	ST15	ST16
Acropora	x	x	x	x	x	x	x	x	x	x	x	x
Alveopora	-	x	-	-	-	-	-	-	-	-	-	-
Astreopora	-	-	-	-	-	x	-	-	-	-	x	-
Coral Milepora	x	-	x	-	x	x	-	-	x	x	-	-
Ctenactis	x	-	-	-	-	-	-	-	x	-	-	x
Cyphastrea	-	x	x	-	-	x	-	-	x	-	-	-
Diploastrea	x	-	-	-	-	-	-	-	x	x	-	-
Echinophyllia	-	-	-	-	-	-	-	-	x	x	-	-
Echinopora	x	-	-	-	x	-	-	-	x	x	-	-
Euphyllia	-	x	-	-	-	-	-	-	-	x	-	-
Favia	-	x	x	x	-	x	x	x	-	x	x	x
Favites	x	x	x	x	-	x	x	x	x	x	x	-
Fungia	x	x	x	x	x	-	-	-	x	x	-	x
Galaxea	x	-	x	x	x	x	x	x	x	x	x	x
Goniastrea	x	-	x	-	-	x	-	-	x	-	x	-
Goniopora	-	x	x	x	-	-	-	-	-	-	-	-
Heliofungia	x	x	-	-	-	-	-	-	-	x	-	x
Herpolitha	x	x	x	-	-	-	-	-	x	x	-	-
Hydnophora	-	x	-	-	-	-	-	-	-	x	-	-
Lobophyllia	x	x	-	-	-	x	-	-	-	x	-	-
Merulina	-	-	-	-	-	-	-	-	x	x	-	-
Montipora	x	x	x	x	x	x	x	-	x	x	-	x
Mycedium	-	-	-	-	-	-	-	-	-	x	-	-
Oulophyllia	-	-	-	-	-	-	-	-	-	x	-	-
Oxypora	-	x	-	-	-	-	-	-	x	-	-	-
Pachyseris	-	x	-	-	-	x	-	-	-	x	-	-
Pavona	-	-	-	-	x	-	-	-	x	-	-	x
Pectinia	x	x	x	-	-	-	-	-	x	x	-	-
Platygyra	x	-	x	x	-	x	-	-	x	x	x	-
Pocillopora	x	x	-	x	x	x	-	-	x	x	x	x
Podabacia	-	x	x	-	-	-	-	-	-	-	x	-
Polyphyllia	x	x	-	-	-	-	-	-	-	-	-	-
Porites	x	x	x	x	x	x	x	x	x	x	x	x
Scolymia	-	x	x	-	-	-	-	-	-	-	-	-
Seriatopora	x	-	-	x	-	x	-	x	-	x	-	x
Stylophora	-	-	-	-	-	-	-	-	-	x	x	x
Symphyllia	x	x	x	-	-	x	-	-	x	x	-	-
Turbinaria	-	x	x	-	-	x	-	-	x	x	-	-
Total	20	23	18	10	9	17	5	3	22	27	11	11

The corals in LMP is dominated by branching / tabulate, foliose and massive growth form with percentage cover of 22.12% from total coral cover in LMP. Branching / tabulate coral covering 9.76% of the reef follow by massive (6.07%) and foliose (6.28%) as shown in Figure 3.

Among all genera recorded, only *Acropora* can be found in all localities. *Acropora* represent 8.58% from 27.04% of total coral cover in LMP. This species can be found extensively in branching and tabulate growth form. *Montipora* can be found in most of the station except at ST12 and ST15. This species represents 4.53% from the total coral cover in LMP with a foliose growth form. Meanwhile, massive *Porites* coral can also be found in most of the survey station with the percentage cover of 2.59%. Details of dominant corals in LMP is showed in Figure 4.

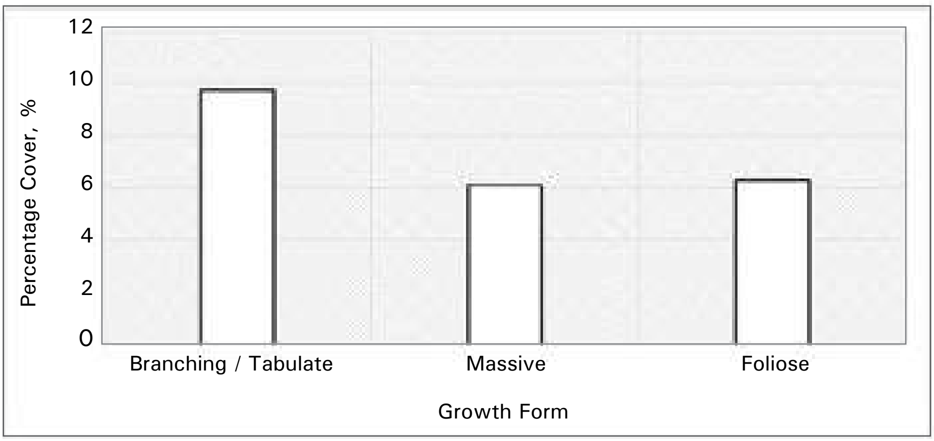

FIGURE 3: Percentage cover of dominant coral growth form in Labuan Marine Park

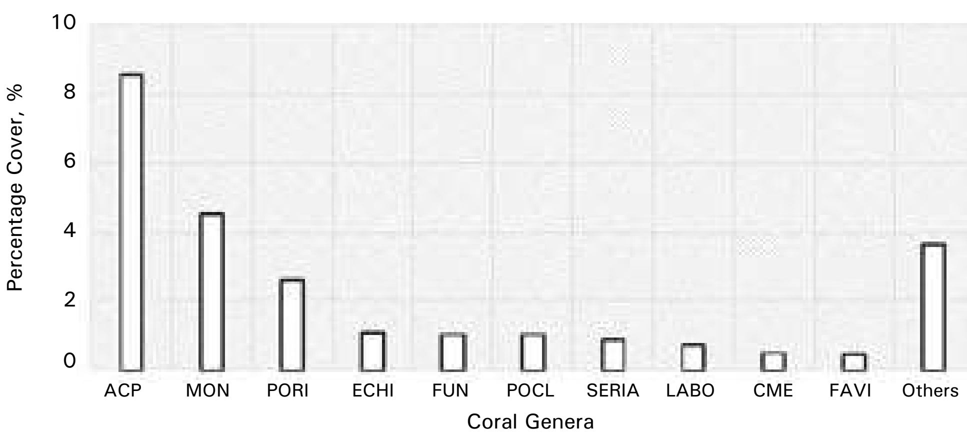

FIGURE 4: Percentage coral cover of dominant coral genera recorded in Labuan Marine Park. Coral genera denoted as ACP = *Acropora*, MON = *Montipora*, PORI = *Porites*, ECHI = *Echinopora*, FUN = *Fungia*, POCL = *Pocillopora*, SERIA = *Seriatopora*, LOBO = *Lobophyllia*, CME = Fire Coral, FAVI = *Favites*. 'Others' represent total of non-listed coral genera with each has percentage cover < 0.4%

CONCLUSION

Overall reef condition in LMP is summarized in Figure 5. Generic diversity classification are based on number of coral genera counted from CVT data (≤ 5; poor, > 5 but < 10; moderate, ≥ 10 but < 20; good, ≥ 20; excellent).

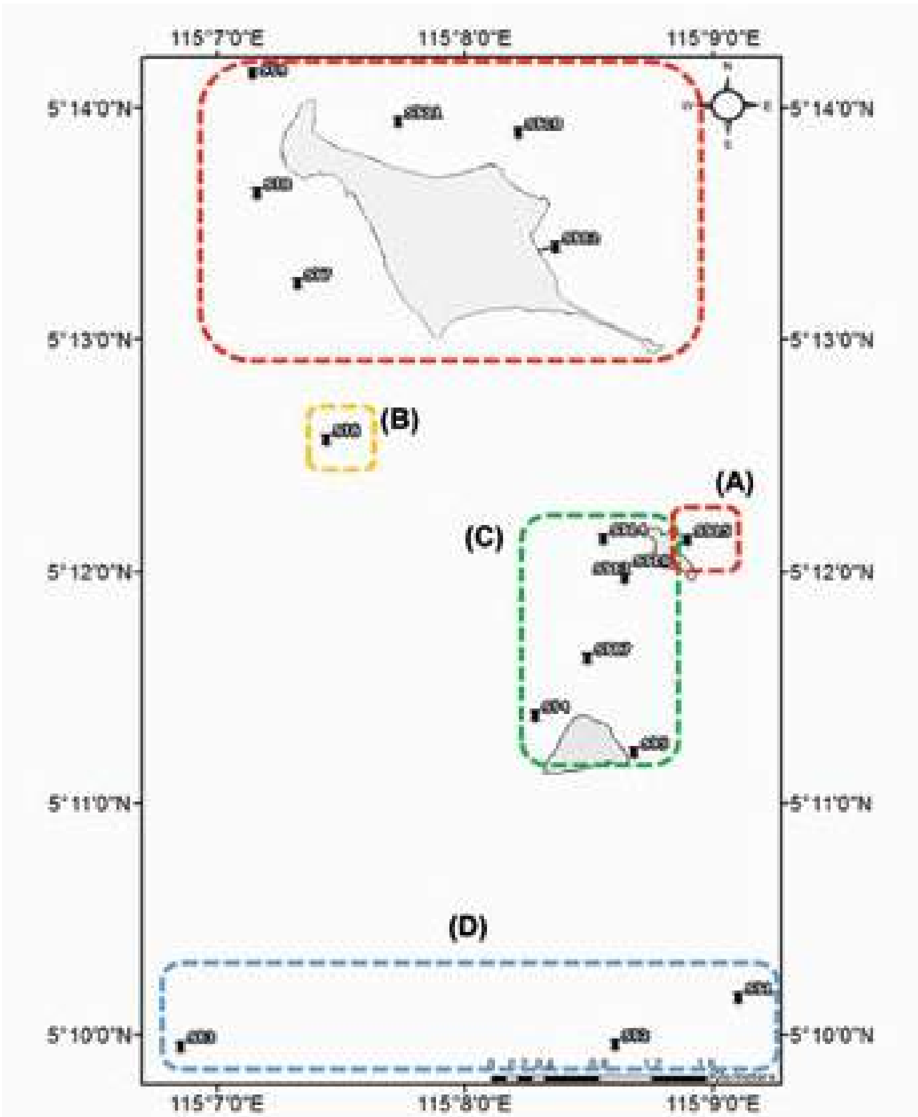

FIGURE 5: A brief description on coral reef status around Labuan Marine Park. (A) Red box indicates 'poor' reef condition with low diversity, (B) brown as sandy area, (C) green as 'good' coral condition and high diversity, and (D) blue as 'fair' reef condition with high diversity

