EXPEDITION REPORT

Expedition dates: 16 – 23 August 2016

Report published: April 2017

Paradise in peril: studying & protecting reefs within the Tioman Archipelago Marine Protected Area, Malaysia

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Abstract

In August 2016 citizen science volunteers from Biosphere Expeditions along with a marine scientist from Reef Check Malaysia conducted reef health assessments at various sites around Tioman Island (Malaysia), using the Reef Check methodology. The surveys were part of a continuous study first started in 2012 and replicated in 2013. Results showed that generally coral reefs in the area were in ‘Good’ condition (as defined by Chou et al. 1994) with a total average of 58% live coral cover (50% hard coral and 8% soft coral). This is higher than the national average of 46% recorded in 2015 (Reef Check Malaysia 2016) and an improvement on the 52% recorded during the last Biosphere Expeditions survey in 2013. Furthermore, coral reefs around Tioman also appeared to be resilient to the 2015/16 global bleaching event, with only 4% of the population showing signs of bleaching. Corals which did bleach also showed positive signs of recovery as only 13% of the surface area of colonies were still bleached by August 2016 and less than 1% of recently killed coral was recorded. However, highly-priced marine life collected for the food and curio trades continue to be either absent, or were recorded in very low numbers throughout all survey sites. Moreover, discarded fishing gear along with algae that indicate high nutrient content in the water confirm that illegal harvesting of marine life along with increased development on land continue to be the main threats to reefs around Tioman. Improved enforcement of existing Marine Park laws to protect fish no-take zones, better coastal development planning, reduction of tourism impacts, as well as better waste management and sewage treatment systems are critical if local threats are to be reduced and resilience of the reefs within the Tioman Archipelago towards global impacts is to be achieved.

Abstrak

Pada bulan Ogos 2016, sukarelawan dari Biosphere Expeditions bersama dengan penyelidik dari Reef Check Malaysia, telah menjalankan pemantauan kesihatan terumbu karang di sekitar perairan Pulau Tioman dengan menggunakan kaedah Reef Check. Pemantauan ini merupakan sebahagian daripada satu penyelidikan jangka panjang yang telah bermula pada tahun 2012 dan di ulangi pada 2013 bersama Biosphere Expeditions.Kajian menunjukkan bahawa secara amnya terumbu karang di sekitar perairan Pulau Tioman berada dalam keaadan yang ‘Baik’ (seperti ditakrifkan oleh Chou et al1994) dengan purata litupan karang hidup setinggi 58% (50% Karang Keras dan 8% Karang Lembut) dan adalah lebih tinggi daripada purata kadar litupan karang hidup untuk Malaysia yang hanya 46% pada tahun 2015 (Reef Check Malaysia 2016) dan peningkatan dari 52% yang telah direkod semasa Ekspidisi Biosphere pada 2013. Terumbu di perairan ini juga mempunyai daya tahan yang tinggi terhadap kelunturan karang 2015/16 dimana hanya 4% populasi karang terluntur. Karang ini jugak menunjukkan kadar pulih yang tinggi dimana hanya 13% permukaan karang yang masih luntur dan kurang daripada 1% yang mati. Walaubagaimanapun, hidupan laut bernilai tinggi yang dijual untuk makanan atau industri perhiasan dan cenderahati jarang dijumpai di kebanyakan kawasan yang dipantau. Kehadiran alatan penangkapan ikan terbiar dan rumpai laut berlebihan di terumbu karang, menunjukkan bahawa penangkapan ikan secara haram dan pembangunan pesat di pulau adalah ancaman utama kepada terumbu karang di perairan Pulau Tioman. Penguatkuasaan undang-undang Taman Laut yang lebih baik untuk melindungi kawasan terpelihara, peranchangan pembangunan persisiran pantai yang lebih baik, pengurangan impak pelancongan serta pengurusan sisa pepejal dan sisa kumbahan yang lebih baik adalah penting untuk menguragkan impak tempatan dan meningkatkan daya tahan terumbu karang di perairan Tioman terhadap ancaman global.

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1. Expedition Review

Matthias Hammer
Biosphere Expeditions

1.1. Background

Biosphere Expeditions runs wildlife conservation research expeditions to all corners of the Earth. Our projects are not tours, photographic safaris or excursions, but genuine research expeditions placing ordinary people with no research experience alongside scientists who are at the forefront of conservation work. Our expeditions are open to all and there are no special skills (biological or otherwise) required to join. Our expedition team members are people from all walks of life, of all ages, who are looking for an adventure with a conscience and a sense of purpose. More information about Biosphere Expeditions and its research expeditions can be found at www.biosphere-expeditions.org.

This report deals with an expedition to Pulau Tioman Island Marine Park, Malaysia Peninsula that ran from 16 – 23 August 2016. Its aims included: (1) monitoring the health of the Pulau Tioman Island Marine Park's reefs so that informed management, education and conservation decisions can be made by government and NGOs, and (2) contributing to the conservation of Malaysia's valuable ecological resources. Data collection followed an internationally recognised coral reef monitoring programme, called Reef Check, and will be used to make informed management and conservation decisions within the area. The expedition included training participants as Reef Check EcoDivers.

Tioman is located 40 km off the east coast of the Malaysian Peninsula. The reefs of Tioman Island Marine Park are some of the healthiest and most diverse around the peninsula and situated inside the 'coral triangle', an area that has been identified as having the highest diversity of coral species anywhere in the world. The reefs in the coral triangle support over 600 genera of reef-building corals, over 3000 species of fish and contain 75% of all coral species known to science (The Nature Conservancy 2008). The coral triangle was identified as a priority area for marine conservation and, during the 2007 United Nations Climate Change conference in Bali, a pledge to protect this marine environment was drawn up between the countries of Malaysia, Indonesia, the Philippines and Papua New Guinea. Tioman was gazetted as a nature reserve and Marine Park in 1998 to protect these valuable resources. A Marine Parks division of the government is present on the island.

However, the island's growing tourist trade, crown-of-thorns population booms, and developments on land are threatening the reefs' health and so data on the current biological status of the reefs and of population levels of key indicator species are crucial for park management and for educational efforts. Tourism development is a priority for the government, but sustainable tourism is being overlooked in favour of cheaper and more damaging mass tourism. If Malaysia's government and local populations can see small-scale, responsible tourism development working for them, then the country's rich natural resources could be protected more effectively.

1.2. Research area

Malaysia is a federal constitutional monarchy in Southeast Asia. It consists of thirteen states and three federal territories and has a total landmass of 329,847 square kilometres. The country is separated by the South China Sea into two regions, Peninsular Malaysia and Malaysian Borneo (also known as West and East Malaysia, respectively). The capital city is Kuala Lumpur, while Putrajaya is the seat of the federal government. The population of Malaysia is around 28 million.

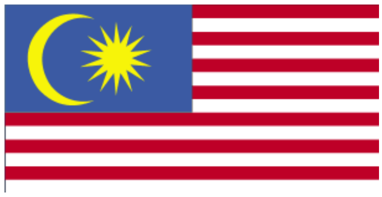

Figure 1.2a. Flag and location of Malaysia and study site.

An overview of Biosphere Expeditions' research sites, assembly points, base camp and office locations can be found at Google Maps.

Malaysia is a megadiverse country, with a high number of species and high levels of endemism. Two-thirds of Malaysia is forested, with a large amount of lowland forest present below an altitude of 760 metres. East Malaysia, like most of Borneo, was traditionally covered with Borneo lowland rain forests, although much has been cleared, causing wildlife to retreat into the upland rain forests inland. Besides rain forests, there are over 1425 square kilometres of mangroves in Malaysia, as well as numerous coral reefs.

1.3. Dates

The project ran over the dates below and was composed of a team of international research assistants, scientists and an expedition leader. Expedition dates were:

2016: 16 – 23 August

Dates were chosen when survey and weather conditions are most comfortable.

1.4. Local conditions & support

Expedition base

The expedition base was a modern three-deck, 85 foot liveaboard yacht with indoor cabins and a lounge (all air-conditioned), and an open air dining area, sun deck and dive platform. Tank refills (including Nitrox on request) and dive services were provided by the crew. A professional cook and crew also provided all meals and special diets could be catered for.

Figure 1.4a. The liveaboard expedition base.

Weather & water temperature

The climate is tropical and maritime. The average day temperature during the expedition months were 34-40°C. Water temperature during the expedition was 28-31°C.

Field communications

The liveaboard was equipped with radio, telephone and satellite communication systems. Mobile phones worked in some parts of the study site, but by no means all. The expedition leader e-mailed and posted a multi-media expedition diary on Wordpress for friends and family to access. Excerpts of the diary also appeared on the Biosphere Expeditions' social media sites such as Facebook and Google+.

Transport, vehicles & research boats

Team members made their own way to the Singapore assembly point. From there onwards and back to the assembly point all transport and liveaboard services were provided for the expedition team, for expedition support and emergency evacuations.

Medical support and insurance

The expedition leader and the expedition scientist were trained first aiders, and the expedition carried a medical kit. The standard of medical care in Malaysia is good with a clinic in Tekek village and Juara village. There are also recompression chambers in Kuantan and Singapore, as well as a large hospital in Mersing, just a couple of hours away by ferry. Safety and emergency procedures were in place, but did not have to be invoked, as there were no incidences, medical or otherwise, during the expedition.

Diving

The minimum requirement to take part in this expedition was a PADI Open Water or equivalent qualification. Team members who had not dived for twelve months prior to joining the expedition were required to complete a PADI Scuba Review before joining the expedition. Standard PADI diving and safety protocols were followed.

Dive groups were divided into different teams, each working on specific areas of survey work. Divers were allocated to teams based on a mixture of personal preference and diving skills.

1.5. Expedition scientist

Alvin Chelliah graduated with a Marine Science degree from the University of Malaysia Sabah and a Masters Degree in Marine Science from the National University of Malaysia. He started working with Reef Check Malaysia in 2011 and is mainly involved with the training of EcoDivers and conducting Reef Check surveys. He has been diving since he was in high school and is a PADI Divemaster.

1.6. Expedition leader

Kathy Gill is a founding member of Biosphere Expeditions and has been there since the start in 1999. Kathy was born and educated in England. Since gaining her BA in Business at Bristol, she has worked in sustainable development and regeneration for a variety of public sector organisations, most recently the Regional Development Agency for the East of England where she was responsible for developing and supporting partnership working to establish sustainable development activities. At the main office Kathy is the organisation's Strategy Adviser. She has travelled extensively, led expeditions and recceed projects all over the world. She is a qualified off-road driver, divemaster, marathon runner, keen walker, sailor, diver and all round nature enthusiast.

1.7. Expedition team

The expedition team was recruited by Biosphere Expeditions and consisted of a mixture of all ages, nationalities and backgrounds. They were (in alphabetical order and with country of residence):

Nora Barson (UAE), Kimberley Cortner (USA), Ng Zhi Li (Malaysia)*, Declan Madigan (Ireland), Helen Merchant (UK), Skye Merriam (USA), Steve Neely (USA), Christian Schneid (China), Eric Schwarzkopf (Germany).

*placement kindly sponsored via a GlobalGiving fundraising campaign

1.8. Partners

On this project Biosphere Expeditions worked with Reef Check Malaysia, the Department of Marine Parks of Malaysia and a local dive centre, as well as sharing data with the Global Coral Reef Monitoring Network (GCRMN), local Universities and government agencies.

1.9. Expedition budget

Each team member paid towards expedition costs a contribution of £1,590 per person per slot. The contribution covered accommodation and meals, supervision and induction, special non-personal diving and other equipment and air, and all transport from and to the team assembly point. It did not cover excess luggage charges, travel insurance, personal expenses such as telephone bills, souvenirs etc., or visa or other travel expenses to and from the assembly point (e.g. international flights). Details on how this contribution was spent are given below.

Income	£
Expedition contributions	13,160
Expenditure	
Research vessel & accommodation includes all board & lodging on land & sea, ship's crew, fuel & oils, diving &other services	10,780
Equipment and hardware includes research materials & gear hired or purchased in UK & Malaysia	701
Staff Includes local and international salaries, travel and expenses	2,102
Administration includes registration fees & sundries	46
Team recruitment Malaysia as estimated % of PR costs for Biosphere Expeditions	6,430
Income – Expenditure	**-6,899**
Total percentage spent directly on project	**152%***

*This means that in 2016, the expedition ran at a loss and was supported over and above the income from the expedition contributions by Biosphere Expeditions.

1.10. Acknowledgements

This study was conducted by Biosphere Expeditions, which runs wildlife conservation expeditions all over the globe, in collaboration with Reef Check Malaysia. Without our expedition team members (listed above) who provided an expedition contribution and gave up their spare time to work as research assistants, none of this research would have been possible. The support team and staff (also mentioned above) were central to making it all work on the ground. Thank you to all of you, and the ones we have not managed to mention by name (you know who you are) for making it all come true. Thank you to all reviewers, anonymous or named, for helpful comments on the drafts of this report. Biosphere Expeditions would also like to thank members of the Friends of Biosphere Expeditions and donors for their sponsorship support. Last but not least we would like to thank the Department of Marine Parks Malaysia for permitting us to carry out this study under the ongoing MoU with Reef Check Malaysia.

1.11. Further information & enquiries

More background information on Biosphere Expeditions in general and on this expedition in particular including pictures, diary excerpts and a copy of this report can be found on the Biosphere Expeditions website www.biosphere-expeditions.org

Enquires should be addressed to Biosphere Expeditions via www.biosphere-expeditions.org.