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APPENDIX

Dive 1

Location:	Southern of Rusukan Besar
Coordinates:	5°10'9.01"N 115° 9'6.05"E
Reef Category:	Patch Reef / Submerged Reef
Visibility:	< 10 m
Survey Depth:	9 m – 10 m
Coral Cover:	35.57 ± 14.54%
Generic Diversity:	Excellent
Description:	The reef mainly dominated by branching, tabulate and massive coral. The reef floor is covered by live and dead coral.

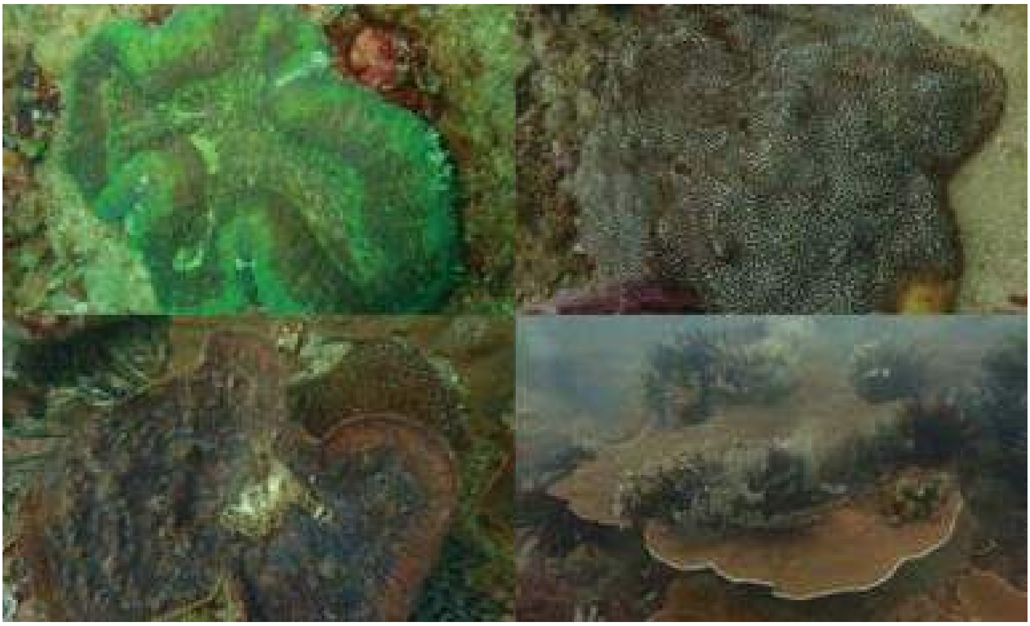
Branching and tabulate coral in ST1

Massive corals in ST1

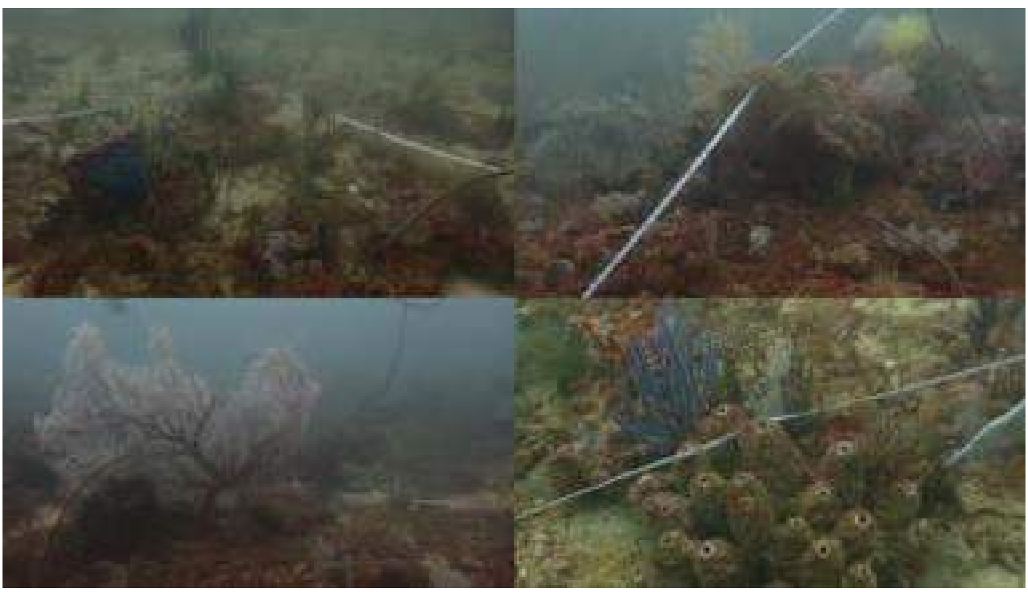
Reef condition in ST1

Dive 2

Location:	Southern of Rusukan Besar
Coordinates:	5° 9’56.95”N 115° 8’36.20”E
Reef Category:	Patch Reef / Submerged Reef
Visibility:	< 10 m
Survey Depth:	12 m - 15 m
Coral Cover:	12.71 ± 12.49%
Generic Diversity:	Excellent
Description:	The reef mainly dominated by massive, plate / laminar and encrusting coral. The reef floor is covered by sand and dead coral. Diverse species of invertebrates such as soft coral and sponges.



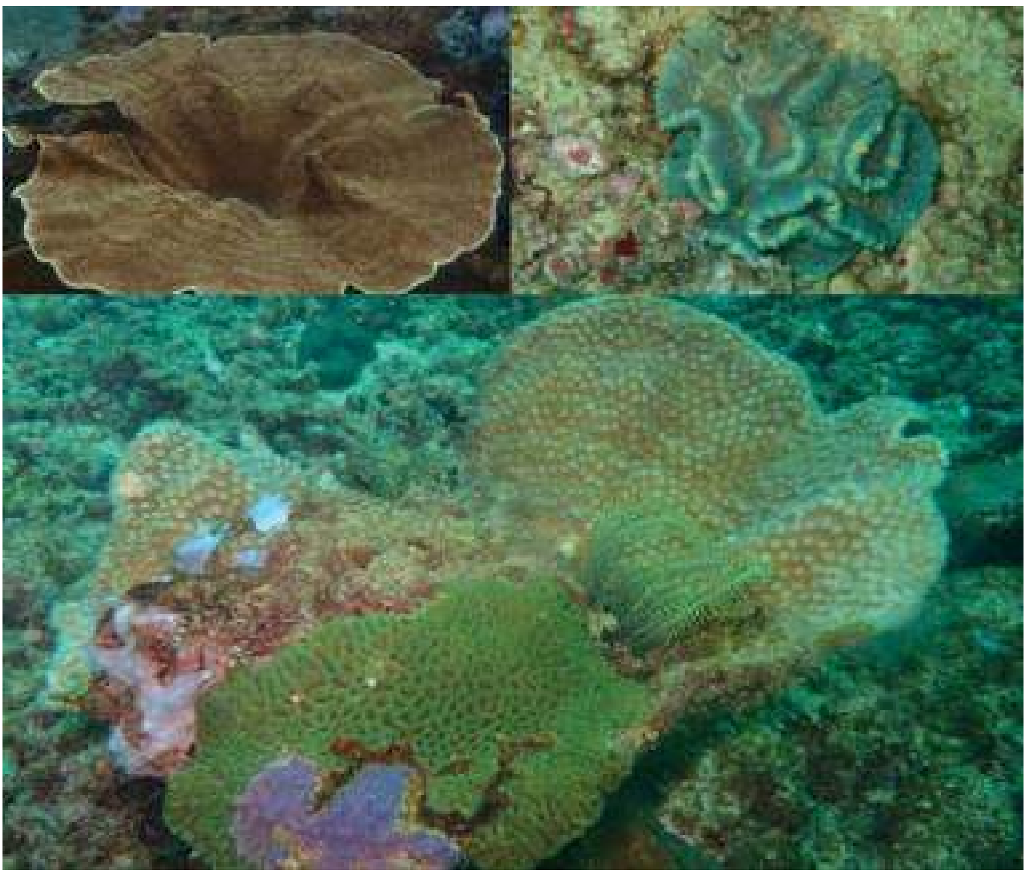
Dominant growth form in ST2



Reef condition in ST1

Dive 3

Location:	South-western of Rusukan Besar
Coordinates:	5° 9’56.40”N 115° 6’51.00”E
Reef Category:	Patch Reef / Submerged Reef
Visibility:	< 10 m
Survey Depth:	6 m - 8 m
Coral Cover:	16.98 ± 5.21%
Generic Diversity:	Good
Description:	The reef mainly dominated by massive and plate / laminar coral. The reef floor is covered by dead coral. Diverse species of invertebrates such as soft coral and sponges.



Dominant growth form in ST2

Common coral growth form in ST3

Dive 4

Location:	Rusukan Besar North
Coordinates:	5°11'22.10"N 115° 8'17.00"E
Reef Category:	Fringing Reef / Shallow Water Reef
Visibility:	< 10 m
Survey Depth:	± 1 m
Coral Cover:	49.33 ± 22.92%
Generic Diversity:	Moderate
Description:	The reef mainly dominated by brancing / tabulate and columnar coral. The reef floor is covered by live and dead coral.

Figure 13: Common coral growth form in ST4

Reef condition in ST4

Dive 5

Location:	Rusukan Besar East
Coordinates:	5°11’12.55”N 115° 8’40.89”E
Reef Category:	Fringing Reef / Shallow Water Reef
Visibility:	< 10 m
Survey Depth:	± 1 m
Coral Cover:	60.5 ± 6.69%
Generic Diversity:	Poor
Description:	The reef mainly dominated by branching / tabulate and foliaceous coral. The reef floor is covered by live and dead coral.

Common corals in ST5

Reef condition in ST5

Dive 6

Location:	Kuraman South
Coordinates:	5°12.560’N 115° 7.437’E
Reef Category:	Sandy Area
Visibility:	± 5 m
Survey Depth:	± 5 m
Coral Cover:	-
Generic Diversity:	-
Description:	This area only covered by sand with small patchy of dead coral and macroalgae.

Surrounding area in ST6

Dive 7

Location:	Kuraman South
Coordinates:	5°13.235'N 115° 7.325'E
Reef Category:	Fringing Reef / Shallow Water Reef
Visibility:	<5 m
Survey Depth:	± 4 m
Coral Cover:	18.15 ± 7.67%
Generic Diversity:	Good
Description:	The reef mainly dominated by massive, branching / tabulate and encrusting coral. The reef floor is covered by macroalgae, live and dead coral.

Dominant coral growth form

Reef condition in ST7

Dive 8

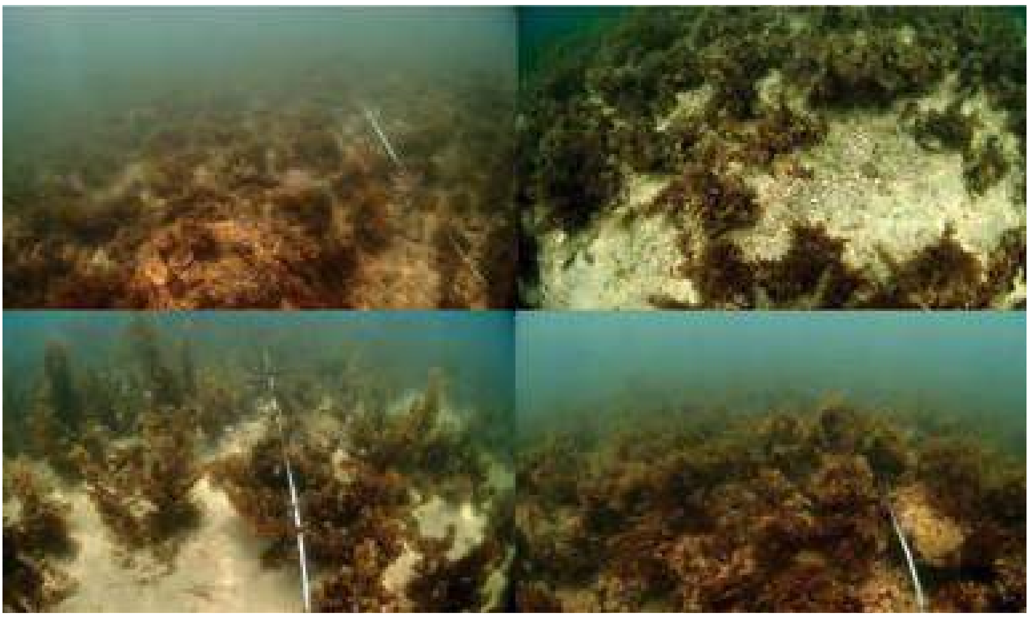
Location:	Kuraman South
Coordinates:	5°13.624'N 115° 7.160'E
Reef Category:	Fringing Reef / Shallow Water Reef
Visibility:	<5 m
Survey Depth:	± 2 m
Coral Cover:	3.37 ± 3.82%
Generic Diversity:	Poor
Description:	The reef mainly dominated by encrusting coral. The reef floor is covered by macroalgae, dead coral and sand.

Dominant corals in ST8

Reef condition in ST8

Dive 9

Location:	Kuraman North
Coordinates:	5°14.142’N 115° 7.144’E
Reef Category:	Fringing Reef / Shallow Water Reef
Visibility:	<5 m
Survey Depth:	± 3 m
Coral Cover:	-
Generic Diversity:	-
Description:	The reef mainly dominated by macroalgae, dead coral and sand.



Surrounding view in ST9.

Dive 10

Location:	Kuraman South
Coordinates:	5°13.885’N 115° 8.214’E
Reef Category:	Fringing Reef / Shallow Water Reef
Visibility:	<5 m
Survey Depth:	± 3 m
Coral Cover:	-
Generic Diversity:	-
Description:	The reef mainly dominated by rock, macroalgae, dead coral and sand.

Underwater seascape in ST10

Dive 11

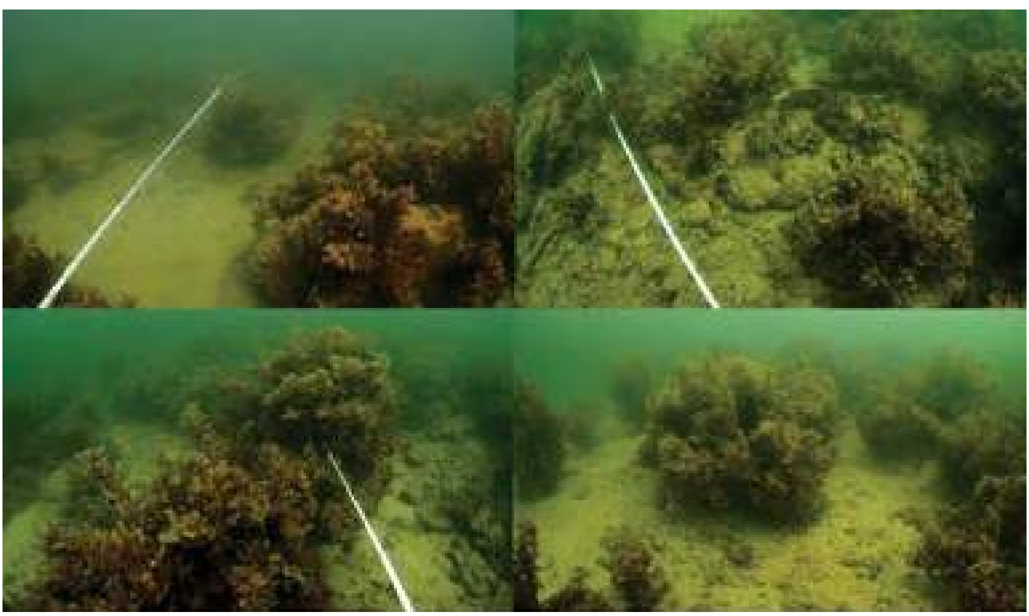
Location:	Kuraman North
Coordinates:	5°13.930'N 115° 7.729'E
Reef Category:	Fringing Reef / Shallow Water Reef
Visibility:	<5 m
Survey Depth:	± 4 m
Coral Cover:	-
Generic Diversity:	-
Description:	The reef mainly dominated by macroalgae, dead coral and sand.

Figure7: Reef condition on ST11

Dive 12

Location:	Kuraman North (Jetty)
Coordinates:	5°13.393'N 115° 8.363'E
Reef Category:	Fringing Reef / Shallow Water Reef
Visibility:	<5 m
Survey Depth:	± 3 m
Coral Cover:	0.97 ± 1.08%
Generic Diversity:	Poor
Description:	The reef mainly dominated by branching / tabulate coral. The reef floor is covered by macroalgae and sand.

Small branching coral colonies in ST12



Reef condition in ST12

Dive 13

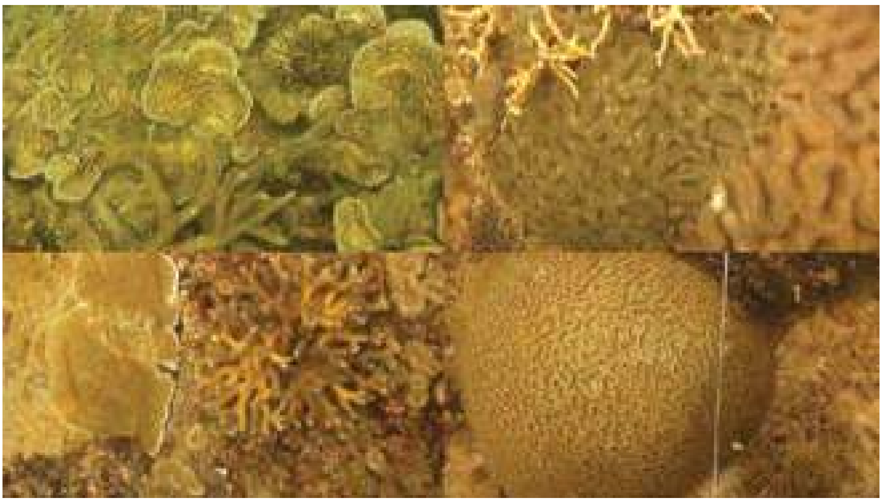
Location:	Rusukan Kecil West
Coordinates:	5°11’57.84”N 115° 8’38.65”E
Reef Category:	Fringing Reef / Shallow Water Reef
Visibility:	< 10 m
Survey Depth:	± 3 m
Coral Cover:	22.5 ± 14.75%
Generic Diversity:	Excellent
Description:	The reef mainly dominated by free living and massive coral. The reef floor is covered by dead coral.