Please note: Each expedition report is written as a stand-alone document that can be read without having to refer back to previous reports. As such, much of this section, which remains valid and relevant, is a repetition from previous reports, copied here to provide the reader with an uninterrupted flow of argument and rationale.

2. Reef Check Survey

2.1. Introduction

Coral Reefs

Coral reefs are part of the intrinsic nature of the tropics, which includes soft sandy beaches, coconut palms, crystal-clear waters and beautiful coral gardens flourishing with colourful fishes. Coral reefs are sometimes referred to as the flowers of the ocean (Chou et al. 1994) but reefs are not only aesthetically beautiful; they are also the most diverse marine ecosystem on earth and a vital element of marine ecology (World Meteorological Organisation 2010).

A coral reef is an ecosystem in which stony corals and calcareous algae dominate in number and volume and provide niches for other animals and plants (Soekarno 1989). Corals and calcareous algae are unique because these marine organisms build their own base structures and continue building upwards and outwards as they grow (Chou et al. 1994, Wilkinson 1994).Coral reefs have very specific requirements for growth and are usually found in very clean, low-nutrient waters. Ideal conditions are tropical waters where temperatures rarely go above 30^{o}C or below 18^{o}C; shallow parts of the photic (sunlight) zone, above a depth of 30 m; with low levels of nutrients, sediments and suspended algal plankton concentrations in the water; and low levels of natural physical disturbances (Wilkinson & Ridzwan 1994).

The importance of coral reefs

Coral reefs are a prized natural resource because they provide a vast array of benefits, including cultural, social, biological and economic benefits otherwise known as ecosystem goods and services. The value of these goods and services can be measured against human development and economic impacts to assess the long-term benefits of developments. They are economically beneficial both locally and internationally. Economic benefits come from the fisheries and pharmaceutical industries as well as from the tourism industry, as they attract SCUBA divers, snorkelers and researchers. Locally, coral reefs are a source of calcium carbonate and provide important coastal protection, which are components of the reef's ecological services. Globally, reefs are prized for their extremely rich ecosystems, for supporting and maintaining high diversity and large marine organism biomass, for their role in the carbon cycle, for their intrinsic existence value, and for the enjoyment SCUBA divers and other people derive from them (Pendleton 1995).

Status of coral reefs in Southeast Asia

The coral reefs in Southeast Asia have the highest degree of biodiversity and most extensive coastlines of all the world's coral reefs, with Indonesia, Malaysia (Sabah) and the Philippines (together with Papua New Guinea) forming the global epicentre of marine species diversity: the Coral Triangle. The total coral reef area is nearly 100,000 km^2, comprising nearly 34% of the world's total coral reef (Tun et al. 2004). Most reefs in Southeast Asia are on the Sunda and Sahul continental shelves, forming fringing, platform, barrier reefs and atolls (Tun et al. 2008) holding more than 75% of the world's coral species (over 600 of the world's nearly 800 reef-building coral species) and more than 33% of the world's reef fish species. They also contain nearly 75% of the world's mangrove species and more than 45% of sea grass species (Burke et al. 2002, Tun et al. 2004).

For thousands of years people have coexisted with coral reef ecosystems in Southeast Asia, enjoying the goods and services, protection and contribution to coastal culture and lifestyle provided by this diverse ecosystem (Burke et al. 2002). However, Southeast Asian coral reefs are also the world's most threatened and damaged reefs, facing unprecedented threat from human activities (Tun et al. 2004). The reefs of the Philippines, Vietnam, Singapore, Cambodia and Taiwan are some of the most threatened in Southeast Asia, each with more than 95% of reefs in danger. Indonesia (over 85% of its coral reefs threatened) and the Philippines together hold 77% of Southeast Asian reefs and 79% of Southeast Asian threatened reefs (Burke et al. 2002). According to Wilkinson (2004), there are few encouraging signs of recovery for Southeast Asian reefs, where human pressures continue to increase. The degradation of these resources is coincident with the globalisation of natural resource markets (e.g. fishing, mariculture and tourism) in line with a significant increase in the human population over the past 30 years.

Status of coral reefs in Malaysia

The 9323 km of coastline in Malaysia is estimated to have about 3,600 km^2 of fringing reefs, patch reefs and atoll reefs (Tun et al. 2004). Little reef development occurs along the heavily sedimented west coast of Peninsular (or West) Malaysia, but the east coast of West Malaysia has some fringing reefs along the coast and many oceanic reefs around the offshore islands (Wilkinson 1994, Burke et al. 2002). East Malaysia consists of the Malaysian states of Sabah and Sarawak, and makes up the northern one-third of the island of Borneo. Due to high sedimentation and land-based pollution, reef development around Sarawak is limited (Burke et al. 2002). However, Sabah has reefs along nearly the entire coastline and surrounding most islands (Pilcher & Cabanban 2000).

A total of 346 hard coral species have been recorded in Malaysia, and many West Malaysian coral reefs are protected as Marine Parks and Reserves under the Fisheries Act 1985 (Wilkinson 1994). In East Malaysia, the coral reefs in northeast and southwest Sarawak are protected by the Department of Fisheries Sarawak, and many of the coral reefs in Sabah are protected by Sabah Parks. Studies of coral reefs in Malaysia show that nearly one-third of the reefs have between 25 and 50% live coral cover, very few reefs have more than 75% live coral cover (Tun et al. 2004), and over 85% of the reefs are threatened by human activities (Burke et al. 2002). In 2012 Burke et al. (2012) reported that threats had escalated and almost all of the reefs in Malaysia were threatened.

The Tioman Archipelago

Tioman Island is located some 32 km from Mersing, off the east coast of Pahang, Malaysia. It is the largest island off the east coast of Peninsular Malaysia measuring 22 km long and 11 km at the widest point. The island has a total land area of 13,360 ha (Jabatan Perhilitan Semenanjung Malaysia 2006). The island has five villages, with a total population of approximately 3,500, which is rapidly growing (Lembaga Pembangunan Tioman 2016), and most of whom work in tourism, the main industry on the islands. The Tioman Archipelago was gazetted as the largest Marine Park in Peninsular Malaysia in 1994 (Chak et al. 2016).

Although tourism started on Tioman in the 1970s, resorts and chalets flourished only in the mid-1990s. The island's long coast line and natural beauty has made Tioman one of the most attractive holiday destinations in Malaysia. The island now has 78 resorts, 30 dive shops and receives over 200,000 visitors annually (Lembaga Pembangunan Tioman 2016).

Project aims

Various researchers and organisations, including Reef Check Malaysia, have carried out coral reef studies in the Tioman Archipelago (Affendi et al. 2005, Guest et al. 2012, Chak et al. 2016), but these have mainly been limited to sites within easy access of the dive centres fringing the northwest coast of the island. In addition, a few (such as Reef Check Malaysia) have included ecosystem-wide, long-term, repeated surveys, which allow changes over time to be assessed (Reef Check Malaysia 2017).

The research objectives of this project were to: (1) monitor the health of the reefs, and (2) assess impacts that may be damaging their health, The aims of these objectives were to (1) gain a fuller understanding of the reefs within the Tioman Archipelago, (2) feed this information back to park management and (3) disseminate ecological information to the scientific community.

2.2. Methods

Reef Check survey

The Reef Check survey methodology is designed to assess the health of coral reefs and focuses on the abundance of particular coral reef organisms that are widely distributed, are easy for non-scientists to identify and provide information about the health of a coral reef ecosystem.

Using a standardised, easy to learn yet scientifically robust methodology, data from surveys in different sites can be compared, whether on an island, regional, national or international basis (see www.reefcheck.org for more details).

The Reef Check monitoring methodology allows scientists and managers to track changes to coral reefs over time. By surveying reefs on a regular basis, deleterious changes can be highlighted early, before they become problems. This gives managers the opportunity to intervene and to carry out additional, more detailed studies and/or initiate management actions to try to reverse the change before permanent damage is done to the reef.

After two days of training culminating in three aptitude tests (on fish, invertebrate/impacts and substrate), which had to be passed for volunteers to be able to collect data, Reef Check surveys were conducted for four days along two depth contours where possible (3 to 6 m and 6 to 12 m depth). A 100 m transect line was deployed and along it four 20 m transects were surveyed, each separated by 5m, which provided four replicates per transect (8 per complete survey) for statistical analysis.

Figure 2.2a. Training & testing on board the liveaboard (above) and underwater (below).

Four types of data were collected:

- Fish abundance: the fish survey was carried out by swimming slowly along the transect line counting the indicator fish within each of the four 20 m long x 5 m wide x 5 m high corridors.
- Invertebrate abundance: divers counted indicator invertebrates along the same four 20 m x 5 m belts.
- Substrate cover: collected by the Point Intercept method whereby the substrate category such as live coral was noted every 0.5 m.
- Impact: the impact survey involved the assessment of damage to coral from bleaching, anchoring, destructive fishing, corallivores such as *Drupella* snails or crown-of-thorns starfish, and rubbish.

All data were collected by expedition team members that passed through an intensive Reef Check training and examination procedure. A project scientist and an expedition leader coordinated team members on the expedition. The primary responsibilities of both were to train the team members in Reef Check methodology and also to coordinate and supervise the subsequent surveys and data collection.

Site selection

Survey sites were chosen around the archipelago to get a good distribution and representation of the island's coral reefs. Table 2.2a lists the sites surveyed and Figure 2.2b shows a map of all the sites surveyed. A total of ten sites were surveyed. Sites selected are permanent transect sites, some of which have been surveyed annually since 2007, while others have been surveyed since 2012.

Site description

A description of each site was written according to observations made during and after the survey and from previous knowledge of each site. The description included how sheltered or exposed the site was and the levels of various impacts acting upon it. The impacts were given a ranking from 'None' to 'High'. In addition, the distances to the nearest settlement and nearest river were recorded using Google Earth and a GPS point was taken.

Table 2.2a. Sites surveyed by the expedition in 2016.

	Site name	Coordinates
1	Chebeh	02 55.946 N104 05.814 E
2	Fan Canyon	02 54.650 N 104 06.753 E
3	Labas North	02 53.318 N 104 03.920 E
4	Labas South	02 53.251 N 104 03.943 E
5	Batu Malang	02 54.139 N 104 06.148 E
6	Nayak	02 46.758 N 104 12.760 E
7	Saing	02 45.502 N 104 11.950 E
8	Sepoi	02 53.883 N 104 03.100 E
9	Teluk Dalam	02 52.456 N 104 11.254 E
10	Teluk Kador	02 54.891 N 104 06.507 E

Figure 2.2b. Sites surveyed by the expedition in 2016. See Table 2.2a for dive site names.

Fish belt transect

First a 100 m long tape was laid along the reef to define the transect. A lag period of 15 minutes was allowed after tape laying before starting the fish visual survey. This waiting period is necessary to allow fishes to resume their normal behaviour after being disturbed by the diver laying the transect (Hodgson et al. 2006).

Fish species of interest include those commonly targeted by fishermen and aquarium collectors. These were recorded when seen within 2.5 m of either side of the tape and up to 5 m above the tape were counted. Data were recorded on underwater slates by swimming over the transect tape very slowly. The indicator fish are butterflyfish (BF, Chaetodontidae), sweetlips (SL, Haemulidae), snappers (SN, Lutjanidae), Barramundi cod (BC, *Cromileptes altivelis*), humphead wrasse (HW, *Cheilinus undulatus*), bumphead parrotfish (BP, *Bolbometopon muricatum*), parrotfish (PF, Scaridae) over 20 cm, moray eel (ME, Muraenidae) and grouper (GR, Serranidae) over 30 cm and in 10 cm increments (Hodgson et al. 2006).

Invertebrate belt transect

The invertebrate survey was similar to the fish visual survey (Hodgson et al. 2006). Invertebrates commonly targeted as food species or collected as curios were counted and data were recorded on underwater slates. The indicator species were: banded coral shrimp (BCS, *Stenopus hispidus*), long-spined black sea urchin or Diadema urchins (DU, *Diadema* spp.), pencil urchin (PU, *Eucidaris* spp.), collector urchin (CU, *Tripneustes* spp.), sea cucumber (SC) species *Thelenota ananas*, *Stichopus chloronotus*, *Holothuria edulis*, lobster (LO, all edible species), triton (TR, *Charonia tritonis*) and crown-of-thorns starfish (COT, *Acanthaster planci)*.

Impact assessment

During the invertebrate survey, human impacts were also assessed. These included coral damage by boat/anchor, dynamite, 'other' damage, and trash by types (fish nets or general trash). The scale of these impacts was assessed using a 0 to 3 scale (0 = none 1 = low 2 = medium, 3 = high). The percentage cover of bleaching and coral disease in the coral reef (colony and population) was also assessed during the surveys (Hodgson et al. 2006).

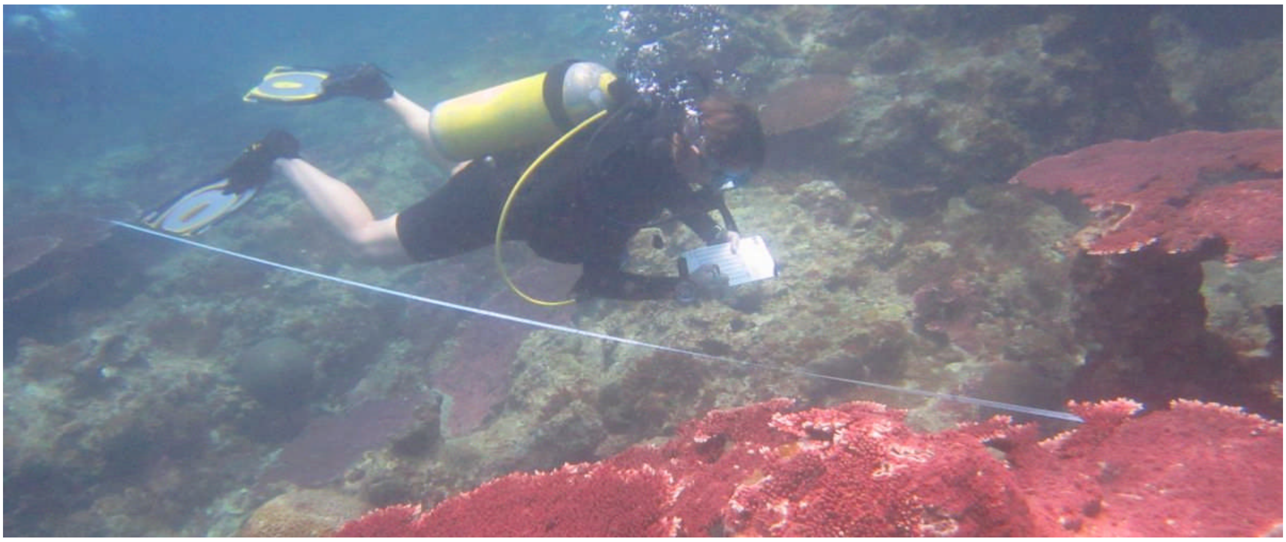

Figure 2.2c. Data collection along the line transect.

Substrate line transect

Starting from 0m, at every 0.5m along the transect tape, the substrate category code was recorded on an underwater slate. The categories recorded were according to Reef Check definitions: hard coral (HC), soft coral (SC), recently killed coral (RKC), nutrient indicator algae (NIA), sponge (SP), rock (RC), rubble (RB), sand (SD), silt (SI) and other (OT). All dives were performed using the same transect tape, with fish recordings being conducted just before the invertebrate and substrate recordings..

Data analysis

All data were entered on underwater slates and immediately transferred onto Reef Check Excel sheets after each survey dive. Belt transect data were used to calculate the mean abundance of each fish and invertebrate taxon for each site. The substrate line transect data were converted to mean percentage cover of each substratum category at each site. Anthropogenic data were represented by mean abundance of each impact at each site.

2.3. Results

Overall status of reefs within the Tioman Archipelago

The results from all 20 surveys (two at each site) were compiled to provide an overview of the status of coral reefs within the Tioman Archipelago. Results showed that the average hard coral cover was 51%, while soft coral cover was 8%. Based on the Coral Reef Health Criteria developed by Chou et al. (1994), the reefs around Tioman have a “Good” live coral cover (58%) (hard coral, HC + soft coral, SC) cover (Fig. 2.3a). This average is higher than the national average of 46% recorded in 2015 (Reef Check Malaysia 2016).

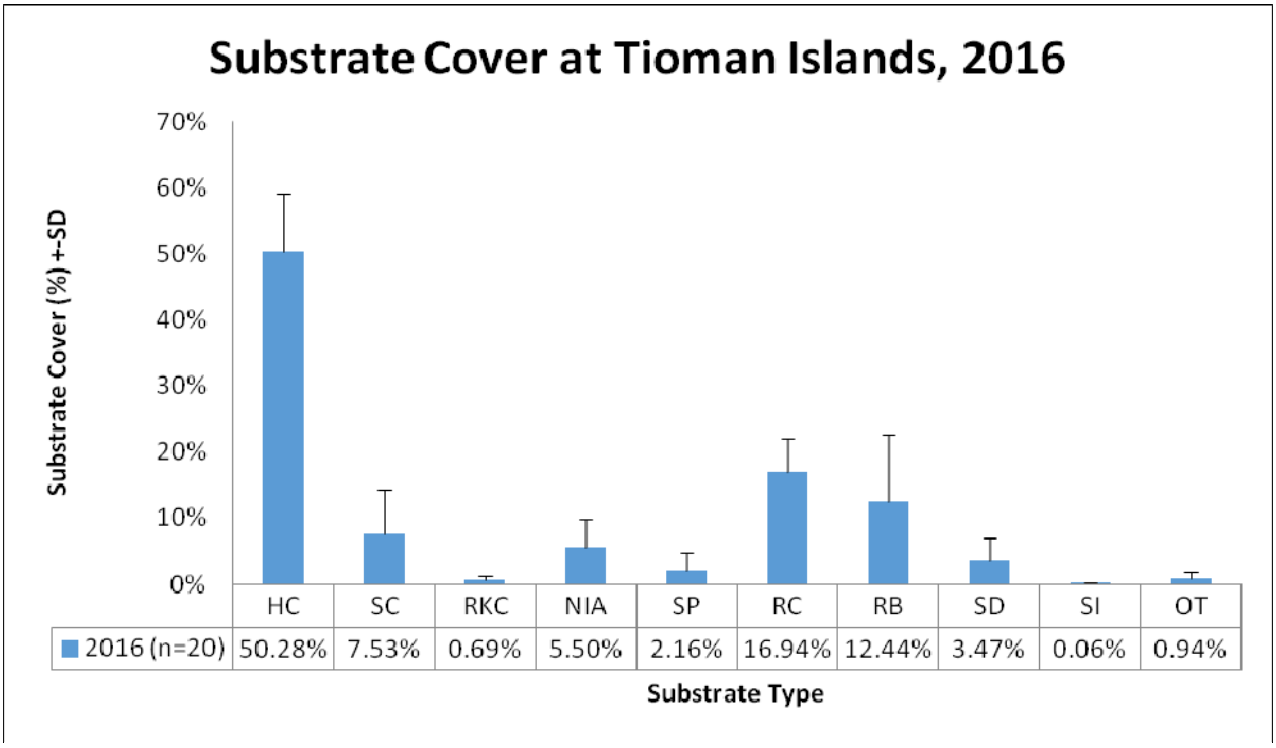

Figure 2.3a. Average percentage of substrate cover per 100 m within the Tioman Archipelago. Codes: HC = hard coral, SC = soft coral, RKC = recently killed coral, NIA = nutrient indicator algae, SP = sponge, RC = rock, RB = rubble, SD = sand, SI = silt, OT = other.

The level of NIA (nutrient indicator algae) on reefs around Tioman does not seem to be an issue, as only 5.5% of the reefs were covered in NIA during surveys in 2016. However, the level shows an increase from previous years (3.18% in 2012 and 3.65% in 2013) (Yewdall et al. 2013; Chelliah & Hammer 2014) and this will need to be monitored closely as a continuous increase may be a sign of nutrient pollution.

On average the amount of rubble recorded on reefs around Tioman during surveys was 12%. This amount has increased slightly only since 2013 (11%) (Chelliah & Hammer, 2014). This indicates disturbances to reefs around Tioman have been low over the last few years.

Recently killed coral (RKC) results from a variety of natural and human impacts were recorded at a low level (below 1%), while Rock (RC), which is critical for reef recovery, regeneration and extension is considered normal at 17% (Fig. 2.3a) (Reef Check Malaysia, 2013).

Sand (SD), a natural component of reefs, can be expected to be found on any surveys. The current level of SD (3%) is within normal levels. Sponge (SP), another natural component of reefs and an indicator of nutrient input, appears normal at 2% (as in 2013). The average level of silt (SI) on reefs within the archipelago is low at 0.06% and the average level of other (OT) was 1% (Fig. 2.3a).

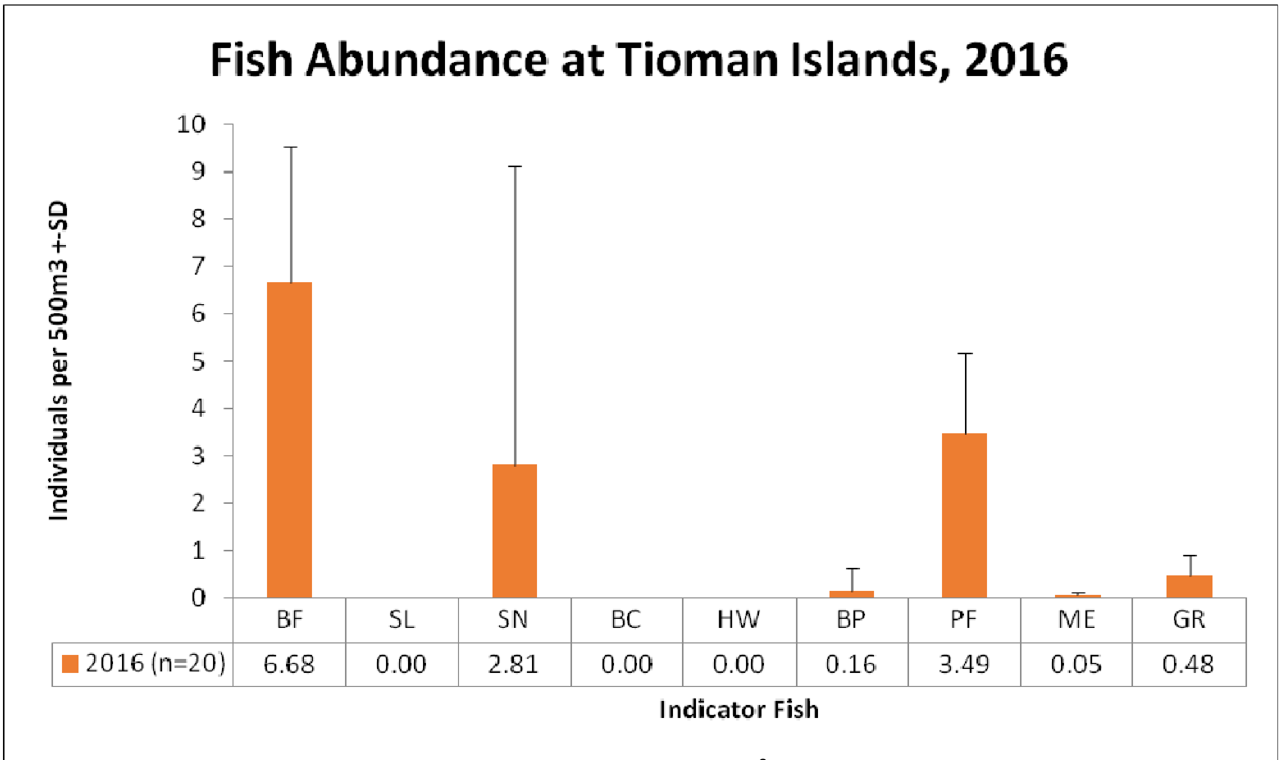

Figure 2.3b. Average number of individuals per 500 m^3 within the Tioman Archipelago.
Codes: BF = Butterflyfish (Chaetodontidae), SL = sweetlips (Haemulidae), SN = snappers (Lutjanidae), BC = Barramundi cod (Cromileptes altivelis), HW = humphead wrasse (*Cheilinus undulatus*), BP = bumphead parrotfish (*Bolbometopon muricatum*), PF = parrotfish (Scaridae) over 20 cm, ME = moray eel (Muraenidae), GR = grouper (Serranidae) over 30 cm and in 10 cm increments.

Abundance of several fish that are targeted for food was low at most of the survey sites (Fig. 2.3b), with abundance recorded at below 1 individual per 500 m^3 survey transect volume (including sweetlips, bumphead parrotfish and moray eel). Highly-prized food fish such as Barramundi cod and humphead wrasse were absent from all survey sites.

Groupers above 30 cm in length are considered high-value food fish and were present in very low numbers (0.48 individual per 500 m^3 survey transect volume). Equally important are healthy butterflyfish and parrotfish populations, but both were present in low numbers (6.68 and 3.49 individuals per 500 m^3 survey transect area respectively). Snappers, a commonly sough-after food fish, were more abundant at certain sites.