Dominant coral in ST13

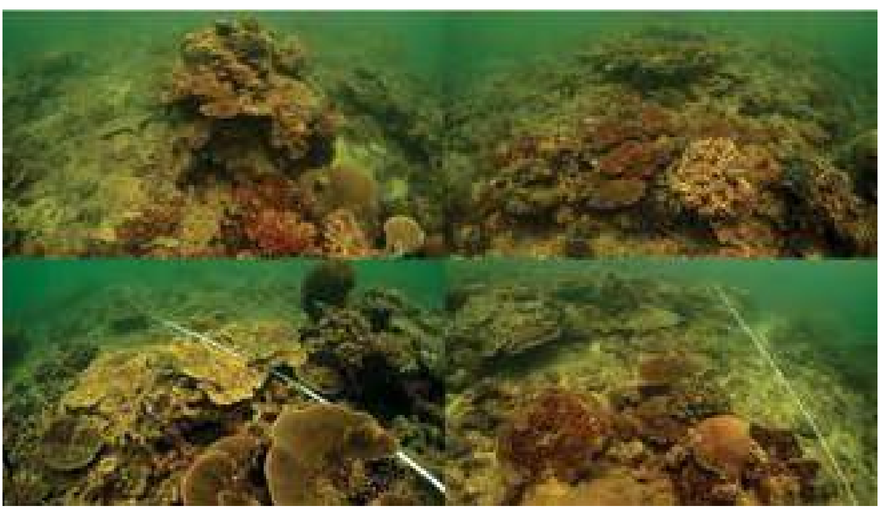
Reef condition in ST13

Dive 14

Location:	Rusukan Kecil West
Coordinates:	5°12.132'N 115° 8.558'E
Reef Category:	Fringing Reef / Shallow Water Reef
Visibility:	< 10 m
Survey Depth:	5.0 m – 8.0 m
Coral Cover:	44.84 ± 9.11%
Generic Diversity:	Excellent
Description:	The reef mainly dominated by branching / tabulate, plate / laminar and massive coral. The reef floor is covered by live and dead coral.



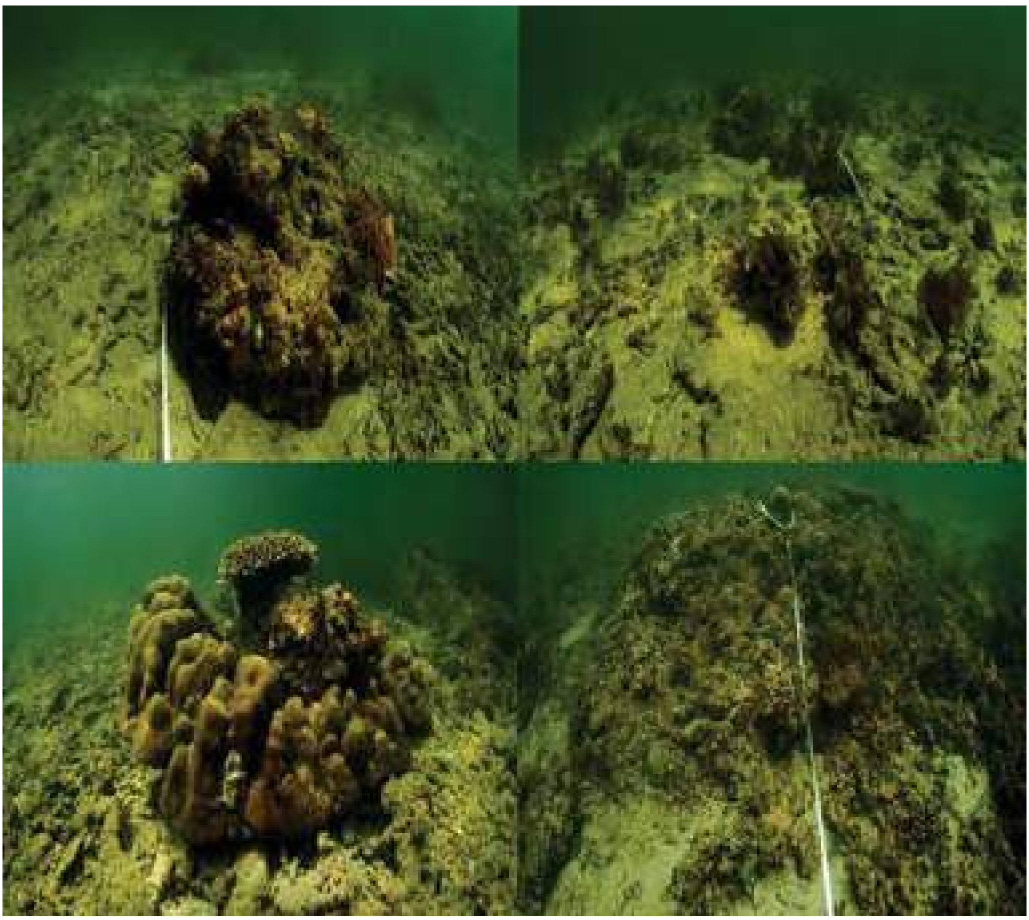
Common coral growth form in ST14



Reef condition in ST14

Dive 15

Location:	Rusukan Kecil East
Coordinates:	5°12.126'N 115° 8.897'E
Reef Category:	Fringing Reef / Shallow Water Reef
Visibility:	± 5.0 m
Survey Depth:	5.0 m – 8.0 m
Coral Cover:	7.44 ± 7.46%
Generic Diversity:	Good
Description:	The reef mainly dominated by massive coral. The reef floor is covered by sand and dead coral.



Reef condition and coral growth form in ST15

Dive 16

Location:	Rusukan Kecil West
Coordinates:	5°11’59.85”N 115° 8’39.04”E
Reef Category:	Fringing Reef / Shallow Water Reef
Visibility:	± 5.0 m
Survey Depth:	1.0 m – 2.0 m
Coral Cover:	52.17 ± 27.29%
Generic Diversity:	Good
Description:	The reef mainly dominated by branching / tabulate and plate / laminar coral. The reef floor is covered by live and dead coral.

Dominant growth form in ST16

Reef condition in ST16

Dive 17

Location:	In between Rusukan Besar and Kecil
Coordinates:	5°11.618’N 115° 8.492’E
Reef Category:	Fringing Reef / Shallow Water Reef
Visibility:	< 5 m
Survey Depth:	± 2 m
Coral Cover:	-
Generic Diversity:	-
Description:	The reef mainly dominated by dead coral, rock and sand.

Reef condition in ST14

Coral Bleaching Monitoring Using Drone Aerial Photo in Selected Areas in Tioman Island, Pahang

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Abstract: In 2016, coral reefs in the world experienced the biggest coral bleaching event ever recorded. As a result of the event, very large areas were bleached. Tioman Island was reported to experience the episodes of bleaching, but the recovery process was not known. This research focused on the current state of corals in the island and to investigate the reliability of using a drone as unmanned aerial vehicle (UAV) for coral bleaching monitoring. The approach of the study was to use the low altitude aerial drone imagery for coral bleaching surveys in combination with Remote Sensing and GIS tools. Sampling sites were fixed at the Renggis, Soyak, Salang, Batu Malang and Tulai at the western part of the island which are known as hot spot for tourists. Bathymetry of the areas was determined, and low altitude drone flights were made twice (morning and evening flight) at every site. Following the drone flight paths, three underwater transect lines were established at every site for underwater video recording. Data were analysed from the drone images and separation was made between coral cover, substrate and water (ISODATA). Marking of possible bleaching was done (based on the B band) using vector coral and Sequential Maximum Angle Convex Cone (SMACC). Results from underwater video analysis using Coral Point Count with Excel Extension (CPCe) were then compared with drone data. Highest sea surface temperature (SST) recorded in 2017 was 31 °C (in May) and lowest temperature was 27°C (in January) which was entirely lower than 2016. There is no significant effect of SST towards bleaching as monitored by CVT and drone in 2017 for all sampling stations. Most of the bleaching from August to October occurred in patches (compared to the whole area such as during 2016 bleaching). The hypothesis that results from drone methods has no difference than CVT for monitoring the patterns of coral bleaching was accepted at 4 stations and rejected at 2 stations. Conclusively, drone was successfully showed the bleaching points in the study area, thus the method is potentially contributing to the bleaching monitoring activities (reduce manpower; reduce cost over large coverage; for the purpose of ad-hoc monitoring; baselines study). If compared to satellite images, drone images may lack in suitable spectral for coral identification, but yet drone images allow continuous non-scheduled time for image acquisitions with high resolutions.

INTRODUCTION

In 2016, coral reefs in the world experienced the biggest coral bleaching event ever recorded. Very large areas were reported to experience bleaching as a result of combination effect from increase of sea surface temperature (SST) and strong El Niño (Great Barrier Reef Marine Park Authority, 2017). The situation in Tioman Island was shown by the relationship of temperature rise and low pH with the coral bleaching incidents found at the six fixed monitoring stations at Renggis, Soyak, Salang, Tulai 1 & 2 and Batu Malang in the west part of the island (Zuhairi et al., 2016). The frequency of bleaching-level thermal stress increased three-fold between1985–1991 and 2006–2012 – a trend climate model projection, suggest will continue (Heron et al., 2016). Nonetheless, Guest et al. (2012) highlighted on the possibility that corals in regions subject to more variable temperature regimes are more resistant to thermal stress than those in less variable environments.