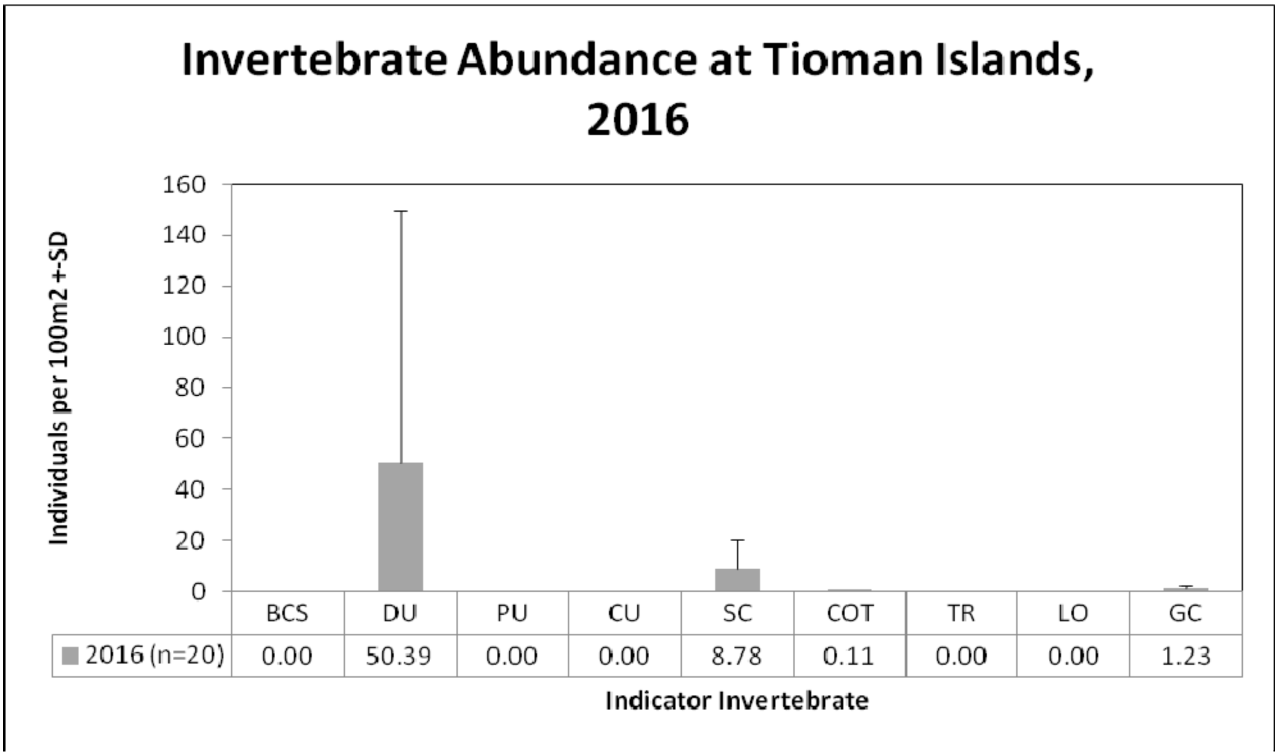

Figure 2.3c. Average number of individuals per 100 m within the Tioman Archipelago. Codes: BCS = banded coral shrimp (*Stenopus hispidus*), DU = long-spined black sea urchin or Diadema urchins (*Diadema* spp.), PU = pencil urchin (*Eucidaris* spp.), CU = collector urchin (*Tripneustes* spp.), SC = sea cucumber species *Thelenota ananas*, *Stichopus chloronotus*, *Holothuria edulis*, LO = lobster (all edible species), TR =triton (*Charonia tritonis*), COT = crown-of-thorns starfish (*Acanthaster planci)*.

Invertebrates harvested for the aquarium trade and souvenirs, such as banded coral shrimp, pencil and collector urchins and triton, were absent during surveys (Fig. 2.3c). Lobster, which is a favourite seafood among tourists, was also absent during surveys. However, the sea cucumber number was high with an average of 8.78 individuals per 100 m^2 compared to the national average of only 1.46 individual per 100 m^2 in 2015 (Reef Check Malaysia 2016). Giant clam was rarely seen, with an average of 1.23 individuals per 100 m^2 (Fig. 2.3c).

Diadema urchin (DU) numbers were exceptionally high (50.39 individuals per 100 m^2) compared with the national average of 29.73 individuals per 100 m^2 in 2015 (Reef Check Malaysia 2016). Crown-of-thorns starfish (COTs) feed on corals and can cause significant damage to coral reefs, destroying large areas in a short period of time. According to CRC Reef Research Centre (Australia), a healthy coral reef can support a population of 20-30 COT per hectare (10,000 m^2), or 0.2-0.3 per 100 m^2 (Harriott et al. 2003) The abundance of COTs found during surveys (0.11 per 100 m^2) is within what a healthy reef can sustain, suggesting that the COT population in Tioman is not a cause for concern. Also, COT abundance during 2016 surveys is lower compared to 2013, which recorded 0.30 individuals per 100 m^2 (Chelliah 2014). The reduction is probably due to frequent COT clean-ups conducted by dive shops in Tioman.

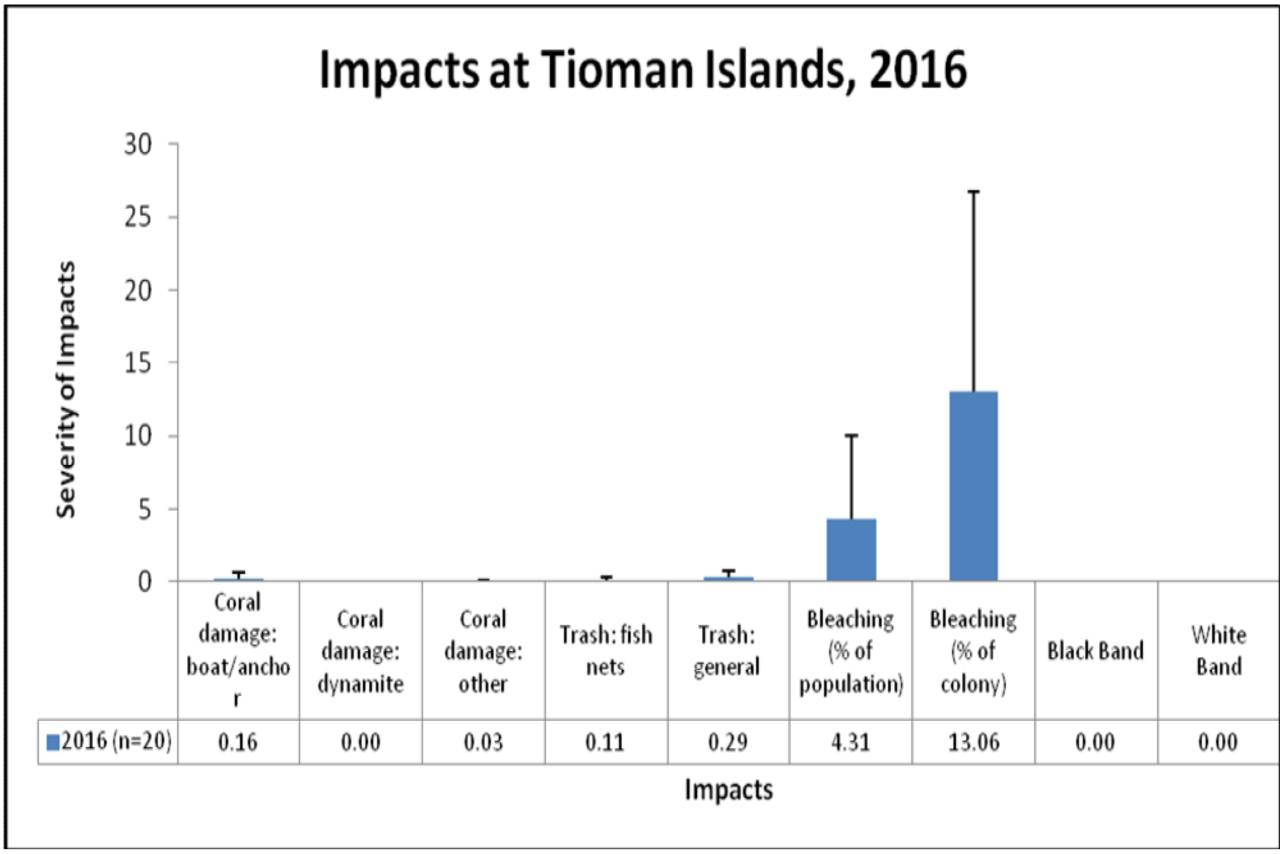

Figure 2.3e. Average coral damage on a scale of 1 to 3 (3 being worst) and percentage of coral bleaching in Tioman.

Visible coral damage caused by human and non-human impacts was also recorded during surveys. The main cause of damage was non-human impacts, which included storms (under coral damage: other) and warm water bleaching (4% of the Tioman coral population surveyed with and average of 15% of each colony surveyed bleached and Recently Killed Coral below 1%). Boat anchor damage, discarded fish nets and trash were present on the reefs, but minimal (Fig. 2.3e). At each site the percentage of coral population bleached and the percentage of each bleached colony's bleached surface area was recorded.

Detailed results from individual sites

Below are details of substrate characteristics, fish and invertebrate populations from all sites surveyed.

Note that for all graphs, data are averaged from the four replicates and all survey depths combined and error bars are Standard Error.

Codes for substrate, fish and indicator invertebrates are given in Figs. 2.3a, 2.3b and 2.3c above respectively.

Teluk Dalam

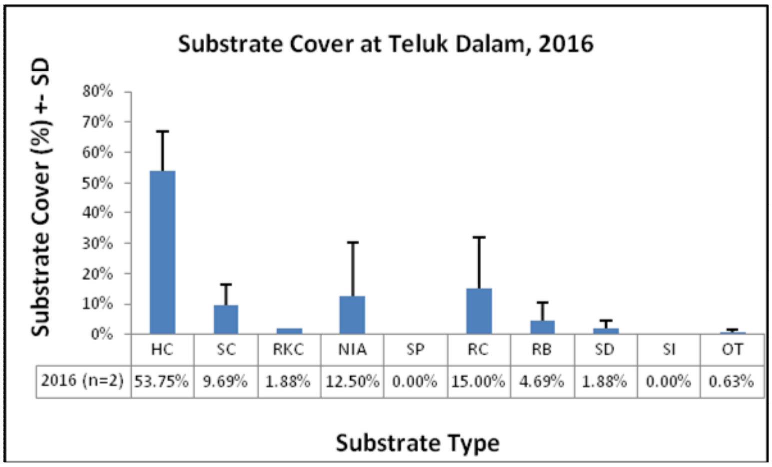

Figure 2.3f(i). Substrate cover for Teluk Dalam.

Teluk Dalam reef is considered to be in a good state with live coral cover of 63.44% (53.75% HC and 9.69% SC) (Fig 2.3f(i)). The level of NIA has increased significantly from 0% in 2013 to 12.50% in 2016. This is a cause for concern and this change needs to be monitored closely. Water quality testing will be able to prove if there is nutrient pollution in this area. It is also important to note that very few herbivores were recorded at this site and the harvesting of herbivores could also be the cause for the increase in NIA.

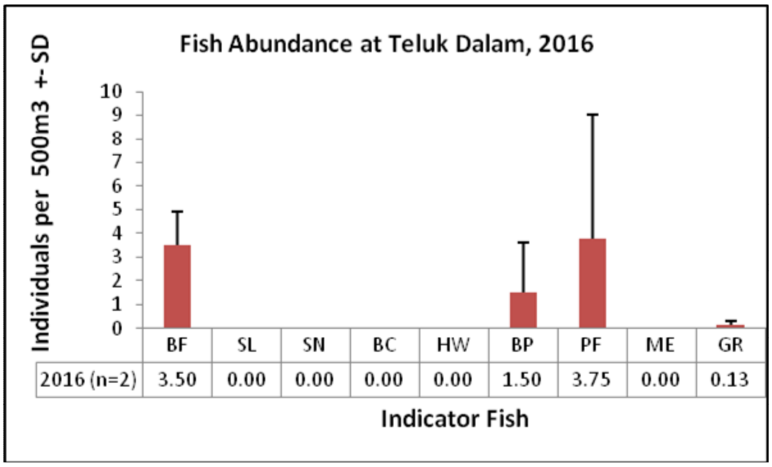

Figure 2.3f(ii). Fish abundance for Teluk Dalam.

Only four indicator species were recorded during the surveys: butterflyfish (3.5 ind./500 m^3), bumphead parrotfish (1.5), parrotfish (3.75) and Grouper (0.13) (Fig 2.3f(ii)). Fishing is common at this bay and this is reflected in the low abundance of grouper and the absence of sweetlips, snappers, barramundi cod and humphead wrasse. Teluk Dalam is one of the two sites to record bumphead parrotfish during surveys.

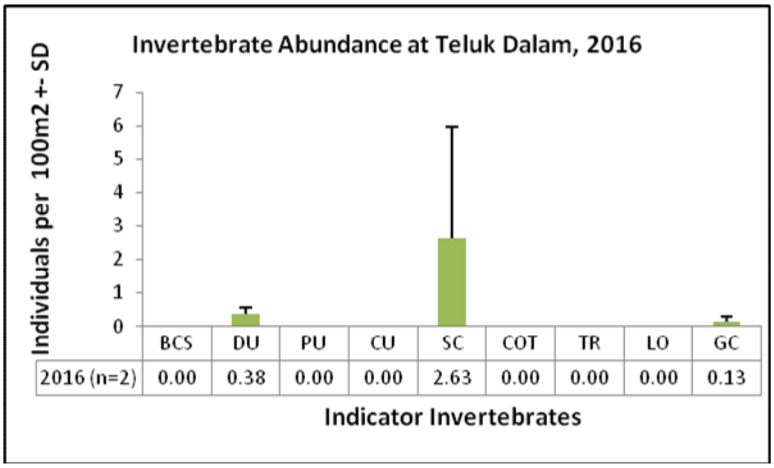

Figure 2.3f(iii). Invertebrate abundance for Teluk Dalam.

Three indicator invertebrates (Diadema urchin 0.38 ind./100m^2, sea cucumber 2.63 and giant clam 0.13) were recorded during the surveys. However, these indicators were all present in low numbers (Fig 2.3f(iii)).

6% of the coral population at this site was bleached, but these were also showing signs of recovery with bleached colonies showing 40.63% of bleached surface area.

Batu Malang

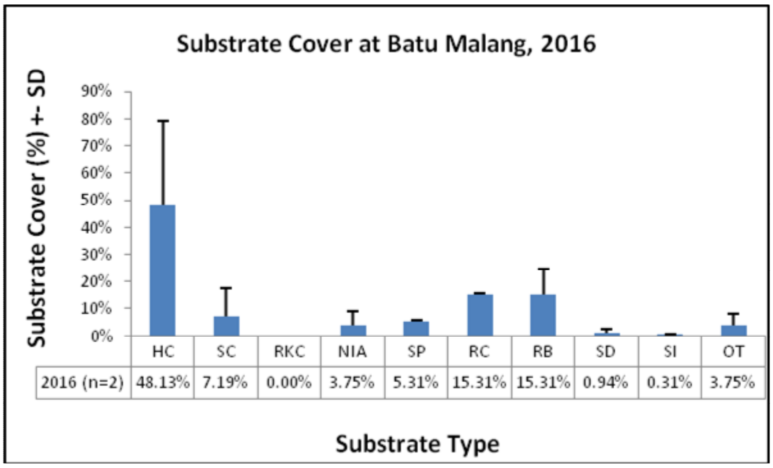

Figure 2.3g(i). Substrate cover for Batu Malang.

Live coral cover was 55.31% (HC 48.13% and SC 7.19%) at Batu Malang (Fig. 2.3g(i)), placing it in the category of good reef condition. The level of RB has increased significantly from 1.25% in 2013 to 15.31% in 2016. NIA level has also increased from 2013, from 0% to 3.75% in 2016. This increase indicates recent damage. Batu Malang is one of the main snorkelling and diving destinations. The damage might be caused by inexperienced snorkelers and divers

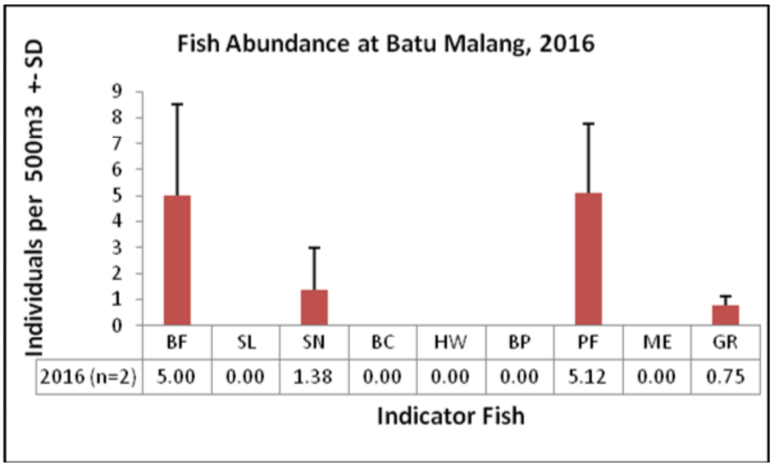

Figure 2.3g(ii). Fish abundance for Batu Malang.

Four indicator fish (butterflyfish 5 ind./ 500 m^3, snapper 1.38, parrotfish 5.13 and grouper 0.75) were present at Batu Malang (Fig. 2.3g(ii)). Prized food fish such as barramundi cod, humphead wrasse and bumphead parrotfish were absent during surveys. Discarded fishing gear, which indicates evidence of illegal fishing activities, was found at this site.

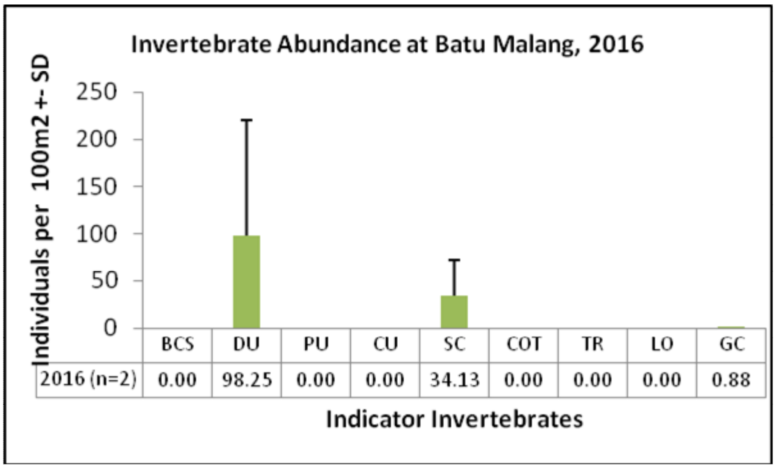

Figure 2.3g(iii). Invertebrate abundance for Batu Malang.

Most of the indicators were absent from the surveys. Only three indicator invertebrates were present at Batu Malang; Diadema urchin (98.25 ind./100 m^2), sea cucumber (34.13) and giant clam (0.88), (Fig. 2.3g(iii)). Batu Malang recorded the highest number of Sea Cucumber of all sites surveyed in Tioman.

Damage was due to discarded fishing nets and trash, as well as bleaching (18% of population). Together with Labas South, bleaching at this site was the highest recorded during surveys. However, on average only 4% of each bleached colony was bleached, indicating good recovery.

Chebeh

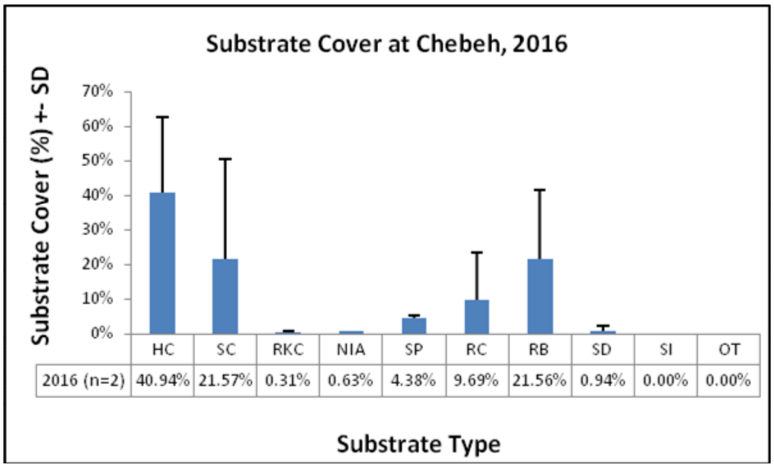

Figure 2.3h(i). Substrate cover for Chebeh.

Chebeh reef is considered to be in good condition with 62.50% live coral cover (40.94% HC and 21.57% SC), (Fig. 2.3h(i)). The high SC level is attributed to zoanthids. The level of RB has increased considerably from 12.5% in 2013 to 21.56% in 2016 and this indicates increase in recent disturbances on the reef. Only 0.63% of the reef was covered in NIA and this is a positive sign.

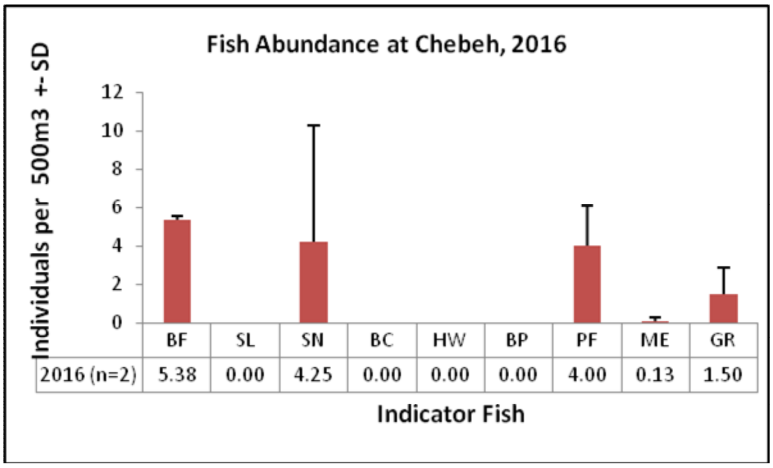

Figure 2.3h(ii). Fish abundancefor Chebeh.

Five indicator fish were observed during surveys; butterflyfish (5.38 ind./500 m^3), snapper (4.25), parrotfish (4), moray eel (0.13) and grouper (1.5), (Fig. 2.3h(ii)). Even though Chebeh is located far from villages on Tioman, highly-prized food fish such as barramundi cod and humphead wrasse were absent.

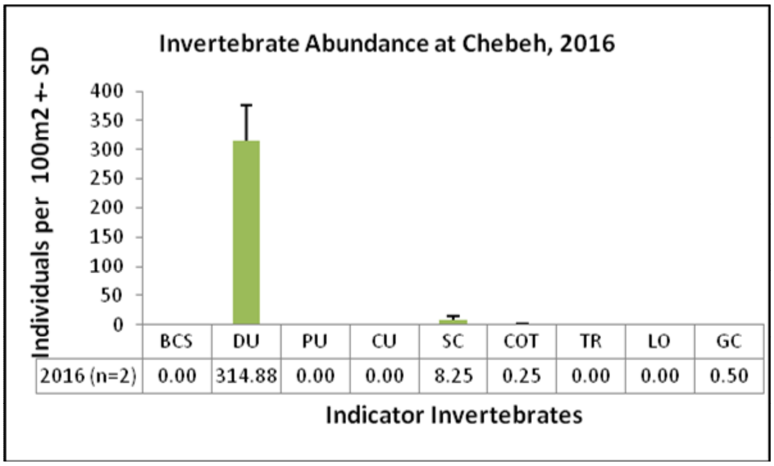

Figure 2.3h(iii). Invertebrate abundance for Chebeh.

Several indicator species were absent, including banded coral shrimp, pencil and collector urchin, triton and lobster. The number of Diadema urchin (314.8 ind./10 $0m^2$) was very high and the highest of all sites surveyed in Tioman. The number of sea cucumber was also high at 8.25 ind./$100m^2$. The number of other indicator was low; crown-of-thorns (0.25) and giant clam (0.5) (Fig. 2.3h(iii)).

Damage due to trash and warm water bleaching was recorded. Only some corals (below 1%) showed signs of bleaching with 7.5% surface area of each bleached colony bleached.

Fan Canyon

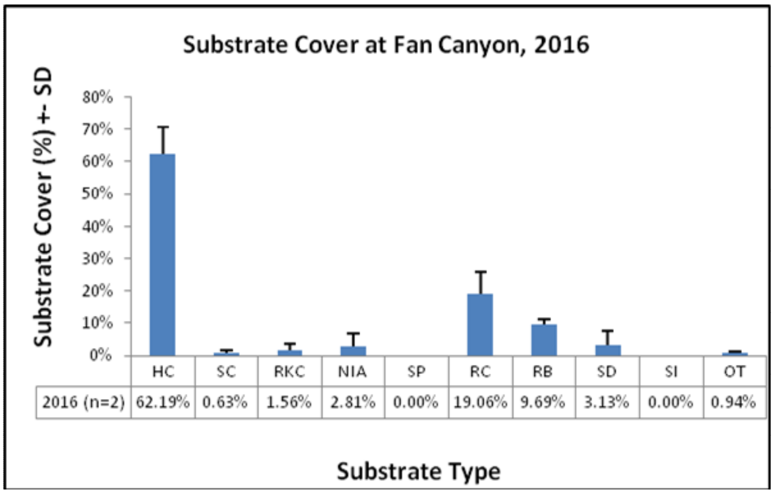

Figure 2.3i(i). Substrate cover for Fan Canyon.

The reef at Fan Canyon was categorised as good with 62.81% live coral cover (HC 62.19% and SC 0.63%) (Fig. 2.3i(i)). Since 2013 HC cover has increased from 10%) while SC cover has dropped from 42.88%. RB cover has decreased markedly from 28.13% in 2013 to 9.69% in 2016. This suggests disturbances at this site reduced considerably over the last few years and has allowed HC to recolonise the site. It is no coincidence that the reefs consists mainly of fast-growing branching *Acropora* sp.

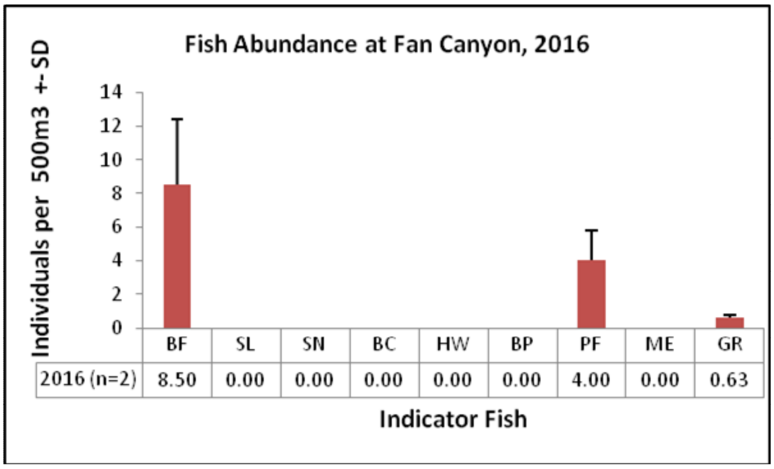

Figure 2.3i(ii). Fish abundance for Fan Canyon.

Only three indicator fish species were present during the surveys and they were present in low numbers: butterflyfish (0.5 indiv/500 m^3), groupers (0.5), parrotfish (1.25) and moray eels (0.5) (Fig. 2.3i(ii)).

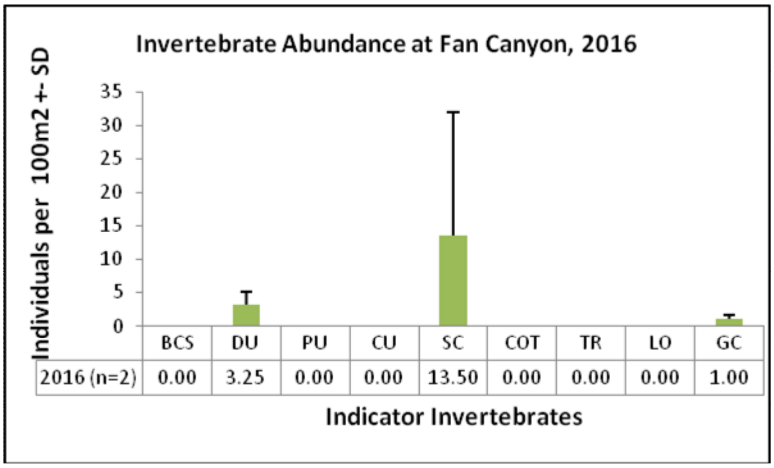

Figure 2.3i(iii). Invertebrate abundance for Fan Canyon.