One of the latest methods to assess coral bleach is using aerial photo. The unmanned aerial vehicle (UAV) platforms for airborne surveys was recognised as a new environmental management tools which will help in environment mapping process such as in coral ecosystem (Hamylton 2017). At the early stage of any coral bleaching study, the monitoring plays a major role in the state of bleaching assessment. Casella et al. (2017) confirmed the possibility of using a consumer-grade drone as a relatively low-cost and rapid survey technique in conditions of calm waters, low winds and minimal sun glint, to produce multispectral and bathymetric data on shallow-water coral reefs.

The present study aimed to report the coral bleaching incidents in the fixed stations (since 2016) at Tioman Island using UAV approach and underwater survey. It is important to document any coral bleaching episodes in Tioman Island through aerial photo and underwater examination so that comparison could be made with the earlier and future data. In addition, even though the extent of thermal stress was well established from SST data, yet the extent and severity of bleaching and recovery levels have not been mapped for the island.

METHODS

Field samplings were carried out monthly between July and October 2017 at the fixed station at Renggis, Soyak, Batu Malang, Salang, Tulai 1 and Tulai 2 in the western part of Tioman Island (Figure 1). In the year 2016-2017, the island experienced the Northeast Monsoon from December to March due to the influence of weak La-Nina episode; and the Southwest Monsoon from March to May (Malaysian Meteorological Department, 2016; 2017).

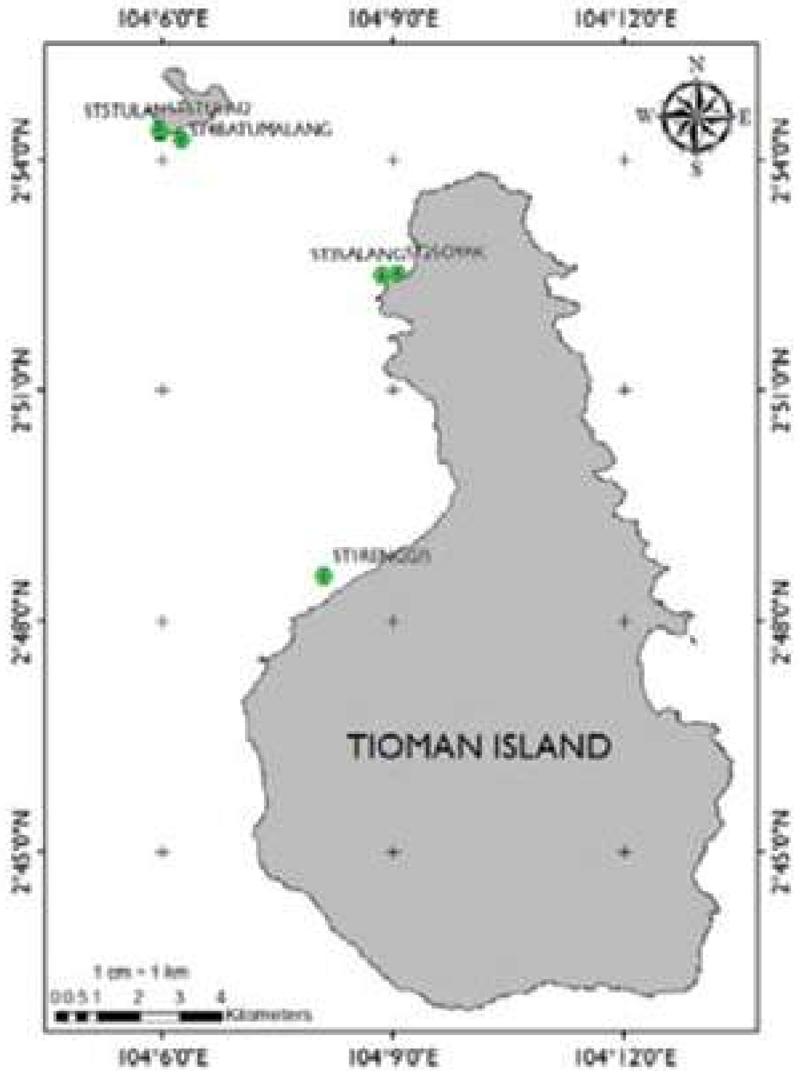

FIGURE 1: Sampling sites (green mark) at Tioman Island

The bathymetry of each station was determined, and stations were classified based on depth; < 6.0 m (shallow); > 7.0 m - 8.0 m (intermediate); > 8.0 m (deep). Renggis, Tulai and Soyak were classified as shallow, while Salang and Batu Malang were intermediate and deep respectively. Drone flights were organised twice at each station (9.30 am - 11.30 am and at 3.00 pm - 4.30 pm) at 100m altitude. Classification of drone data was made to separate the coral from substrate and water following ISODATA (Exelis 2014). Using vector coral and Sequential Maximum Angle Convex Cone (SMACC) End member Extraction the possible area of bleaching was marked. This was determined by the abundance of brightness feature.

Concurrently, the underwater survey was carried out by a team of SCUBA divers. At the sampling point (as followed by the drone flight), three transect lines of 30m each were laid. Video was recorded using an underwater camera (30-50 cm from substrate and 6 minutes per transect line). Video was then analyzed using Coral Point Count with Excel Extension (CPCe) following Kevin and Shaun (2006) and comparison was made with drone data.

FINDINGS AND ARGUMENT

Sea Surface Temperature

The trends of sea surface temperature in 2016 is higher than 2017 in Tioman Island. Year 2016 Temperature rise towards peak in May and decreased towards August and increased again towards December before decline until February 2017. Highest temperature recorded in 2016 (31.7°C in May) while the lowest temperature recorded was 28.5°C in January 2017. Temperature rise towards peak in April, decreased until August and increased again towards December. Highest temperature recorded in 2017 was 31 °C during May. The lowest temperature was recorded for 27°C in January. In average, year 2016 showed higher patterns of temperature for the entire months if compared to 2017.

When compared between the temperature and coral bleaching spots, it was found that there are no significant effects of SST towards bleaching as monitored by CVT and drone in 2017 for all sampling stations. Most of the bleaching from August to October occurred in patches (compared to the whole area such as during 2016 bleaching). The prediction made by Heron (2016) could be camouflaged by the complexity of the habitat in Tioman Island or it could be due to the fact that the island is more exposed to temperature variability as discussed by Guest et al. (2012). Zuhairi et al. (2016) showed how the rise of temperature affects the corals in Tioman in the previous year. Nonetheless, while SST was lower in 2017, the coral bleach incidents were become very patchy.

Relationship of the Drone and Underwater Data

The hypothesis '*Results from drone methods is no difference than CVT for monitoring the patterns of coral bleaching*' is accepted at 4 stations and rejected at 2 stations (Tulai

TABLE 1: Summary of the statistics using regression to show the relationship between coral bleaching spot detected by drone and the coral bleached (CB) as found by underwater video observation

Station	Relationship between drone CB spot and CVT data
Tulai 1	significant relationship - ($R^2 = 0.91$; $p < 0.05$; Sig $F < 0.1$ where $F > p$ value)
Tulai 2	not obviously significant - ($R^2 = 0.02$; $p < 0.35$; Sig $F > 0.1$ where $F < p$ value)
Salang	at the marginal significance - ($R^2 = 0.01$; $p < 0.07$; Sig $F > 0.1$ where $F < p$ value).
Batu Malang	significant relationship - ($R^2 = 0.91$; $p < 0.076$; Sig $F < 0.1$ where $F > p$ value).
Soyak	medium level significance with less meaningful relationship – ($R^2 = 0.48$; $p < 0.02$; Sig $F > 0.1$ where $F > p$ value).
Renggis	significant relationship - ($R^2 = 0.88$; $p < 0.02$; Sig $F < 0.1$ where $F > p$ value)

2 and Batu Malang) as shown in Table 1. Batu Malang is located nearest to Tulai 2 and shared the same result.

Tulai 1 was not as deep as Tulai 2 and they confined by different structure of coral (Tulai 1- branching corals; Tulai 2 - table corals). The condition could affect the reflection received by drone the possible bleaching spot recorded was not significantly related to the spot identified by the CVT. Despite that, the drone images successfully showed the bleaching points in the studied area. This supported the recommendation of Hamylton (2017) and Castella et al. (2017) on the important UAV in helping environmental event monitoring such as the coral bleaching. It could reduce manpower; cost operation over large coverage as well as for the purpose of ad-hoc monitoring and baseline study. Ig compared to satellite images, drone images might be lacking in suitable spectral for coral identification, but yet drone images allow continuous non-scheduled time for image acquisitions with high resolutions.

CONCLUSION AND RECOMMENDATION

Drone for coral bleaching monitoring could be used with the limitation of the site selected, coral structure and flight time chosen. Under good weather conditions, drone images are able to produce good results which can be aligned with the CVT results. It was found that the glares significantly affect the coral bleaching analysis, thus flight time and camera setting position must be determined during the flight planning stage. Laboratory analysis on the brightness parameters and analysis on the targeted pre-frame could improve the results.

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H2O (Highland to Ocean) Songsong-Jerai Expedition 2017: Creating A Corridor of Life and Biodiversity

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Abstract: The H2O (Highland to Ocean) Songsong-Jerai Expedition was jointly organized by the Department of Marine Park Malaysia and USM's Centre for Marine and Coastal Studies (CEMACS) to document the biodiversity of both marine and terrestrial that were found in the area. The study area encompasses the land area of Gunung Jerai, the coastal region and the marine and islands of the Songsong Group in the state of Kedah. Experts from various fields of biodiversity research joined the expedition; members were from universities, government agencies, NGO's and also individual researchers. In this expedition, a total of 43 marine species inclusive of commercial species, 63 species of plants and 15 species of organisms were recorded. The number of species shows that the area is still diverse and many more undiscovered hidden are yet to be discovered. Effective management would restore the ecosystem and provide a suitable economy to the community who are depended on it for their living.