Three indicator invertebrate were recorded during surveys; Diadema urchin (3.25 ind./100m^2), sea cucumber (13.5), and giant clam (1), (Fig. 2.3i(iii)).

Trash and bleaching was recorded at this site. However, both were at minimal amounts with only 0.3% of the population bleached.

Labas North

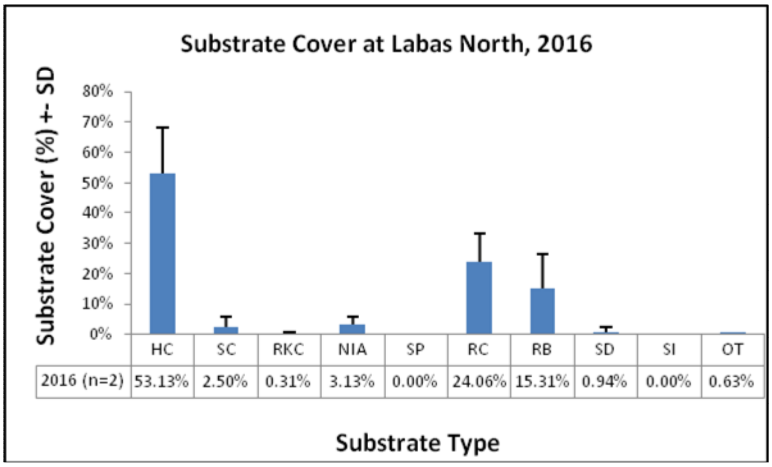

Figure 2.3j(i). Substrate cover for Labas North.

Reefs at Labas North were found to be in good condition with 55.63% live coral cover (53.13% HC and 2.5% SC), (Fig. 2.3j(i)). The level of RB was very high at 15.31%. This indicates recent disturbances at Labas North. Discarded fishing nets were found at this site. Fishing boats commonly seek shelter at Labas and some of the rubble damage could have been caused by these boats. However, there were no clear signs of anchor damage at this site.

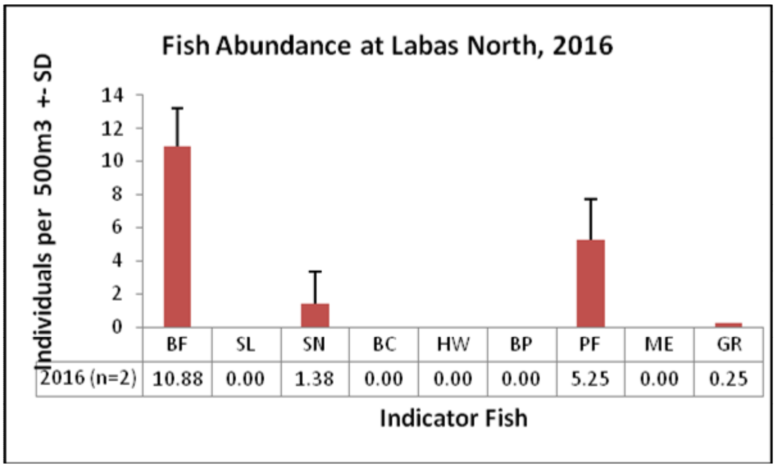

Figure 2.3j(ii). Fish abundance for Labas North.

Only four indicator fish species were observed during the surveys; butterflyfish (10.88 ind./500 m^3), snapper (1.38), parrotfish (5.25) and grouper (0.25). Snapper and grouper were present in low numbers, (fig. 2.3j(ii)). Butterflyfish recorded the highest number and this is the highest of all sites surveyed in Tioman.

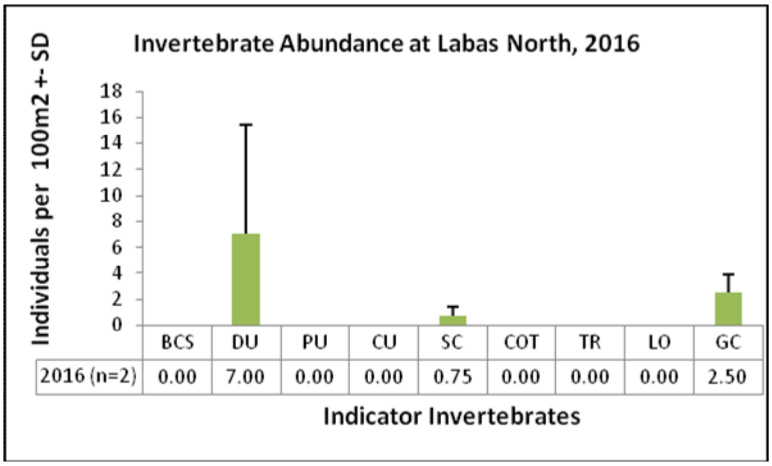

Figure 2.3j(iii). Invertebrate abundance for Labas North.

Three indicator invertebrate were observed during surveys; Diadema urchin (7 ind./100m^2), sea cucumber (0.75) and giant clam (2.5), (Fig. 2.3j(iii)).

Discarded fishing nets were recorded at this site along with 3% coral population bleaching. Bleached corals were on the road to recovery with only 2.5% of their surface area still bleached.

Labas South

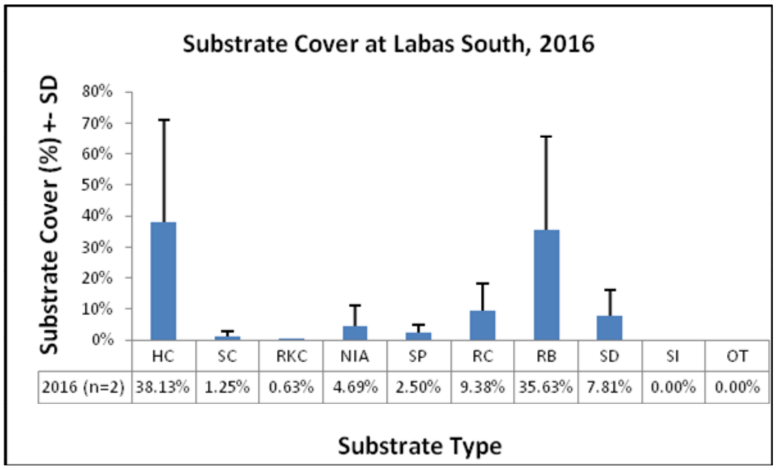

Figure 2.3k(i). Substrate cover for Labas South.

Reefs at Labas South were found to be in fair condition with 39.38% live coral cover (38.13% HC and 1.25% SC), (Fig. 2.3k(i)). The level of RB was very high at 35.63%, double the level at Labas North. Of all the sites surveyed, Labas South recorded the highest level of RB. At this site there were clear signs of anchor damage. It is clear that boats are illegally dropping anchor at this site. Increased patrolling and enforcement by Marine Parks at this site could overcome this problem

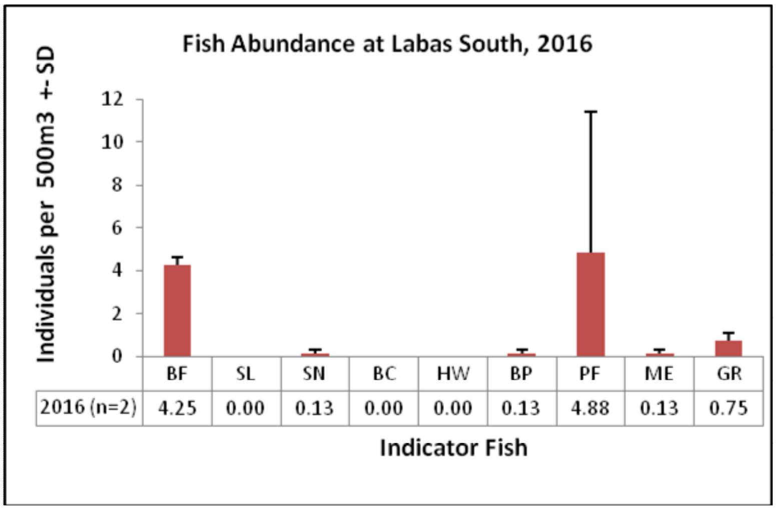

Figure 2.3j(ii). Fish abundance for Labas South.

Only four indicator fish species were observed during the surveys; butterflyfish (4.25 ind./500 m^3), snapper (0.13), bumphead parrotfish (0.13), parrotfish (4.88), moray eel (0.13) and grouper (0.25). Snapper and grouper were present in very low numbers, (Fig. 2.3j(ii)). Labas South is one of only two sites to record bumphead parrotfish during all of the surveys. Fishing nets were found on the reef, indicating illegal fishing at this site. Here too, Marine Parks enforcement would help.

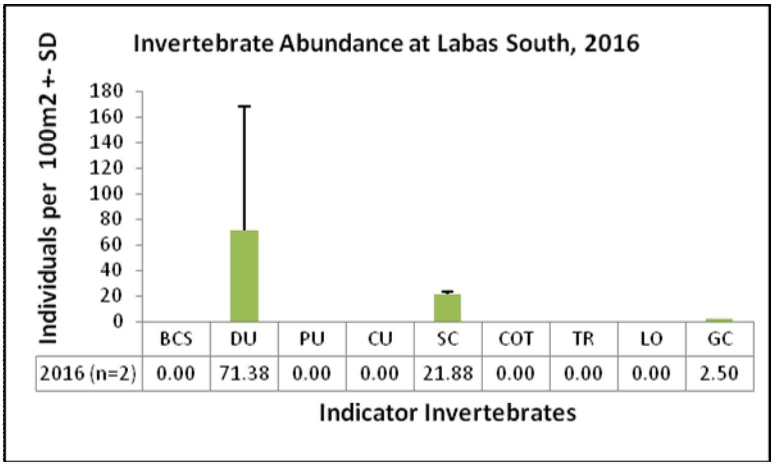

Figure 2.3j(iii). Invertebrate abundance for Labas North.

Three indicator invertebrate were observed during surveys; Diadema urchin (71.38 ind./100m^2), sea cucumber (21.88) and giant clam (2.5), (Fig. 2.3j(iii)).

Damage due to boat anchor, discarded fishing nets, trash and warm water bleaching were recorded. At this site 18% of the coral population was bleached (with 4% average surface area).

Sepoi

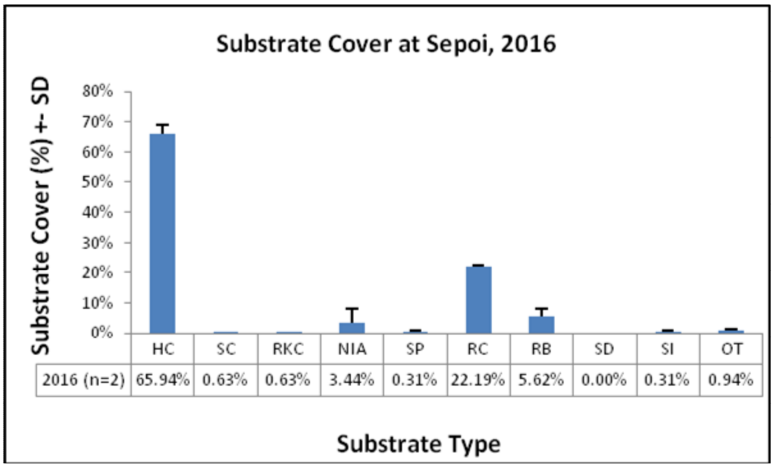

Figure 2.3l(i). Substrate cover for Sepoi.

With 66.56% live coral cover (HC 65.94% and SC 0.63%), (Fig. 2.3l(i)), reefs at Sepoi fall into the good condition category. HC cover has increased at this site since 2013 (55%). The level of RB has decreased from 8.13% in 2013 to 5.63% in 2016, indicating lower recent disturbances at Sepoi. This site appears to be one of the most resilient sites on Tioman proving to recover quickly after damages and bleaching.

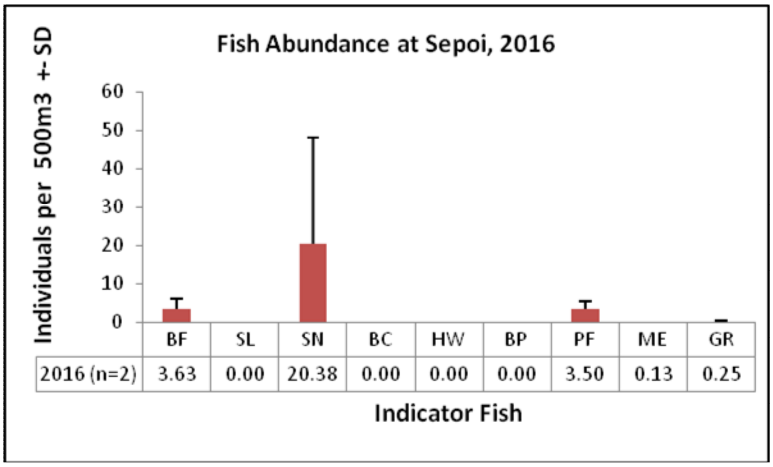

Figure 2.3l(ii). Fish abundance for Sepoi.