Keywords: Straits of Malacca, Biodiversity, Natural Heritage, Flora, Fauna

INTRODUCTION

Pulau Songsong, Pulau Bidan, Pulau Telor and Tukun Terendak commonly referred as Songsong group of islands are coastal islands located in the northern region of the Straits of Malacca. The islands are surrounded with shallow and narrow fringing reefs. These unpopulated islands used to be a military zone of the Royal Malaysian Air Force which has now cease to operate here, where in the year 2009, the islands were turned over to the Kedah State Government. Despite the military activity, the reefs within these islands are still intact. Songsong would be an area with the last standing diverse coral reef from here to Cape Rachado, Port Dickson along the Straits of Malacca. Other places like Pulau Kendi (Penang), Pulau Pangkor and Sembilan group of Islands that are previously known to have diverse reef are in poor condition now, mainly due to human impact.

Meanwhile, Gunung Jerai with the height of 3,854 feet (1,175 m) stands at the border of Kuala Muda and Yan districts. In the year 2017, a total area of 816 km was announced as one of the national Geopark in year 2017, which includes the Songsong group. Gunung Jerai has its own unique attraction from the geological aspect of the formation, its composition of rocks and its importance from aspects of historical value, culture and civilization.

An expedition with the aims to disclose the true biodiversity and socio-economic standing of Songsong Island and Gunung Jerai was initiated by the Marine Parks Department of Malaysia. Preparation for the expedition was started in early 2017 with the first general meeting calling on interested participants held at the Centre for Marine and Coastal Studies (CEMACS), Universiti Sains Malaysia on 14th August 2017. The project originator was the Department of Marine Park Malaysia with CEMACS of Universiti Sains Malaysia as secretariat and planner. Altogether 50 researchers and research assistants from 9 agencies were involved with the expedition. The agencies that were involved were Universiti Sains Malaysia, Department of Marine Park Malaysia, Universiti Utara Malaysia (UUM), Forest Research Institute Malaysia (FRIM), Department of Wildlife and National Parks, Forestry Department, Fisheries Research Institute (FRI) Batu Maung, Malaysia Nature Society (MNS) Penang, and Penang Botanical Garden.

Thus, this expedition would seem to be the important source of information that will form the basis of the management for the human and natural habitats found here, by looking at the possibility to gazette the islands as a Marine Protected area (MPS). This would further help us to conserve this important natural heritage for future generations.

METHODS

The Songsong-Jerai Expedition itself was divided into the Land Component and the Marine Component (Figure 1), which commenced from 26th September – 3rd October 2017. Kicking off were the marine expeditioners on board the MV Delisha. It transited Kuala Kedah towards Pulau Songsong in fair weather. On board were the dive teams and scientists studying the coral reefs and intertidal areas of Pulau Songsong and Tukun Terendak. Tukun Terendak, the rocky outcrop with submerged reef on the southwest of Pulau Songsong was also included in the study. Another marine team comprising of ichthyologists and marine mammal group had its base in CEMACS, Penang. They commuted daily to Pulau Songsong and also delivered samples back to the centre for safekeeping. Meanwhile, the terrestrial teams were based in Yan, Kedah.

During the initial stages of the expedition, the terrestrial team explored the coastal areas of Pulau Songsong, Pulau Telor and Pulau Bidan from Tanjung Dawai on the mainland. While, MV delisha returned to Kuala Kedah on 29th September 2017, the terrestrial team started their investigation on the biodiversity at Gunung Jerai. These comprised of zoologist, botanists, and the social scientists. Activities on sampling and observations ran from morning to late at night. The state forest department and the District Office of Yan were advisory to the research here.

This study also explored the social, cultural and economic aspects in the land area of Gunung Jerai to the islands of Songsong Group including the coastal region. The data and information of the study were gathered through literature review and observation on the study site. Four factors were focused during the data collection, which were the sources of income of the local community, the value and culture, education levels and health status.

FIGURE 1: The Songsong group of islands lies in close proximity to the peninsular mainland and Gunung Jerai

FINDINGS

a) Flora and Fauna of Songsong group of Islands

Pulau Songsong, which was focused in this expedition for marine component, was the biggest among the three islands, lies in shallow tropical seas and is surrounded by several types of coastal habitats. The exposed western area comprises of rocky steep cliffs that are covered with land vegetation that was previously logged. This extends to the north and south of the island. There is a small beach to the southwest. On the west too are two caves that are partially tidal. The largest reef area is found to the south of Pulau Songsong. It is a fringing reef but was not diveable during the expedition due to the rough seas. The largest beach is found fronting the east part of the island with a rocky shore to its north. This is the main study location. We can divide the microhabitats found here into the terrestrial section and the marine section. The Figure 2 illustrates the cross-sectional profile of eastern Pulau Songsong from the steep terrestrial slopes towards the marine areas beyond the coral reef.

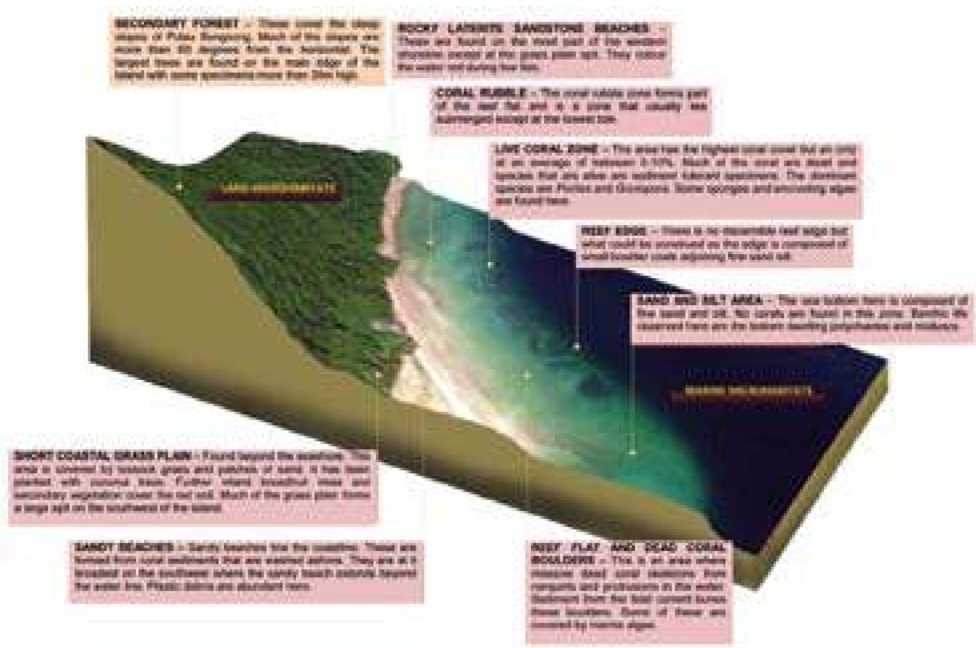

FIGURE 2: Illustrates the cross-sectional profile of eastern Pulau Songsong

Pulau Telor, which is situated between Pulau Songsong and Pulau Bidan, is the smallest island, with the highest point approximately 68 m above sea level. This island consists of rocky boulders with sparse vegetation. There is only one sandy beach on the east side of the island, while the rest is mostly steep cliffs. North and south of this spit are small patches of reef. Meanwhile, Pulau Bidan was packed with vegetation, especially timber trees, and rises sharply to almost 83 m above sea level to a ridge. There are areas of sandy beach, but most of the shoreline is rocky without a sandy beach and has steep sheer cliffs and also waterline caves. There are several abandoned concrete buildings on the flat land area on the eastern part of the island. The waters of Pulau Bidan are turbid and no diving was possible here during the study.

The vegetation of the islands was found to be very different from the lower montane forest of Gunung Jerai. The beach areas were slightly disturbed with *Fimbristylis sp.* grass and *Stachytarpheta jamaicensi*. Although the creepers are common, their constant flowering may be a main food source for supporting the bees' population on the islands. Few uncommon plants were found near coast at Pulau Songsong, especially *Erycibe sp.,* which the fruits were reported as a tapir food and the woody climber with very large pods, *Entada sp.* Besides that, the climbing bamboo, *Dinochloa sp.,* was discovered in Pulau Bidan, which is endemic to Peninsular Malaysia (Wong, 1995). Several important endemic coastal plant species were also recorded during the expedition, *Archidendron contortum,Canavalia rosea, Caesalpinia bonduc, Entada spiralis, Thespesia populnea,* and *Ipomoea violacea*.

A notable decline in fish and hard coral species diversity was observed in a five years period, when we compared the data with previous marine biodiversity expedition at Songsong (Zulfigar et al., 2013). However, more soft coral species and newly discovered seacucumber *Stichopus formiossa* (Woo et al., 2015), which consider rare and commercial valued was recorded during this expedition. The summary of the flora and fauna at Songsong group is presented in Table 1.

Harmful Algal Blooms (HABs) or commonly known as "red tides" which happens due to changes of environmental conditions were observed during the expedition around Pulau Songsong and Tukun Terendak. The dinoflagellates were identified as *Ceratiumfurca* (Order: Gonyaulacales, Family: Ceritiaceae). Activities in coastal areas such as agriculture and sewage release from Merbok River to the sea were suggested to cause the nutrient imbalance that may increase the chances of the bloom.