Only four fish indicator species were recorded during the surveys. The abundance of snapper is high (20.38 ind./500 m^3) and is the highest of all sites surveyed in Tioman. Moray eel (0.13) and grouper (0.25) were present in low numbers. Butterflyfish recorded 3.63 ind./500m^3 and parrotfish 3.5. Prized food fish such as barramundi cod, bumphead parrotfish and humphead wrasse were absent (Fig. 2.3l(ii)).

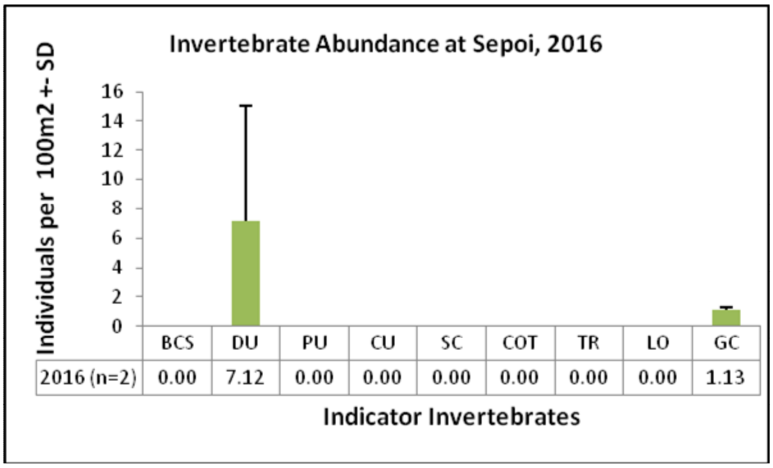

Figure 2.3l(iii). Invertebrate abundance for Sepoi.

Only two indicator invertebrate were present during surveys; Diadema Urchin (7.13 ind./100m^2) and Giant Clam (1.13), (Fig. 2.3l(iii)).

Sepoi was the only site which recorded no signs of bleaching. Its location some distance from Tioman and exposed to deep water and strong currents is likely to be the reason for this.

Teluk Kador

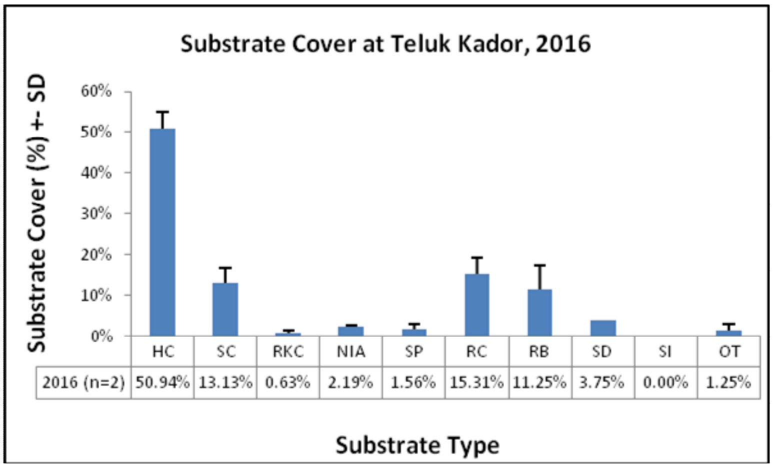

Figure 2.3m(i). Substrate cover for Teluk Kador.

Live coral cover at Teluk Kador was 64.06% (HC 50.94% and SC 13.13%), (Fig. 2.3m(i)), placing the reefs in the good condition category. The level of RB is high at 11.25%, increased significantly from 2013 (1.88%). This indicates higher recent disturbances at Teluk Kador.

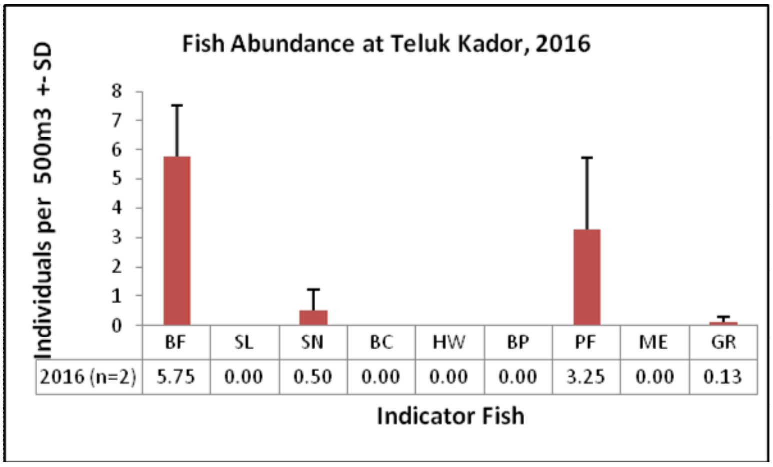

Figure 2.3m(ii). Fish abundance for Teluk Kador.

Most of the fish indicator species were absent during surveys (sweetlips, barramundi cod, humphead wrasse, bumphead parrotfish and moray eel). Only four indicator species were present: Butterflyfish (5.75 ind./500m^3), snapper (0.5), parrotfish (3.25) and grouper (0.13), (Fig. 2.3m(ii)). Illegal fishing gear was found on reefs at this site.

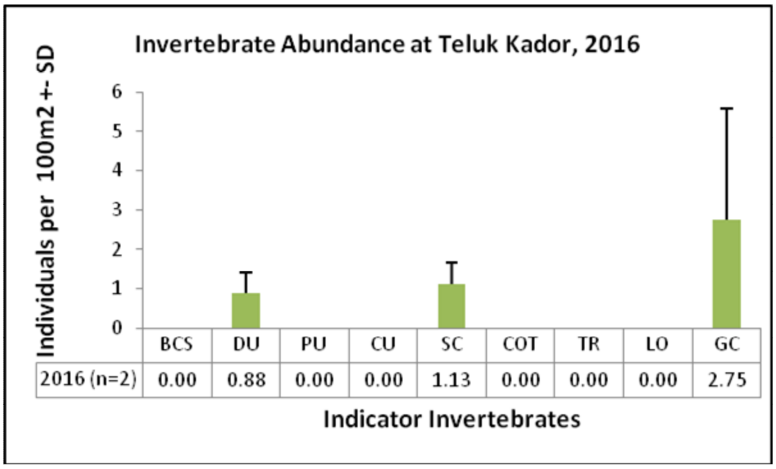

Figure 2.3m(iii). Invertebrate abundance for Teluk Kador.

Only three indicator invertebrates were present during surveys; Diadema urchin (0.88 ind./100m^2), sea cucumber (1.13) and giant clam (2.75), (Fig. 2.3m(iii)).

A special find during surveys at Teluk Kador was the presence of a single *Hippopus hippopus* giant clam. This is the first record of this species within the Tioman Marine Park.

Damage due to discarded fishing nets, trash and warm water bleaching was recorded. Only 2.5% of the population was bleached. Bleached colonies here showed signs of recovery and had regained most of their colour with 30% of surface area still bleached.

Nayak

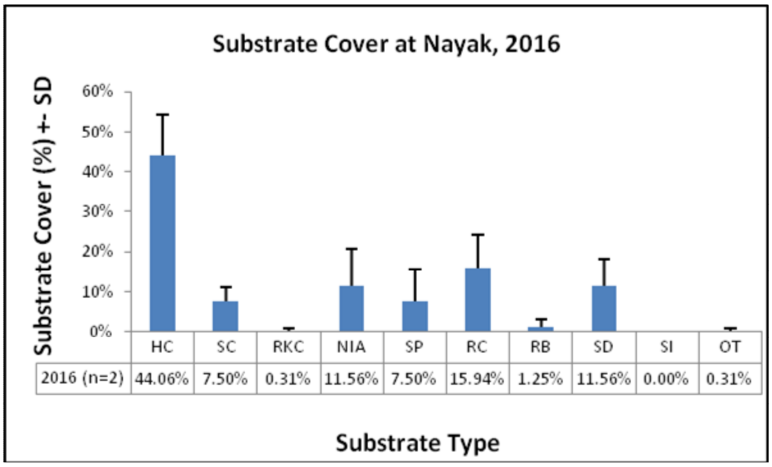

Figure 2.3n(i). Substrate cover for Nayak.

Reefs at Nayak were considered to be in good condition with 51.56% live coral cover (44.06% HC and 7.5% SC), (Fig. 2.3n(i)). The level of NIA is high at 11.56% and has increased from 3.75 in 2013 (Reef Check Malaysia 2014). Nayak is situated close to Juara beach, which has seen an increase in resort development over the last three years. Nutrient runoff from land is likely to be one of the reasons the level of NIA has increased at Nayak.

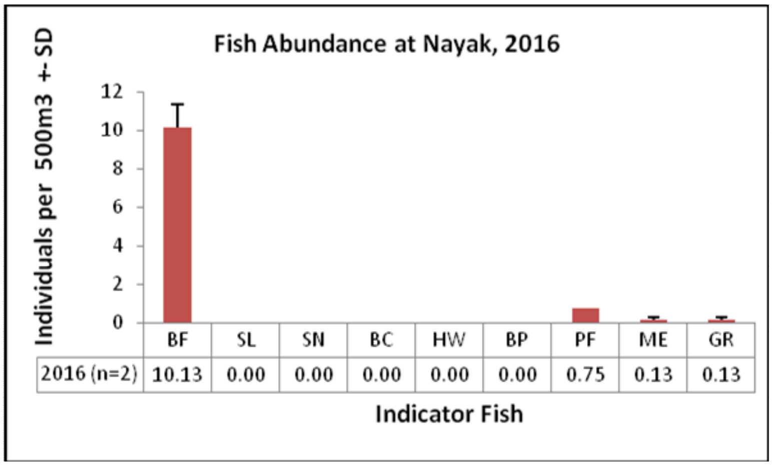

Figure 2.3n(ii). Fish abundance for Nayak.

Most of the fish indicator species were absent during surveys (sweetlips, snapper, barramundi cod, humphead wrasse and bumphead parrotfish). The abundance of butterflyfish is high (10.13 ind./500 m^3). Parrotfish (0.75), moray eel (0.13) and grouper (0.13) were present in very low numbers, (Fig. 2.3n(ii)).

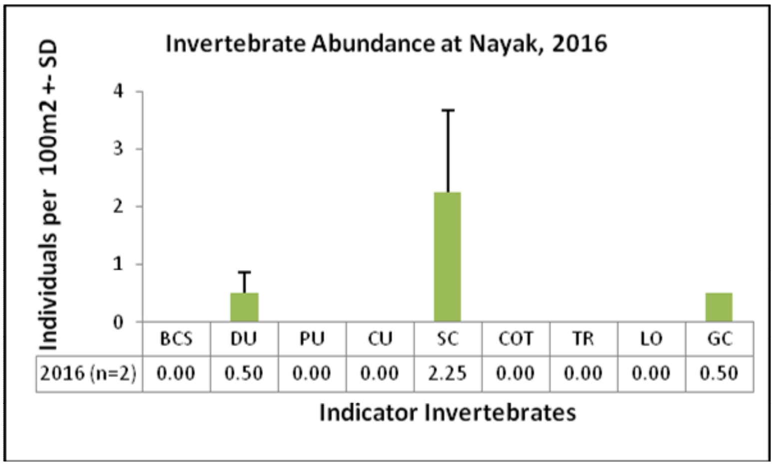

Figure 2.3n(iii). Invertebrate abundance for Nayak.

Only three indicator invertebrate were present during surveys; Diadema urchin (0.50 ind./100 m^2), sea cucumber (2.25) and giant clam (0.50), (Fig. 2.3n(iii)).

Nayak recorded minimal amounts of trash and bleaching with only 0.5% of the population and 2.5% of colony surface area showing signs of bleaching.

Saing

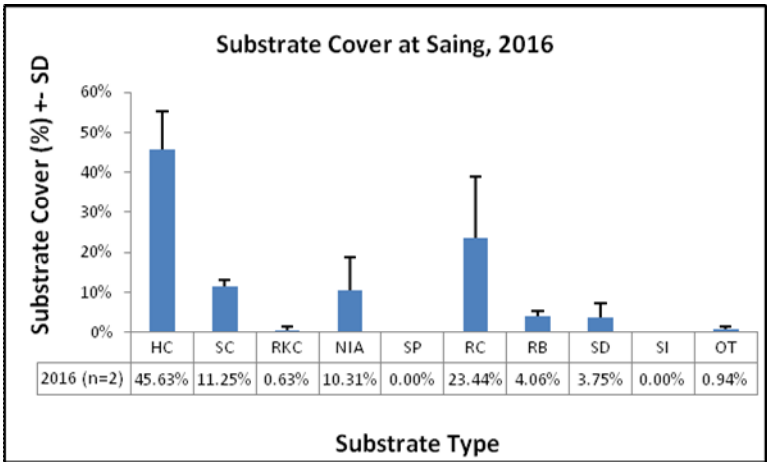

Figure 2.3o(i). Substrate cover for Saing.

Reefs at Saing were considered to be in good condition with 56.88% live coral cover (45.63% HC and 11.25% SC), (Fig. 2.3o(i)). The level of NIA is high at 10.31% and has increased from 6.88% in 2013. This is a cause for concern, and once again may be a reflection of the increased number of resorts and tourists at Juara over the last couple of years. Further water quality testing could show if sewage pollution is indeed a problem at Juara.