TABLE 1: Summary of the flora and fauna at Songsong group

No.	Group	Family	Genus	Species	Location
Land					
1	Plants	35	48	48	Pulau Songsong, Pulau Bidan, Pulau Telur
2	Herpetofauna	1	1	1	Pulau Songsong
Marine					
1	Fish	8	-	16	Pulau Songsong, Tukun Terendak
2	Seacucumber	2	2	2	Pulau Songsong
3	Hard corals	6	9	12	Pulau Songsong
4	Soft coral	4	6	6	Pulau Songsong, Tukun Terendak
5	Marine Crabs	4	4	4	Pulau Songsong
6	Marine mammals	2	2	3	Pulau Songsong

b) Flora and Fauna of Gunung Jerai

Despite the limited time, the terrestrial team explored a small area at the peak and base of Gunung Jerai. The summary of the terrestrial team's finding is presented in Table 2. Several important endemic plant species were found during the expedition, *Begonia sibthorpioides, Utricularia striatula, Utricularia involvens, Corybas geminigibbus, Torenia atropurpurea, Sonerila calophylla, Sonerila linearis* and *Nepenthes albomarginata,* while wildlife team too spotted a frog species, which is endemic to Gunung Jerai, *Oddorana monjerai*.

TABLE 2: Summary of the flora and fauna at Gunung Jerai

No.	Group	Family	Genus	Species	Location
Land					
1	Plants	13	15	15	Peak of Gunung Jerai
2	Herpetofauna	5	8	14	Sg. Teroi, Gunung Jerai

c) Socioeconomics

Based on the findings and our observation during the expedition, the local communities main economic activities were agriculture and fisheries. The high numbers of fishing vessels and activities observed in the waters of Pulau Songsong is indicative of the importance of these water for the fishing industry. Besides that, Songsong group of islands has recently attracted a growing number of tourists especially from Penang and the mainland Kedah.

Yan also possess outstanding natural beauty that can stimulate positive impact to the livelihood of the local communities. From highland to ocean, Yan can offer plenty of attractive destinations that will generate income to the people of Yan specifically and Kedah state in general. Besides identifying the main economic activities, the social environment and also the quality of life of the local community, the study also highlighted the potential value in the studied area that can be put forward to expand the economic activities of the community.

CONCLUSIONS

The number of species shows that the area is still diverse and many more undiscovered hidden are yet to be discovered. However, the evidence also indicates that the biodiversity of study area has suffered from moderate to high pressure by resource users, and high rates of sedimentations from coastal rivers. An environmental education program with the long-term goal to increase resource use awareness by promoting direct participation and involvement of different stakeholders in environmental issue in the area is crucial. Particularly in determination of fishing buffer zone to sustain the resource. Since there are huge potential for tourism activities, the state government of Kedah should emerge with comprehensive policy framework to preserve and conserve the natural treasure of Yan to ensure the sustainability of the natural resources. In addition, a thorough scientific study may lend a powerful support for the inclusion of the area into the Marine Park system.

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Connectivity of Marine Habitats of Pulau Tinggi Through Fish Diets

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Abstract: This paper reports on the fish species sampled from the mangroves, seagrass beds and coral reefs of P Tinggi in order to demonstrate connectivity of the habitats via fish diets. 78 species were sampled from 39 families utilizing gill nets of mesh sizes 1.5", 3" & 5". The total fish biomass was 41.2 g/m^2/hr while the total density was 0.16 no/m^2/hr. The Margalef's index was 11.8, Shannon-Weiner index was 3.36, and Pielou index was 0.77. Fishes from mangroves recorded higher empty stomachs (53%) while fishes from the coral habitat showed higher full and gorged stomachs (22%). The important diet types were decapoda (31%), teleost (27%), plant matter (10%) and unidentified materials (14%). Fishes showed diet partitioning between habitats where different food categories were consumed in different habitats, especially for the carnivorous fish. Connectivity of habitats through diets was demonstrated by 7 fish species sampled.

Keywords: mangrove, seagrass, coral, fish diet, habitat connectivity

INTRODUCTION

Studies on the marine habitats and their biodiversity of Pulau (P) Tinggi are known (Department of Marine Parks, 2013; Ooi et al., 2011 2014, 2017; Ponnampalam et al., 2014). The marine habitats of P Tinggi include mangroves, seagrass beds and coral reefs but there has not been any attempt to show linkages between these habitats. Habitat connectivity between biotopes by fishes has been shown for feeding, nursery, shelter and breeding (Chong & Sasekumar, 2002; Berkström et al., 2012; Lau, 2014), indicating community structure and biomass differences (Mumby, 2006), and juvenile-adult life stages (Ramos et al. (2015). This paper reports on the connectivity of habitats of P Tinggi (mangrove, seagrass and coral) through fish diets.

METHODS

Fish Sampling

Fish sampling was conducted between August 2017 to November 2017 at Pulau Mentinggi (coral habitat), Teluk Tereh and Teluk Pinang (mangrove habitat), and at Pulau Apil (segrass habitat). Three types of monofilament gill nets [1.5" & 3" (dimensions of 168 m x 1.8 m) and 5" (dimensions 336 m x 1.5 m)] were utilized together to sample fish from the three habitats. The 1.5" and 3" gillnets were each employed 26 times while the 5" gill net was employed 28 times. Gill nets were placed for a period of between 11 – 13 hours before fish collection. All fishes caught were enumerated and measured (standard length, total length, fork length and weight) on the same day after collection.

Stomach Fullness and Stomach Content Analysis

All fishes sampled were noted for their stomach fullness (0-empty, 1-¼ full, 2-½, 3-¾ full, 4- full, 5-gorged) (Singh, 2004) and only stomachs that were half full and above were stored in 10% buffered formalin and later analysed to determine their gut content in the lab at Universiti Teknologi MARA, Shah Alam. For ease of analysis, the diet items were categorized into 12 groups. The index of relative importance (IRI) (Pinkas et al., 1971; Hyslop, 1980) was used for diet analysis but was modified and is expressed as, IRI = (%W) (%F) (Singh, 2003) (%W is percent weight and %F is frequency of occurrence).

Diversity

The Margalef's index, D; Shannon-Weiner index for heterogeneity and diversity, H'; and Pielou's index for eveness, J, were utilized to determine fish community structure.

FINDINGS

Fish Distribution and Abundance

Thirty-nine families comprising 78 species were sampled from the mangrove, seagrass and coral habitats of Pulau Tinggi (Table 1). Among the fish families, the Carangidae (7 species), Nemipteridae (5 species), Lethrinidae (4 species), Lutjanidae (4 species) and Dasyatidae (4 species) were the most represented. *Crenimugil buchanani* (n = 85), *Sargocentron rubrum* (n = 76), *Siganus guttatus* (n = 73) and *Lutjanus fulviflamma* (n = 62) were the most abundant.

Twenty-six species were sampled from the mangrove habitat, 13 species from the seagrass habitat and 14 species from the coral habitat. Mixed habitats showed lower number of species as compared to single habitats [mangrove-seagrass = 13; mangrove-coral = 4; seagrass-coral = 2; mangrove-seagrass-coral = 6). The total fish biomass was 41.2 $g/m^2/hr$ (mean = 0.52 ± 0.84 $g/m^2/hr$) while the total density was 0.16 $no/m^2/hr$

(mean = 0.002 ± 0.003 no/m^2/hr). The fish biomass and density was higher from the mangrove habitat [biomass, total = 26.94 g/m^2/hr, mean = 0.71 ± 1.10 no/m^2/hr, density, total = 0.08 no/m^2/hr, mean = 0.002 ± 0.003 no/m^2/hr], followed by the seagrass habitat [biomass, total = 9.96 g/m^2/hr, mean = 0.41 ± 0.49 no/m^2/hr; density, total = 0.06 no/m^2/hr, mean=0.003±0.004 no/m^2/hr)] and the coral habitat [biomass, total=4.35 g/m^2/hr, mean = 0.24 ± 0.41 no/m^2/hr; density, total = 0.02 no/m^2/hr, mean = 0.001 ± 0.002 no/m^2/hr]. The 1.5”, 3” and 5” gill nets sampled 50, 42 and 29 species of fish respectively while total numbers of fish sampled were 381, 176 and 96 in the same order from the three habitats. The community indices showed high value for the overall Margalef’s index (11.8), medium value for the Shannon-Weiner index (3.36) and medium to high value for the Pielou index (0.77). The diversity indices were generally higher for the mangrove fish community and lowest for the coral fish community except for the Pielou index which was highest for the coral fish community (J = 0.9)

TABLE 1: Fish species sampled from the mangrove, seagrass and coral habitats of Pulau Tinggi

Family	Species	Family	Species	Family	Species
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Stomach Fullness

Almost half the fishes sampled recorded empty stomachs (Fig. 1, All Habitats). Only 37 species out of the 78 species sampled had stomachs that could be used for diet analysis (stomach fullness index of >2). Fishes from the mangrove habitat recorded higher empty stomachs (53%) while fishes from the coral habitat showed higher full and gorged stomachs (22%).

Fish Diets

Among the fishes with stomach contents, the important diet types were decapoda (31%), teleost (27%), plant matter (10%) and unidentified materials (14%) (Fig. 2, Overall), but

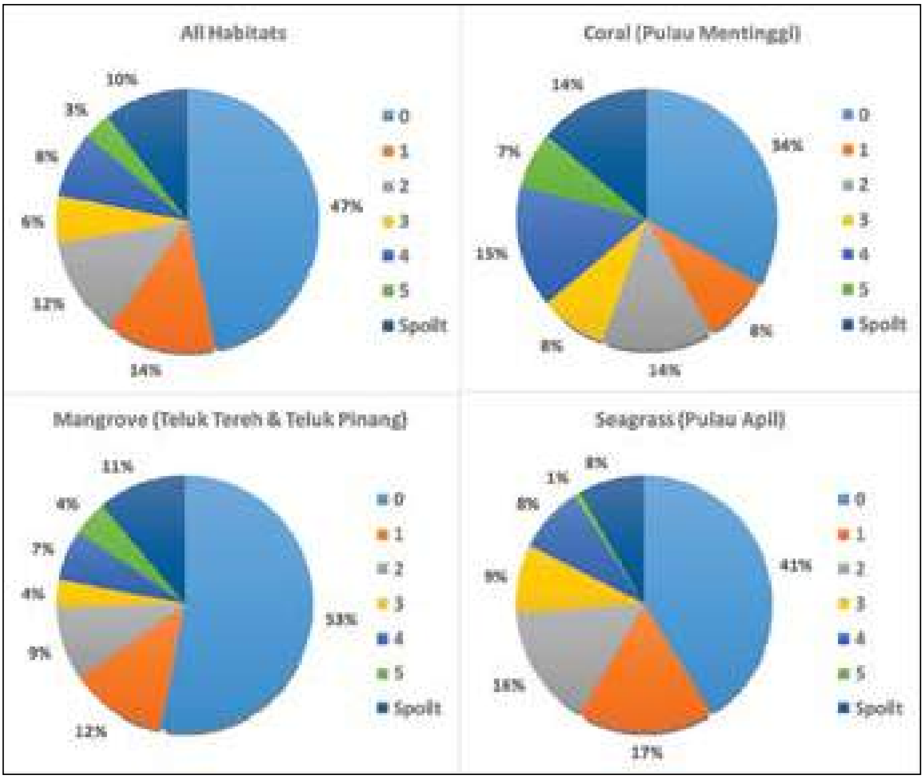

FIGURE 1: Stomach fullness index from fishes sampled from the mangrove, seagrass and coral habitats of Pulau Tinggi

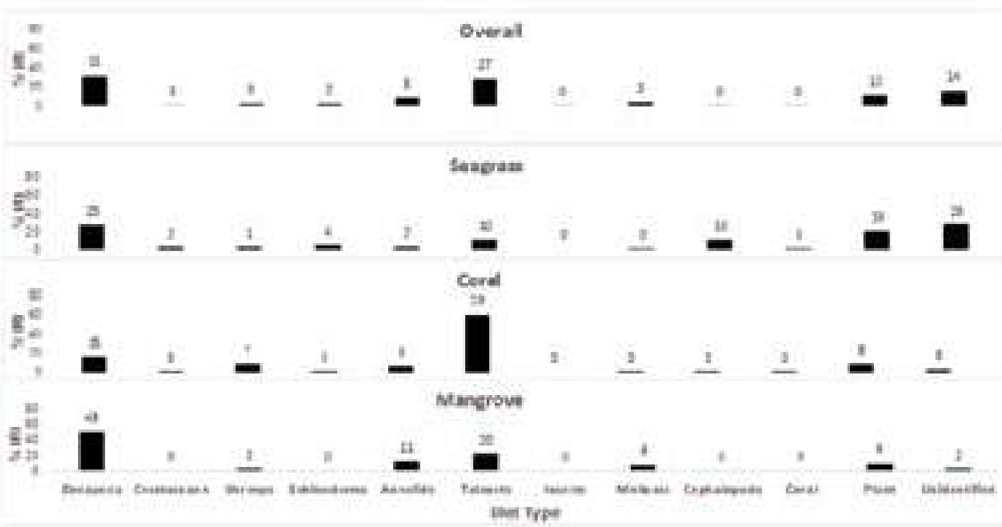

FIGURE 2: Index of Relative Importance (IRI) of fish diets sampled from the mangroves, seagrass and coral habitats of Pulau Tinggi

varied between habitats. The decapoda (49%) and teleost (20%) were important diets for fish from the mangrove habitat; the teleost (59%) and decapoda (15%) were important fish diets from the coral habitat; the decapoda (25%) and plant matter (19%) were important fish diets from the seagrass habitat.

Fish Habitat Connectivity

Sargocentrum rubrum & Plectorhinchus gibbosus (mangrove-seagrass habitats); *Atelomycterus marmoratus* (mangrove-coral); *Lethrinus lentjan* (seagrass-coral habitats), *Siganus guttatus* (seagrass-coral habitats); *Kyphosus cinerascens* (mangrove-seagrass habitats) moved between 2 habitats to feed; while *Lutjanus fulviflamma* moved between 3 habitats (mangroves-segrass-coral) to feed. Habitat connectivity of fish may not only be indicated by feeding in different habitats, but also by community structure and biomass (Mumby, 2006), nursery function (Berkström et al., 2012) and juvenile-adult life stages (Ramos et al. (2015).

Among the carnivorous fish feeding in two habitats, *S. rubrum* fed mainly on decapods in the mangrove (89%) and segrass habitats (71%) but it's diet also comprised of shrimps (14%), crustaceans (7%) and teleost (6%) in the latter habitat (Fig 3). *Atelomycterus marmoratus* fed mainly on decapods in the mangrove habitat (90%) but its diet in the seagrass habitat comprised mainly of teleosts (66%) followed by shrimps (24%). The main diet of *P. gibbosus* was decapods for both the seagrass (100%) and the mangrove (68%) habitats but it also fed on shrimps (16%) and teleosts (9%) at the latter habitat. *Lethrinus lentjan* fed solely on cephalopods (100%) in the seagrass habitat but fed on decapods (87%) in the coral habitat. The diets of *L. fulviflamma* varied between the three habitats. Its diet comprised mainly of teleosts (57%) and decapods (33%) in the mangrove habitat; it was mixed in the seagrass habitat (shrimps = 37%, decapods = 26%, crustaceans = 16% & teleosts = 13%); and was dominated by decapods (54%) followed by shrimps (19%) and teleosts (15%) in the coral habitat. Among the herbivorous fish (*S. guttatus* & *K. cinerascens*), the diet mainly consisted of plant material (> 98%) in both habitats (seagrass-coral and mangrove-seagrass).

The carnivorous fish showed diet partitioning between habitats where different food categories were consumed in different habitats. This diet shift behaviour is important to minimize intra and inter specific competition for food (Singh, 2003; *Tanaka* et al., 2011; Cachera et al., 2017). Lau (2014) showed that fish movement (for feeding) and outwelling of extruded mucus (from corals) and zooplankton connected coral reefs to mangroves in the north eastern part of Langkawi Island.

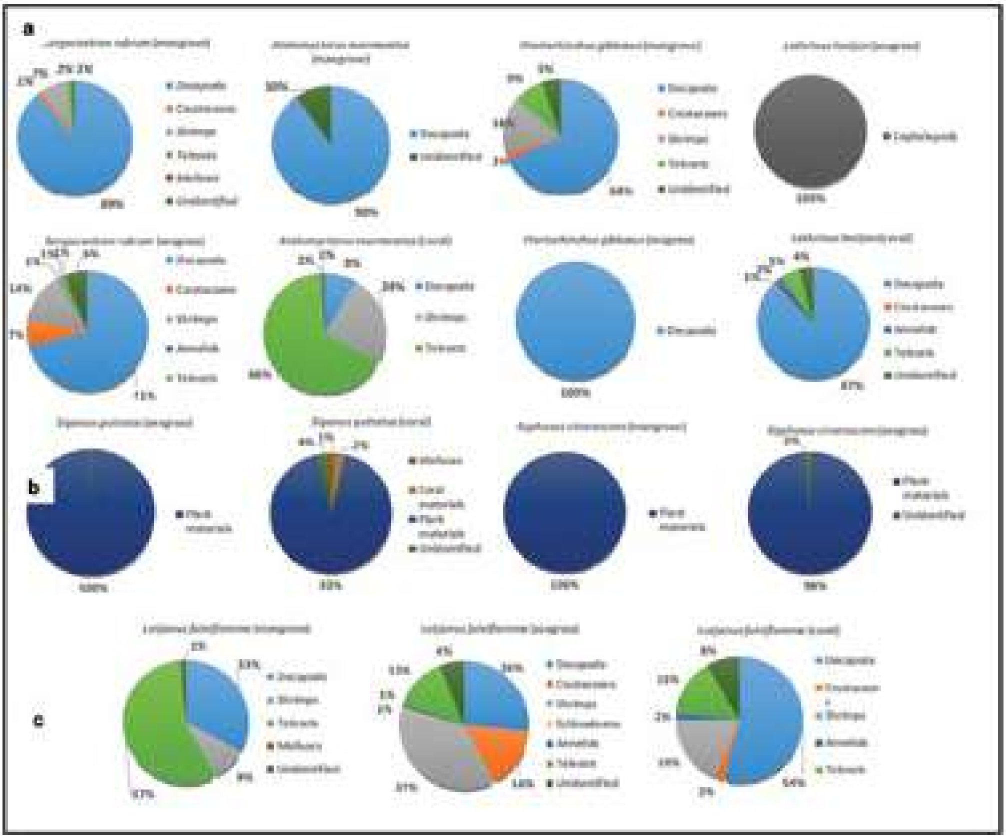

FIGURE 3: Diets of fishes sampled from various habitats of Pulau Tinggi. a) carnivorous fishes from 2 habitats, b) herbivorous fishes from 2 habitats, and c) carnivorous fish from 3 habitats

CONCLUSION

Fishes move between habitats (mangrove, seagrass and coral) to feed but their diet vary between habitats. The inter habitat movement and feeding by fishes shows connectivity of the habitats of P Tinggi. The conservation and management of these habitats and their biodiversity is imperative for their sustainability.

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