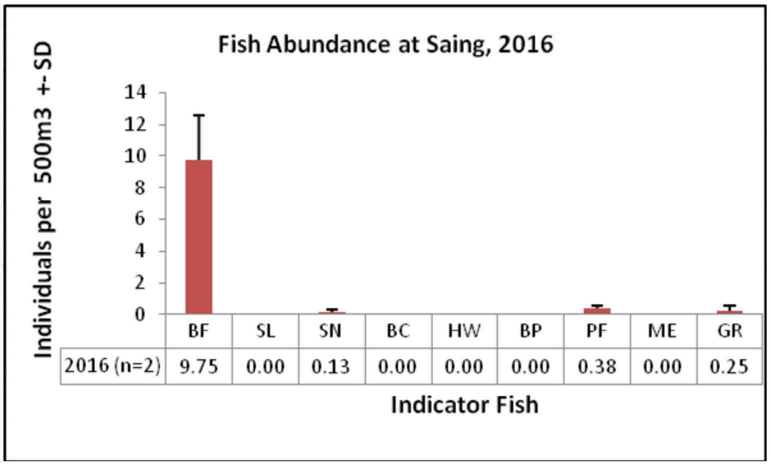

Figure 2.3o(i). Substrate cover for Saing.

Most of the fish indicator species were absent during surveys. Only four indicator fish were observed. The abundance of butterflyfish is high (9.75 ind./500 m^3). Other indicator fish were present in very low numbers: Snapper (0.13), parrotfish (0.38) and grouper (0.25), (Fig. 2.3o(ii)).

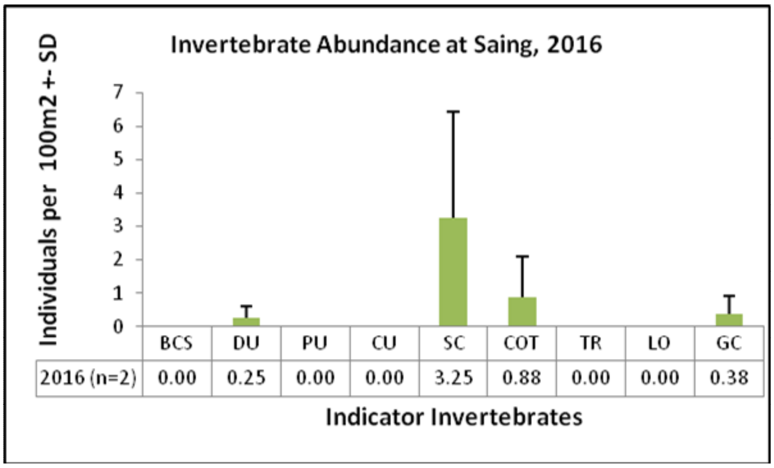

Figure 2.3o(iii). Invertebrate abundance for Saing.

Only four indicator invertebrate were present during surveys; Diadema urchin (0.25 ind./100 m^2), sea cucumber (3.25), crown-of-thorns (0.88) and giant clam (0.38), (Fig. 2.3o(iii)). The abundance of Crown-of-thorns at Saing is above what a healthy reef can sustain (0.2-0.3).

Bleaching affected 2.5% of the population and bleached colonies were regaining their natural colour and only showed 18% of bleached surface area. No other damage was reported at this site.

2.4. Discussion & conclusions

Substrate cover

According to the widely accepted status of reefs by Chou et al. (1994), reefs with 0% to 25% live coral cover (HC plus SC) are considered to have ‘Poor’ coral cover, while reefs with 25% to 50% live coral cover are considered ‘Fair’, reefs with 50% to 75% live coral cover ‘Good’ and reefs with 75% to 100% to have ‘Excellent’ coral cover.

On average reefs around Tioman are considered to have ‘Good’ coral cover (58%) and this was true for majority of the sites surveyed (80%). The remaining 20% of survey sites were found to have ‘Fair’ coral cover. It should also be noted that none of the sites surveyed had ‘Excellent’ or ‘Poor’ coral cover.

Results from the previous Biosphere Expeditions surveys that visited the same permanent transect sites around Tioman in 2013 also found that reefs in Tioman fall under the “Good” category with 53% live coral cover (Chelliah 2014). This shows that the health of the reefs around Tioman has not decreased, but in fact has improved slightly over the years. Although in 2016 there was a global bleaching event, Tioman reefs did not record high levels of bleaching during this study. This was also noticed by Guest et al. (2012), when they were studying the impacts of the 2010 bleaching event.

Rubble (RB) comprises small pieces of rock, coral fragments, dead shells and other small pieces of substrate. These are created by a number of different events, some occur naturally, such as wave action (normal and storm surge), and others are man-made, including destructive fishing methods and physical impact (from boats, anchors and reef users). Changing levels of RB can be an indicator of recent disturbance, and on damaged reefs with high levels of RB, coral regeneration is slow due to the difficulty of coral recruitment onto mobile substrates; new coral recruits are easily damaged or displaced on a mobile substrate as it moves around in local currents (Reef Check Malaysia 2012). A relatively high percentage of RB was noted at some sites, recording as high as 35.63% at one site (Labas South). Clear evidence of anchor damage was also recorded at this site, showing that illegal anchoring on reefs continues. in addition, discarded fishing gear was found at this site, suggesting that illegal fishermen encroaching into the MPA might be responsible for the anchor damage.

Nutrient Indicator Algae (NIA) is a measure of the amount of algae growing on reefs, and can provide an indication both of the health of herbivorous fish populations on reefs and of the level of nutrient input to reefs. Algae are a natural and essential part of a coral reef, but if allowed to grow unchecked, can smother corals by cutting off the sunlight they need for photosynthesis and will eventually kill them. This leads to a phase shift from coral- to algae-dominated reefs, which are much less productive than coral-dominated reefs (McManus & Polsenberg 2004). The level of NIA is generally high along the east coast of Tioman (sites off Juara Village). Nayak, Saing and Teluk Dalam recorded more than 10% NIA compared to other survey sites on west of Tioman, which recorded less than 5%. This may be due to the low abundance of herbivory fish such as parrotfish, as well as algae grazer invertebrates such as Diadema urchin at Nayak, Saing and Teluk Dalam, to control the algae population. Grazing pressure from herbivory fish controls algal abundance, production and distribution in coral reef communities (Carpenter 1988, Paddack et al. 2006).

According to McClanahan et al. (1996), sea urchins are an important part of the reef's ecology as they help to scrape algae off the substrates. Diadema urchin also feed on live corals, but they prefer fleshy turf algae over corals (Carpenter 1981). The low abundance of parrotfish and Diadema urchin at these three sites was confirmed by the 2016 expedition.

Another possible reason is nutrient runoff from land. Juara village is the only village that is still engaged in agricultural activity to generate a source of income. There are many fruit orchards and rubber plantations at Juara. The usage of fertilisers to increase agricultural products can cause nutrient runoff into the reefs, which can cause high levels of NIA. Juara village has also seen an increase in development and tourism within the last three years. Three new resorts have been built and the numbers of tourists visiting the village has increased from 214,477 people in 2012 to 231,238 people in 2015 (Lembaga Pembangunan Tioman 2016). Future water quality testing could show if the water is indeed polluted by fertilisers from the plantations or sewage from the village.

Recently Killed Coral (RKC) results from a variety of impacts, including, predation (e.g. by crown-of-thorns starfish and *Drupella* snails) other local stressors (e.g. sedimentation), and bleaching. During this study very little RKC was recorded even though some bleaching was present. The lack of RKC supports other findings that suggest Tioman reefs have adapted to thermal stress (Guest et al. 2012). Silt (SI) arises from a variety of natural sources (mangroves and mud flats) as well as from land use changes, including agriculture, forestry and development. The low level of RKC and SI recorded within the archipelago is a good sign.

Rock (RC) comprises both bare natural rock and dead consolidated coral that has not disintegrated into rubble, nor been colonised by algae or corals. RC is critical for reef recovery, regeneration and extension, as it forms the base for new corals to recruit onto. Therefore some amount of RC is important and the amount of RC recorded during surveys (16.94%) is normal. It should be noted that new coral recruits cannot settle onto RC that has significant algae coverage and under these conditions settlement of new recruits will be reduced. This demonstrates the importance of healthy herbivore populations, which graze on algae and keep it under control, providing clean surfaces for coral recruits.

Sand (SD) is a natural component of reefs, and can be expected to be found on any survey. Increasing amounts of SD in a given coral reef can be an indication of disturbance as dead coral breaks off and is eroded into fine particles (sand) by wave action. Sponges (SP) are another normal component of coral reefs that, under the right conditions, can proliferate in the presence of high levels of nutrients. Similar to NIA, sponge will compete for space with corals and can outgrow the slower growing corals, eventually killing them. At 2.16%, the level of SP does not appear to be a threat.

Fish abundance

Though research has shown that the abundance of butterflyfish can be directly correlated with the distribution and abundance of corals (Crosby & Reese 1996) and that a drop in live coral cover can reduce the abundance of butterflyfish (Russ & Alcala 1989), others claim that there is no correlation. Koh et al. (2002) documented that there was no relationship between coral cover and the number of butterflyfish, as not all butterflyfish are coral polyp feeders (Allen et al. 1998).

Some butterflyfish are benthic omnivores and some are planktivores (Crosby & Reese 1996). Hence, butterflyfish abundance cannot provide an accurate indication of reef health. However, surveys in 2016 showed an increase in butterfly fish abundance around Tioman (6.68 individuals per 500 m^3) compared to 2013 (3.85 individuals per 500 m^3) (Chelliah & Hammer 2014). The increase in butterflyfish abundance does however suggest that there is no threat of illegal fishing for the aquarium trade within the Tioman archipelago.

Snappers, a common food species, also recorded an increase in abundance in 2016 (2.81 individuals per 500 m^3) compared to 2013 (0.9 individuals per 500 m^3) (Chelliah & Hammer 2014). Parrotfish numbers also saw a slight increase in 2016.

Though the Tioman Archipelago is protected as a Marine Park, and some species of fish have shown an increase in abundance over the past few years, illegal fishing and encroachment by fisherman was described as rampant (Yewdall et al. 2013). On this expedition too, discarded fishing gear was found on numerous surveys and the impacts of overfishing is reflected in the scarcity of high-value food fish. Food fish such as grouper, sweetlips, barramundi cod, bumphead parrotfish and humphead wrasse, were hardly sighted throughout the surveys. Overfishing in the past combined with current illegal fishing has inhibited population recovery of these species even after more than 22 years of protection on paper.

Invertebrate abundance

Invertebrate bioindicator abundance did not show any significant change since the last Biosphere Expeditions surveys in 2013. Only Diadema urchin numbers reduced slightly from 55.47 individuals per 100 m^2 in 2013 to 50.39 individuals per 100 m^2 in 2016.

Edible sea cucumbers, giant clams and lobsters were scarce. They are consumed locally and in the past were harvested commercially for trade. Banded coral shrimp, collector urchin, pencil urchin and triton shells are highly prized by the curio trade (Hodgson et al. 2004). However, there are no signs of collection or sale of these animals on the island and they are rare throughout the country (Reef Check Malaysia 2013).

The crown-of-thorns starfish (COT) was present in low numbers and its scarcity indicates no COT population outbreaks (Hodgson et al. 2004). Considerable efforts have been made by Marine Park authorities, Tioman Marine Conservation Group and local dive centres to control COTs numbers by organising regular COTs monitoring and removal activities to reduce the threat posed by these voracious predators of corals. Though their numbers have fallen since 2012 (0.46 individuals per 100 m^2 in 2012) (Yewdall et al. 2013), and 0.3 individuals per 100 m^2 in 2013, continued monitoring is essential to track and help to manage significant outbreaks of this dangerous coral predator. Outbreaks of COTs can cause extensive damage to hard coral cover on the reef (Comley et al. 2005).

The involvement of local community members as well as dive shops in the control of COT outbreaks has proven to be successful. It would therefore make sense if the local community was also involved in co-management and enforcement to overcome illegal fishing within the MPA.

2.5. Summary & recommendations

Reef health

The reefs around the Tioman Archipelago were generally in good, healthy condition, with 58% live coral cover (50% hard coral and 8% soft coral). The amount of live coral at most sites was attributed to hard coral cover and this is good as hard coral is the builder of the reef structure as opposed to soft corals, which lack the hard calcium carbonate skeletal structure and are therefore not reef builders. Fish and invertebrate abundance was low and the lack of herbivorous fish and invertebrates on reefs can lead to excessive growth of algae, which in some cases can result in a phase shift from a coral dominated reef to an algal dominated reef (Paddack et al. 2006). This is an ongoing cause for concern, as is the Marine Park's apparent inability to control illegal fishing.

Impacts damaging reef health and suggestions for management

Storm damage

Quite a few factors could have contributed to the reef damage observed around the Tioman Archipelago. Based on the results gathered during the expedition, storm disturbance emerges as the most likely cause of damage. The annual monsoon damages reefs every year and the evidence of the damage was witnessed on most reefs around the archipelago.

Tourist impacts

Tourism is the main economic driver on Tioman. The continuous increase of tourists visiting the island each year has resulted in an increase in infrastructure development. Some of these developments are poorly planned and do not have appropriate mitigation measures to protect the environment (for example silt curtains). This can then result in sedimentation and nutrification of nearby reefs. Infrastructure development should be strictly monitored in order to ensure that minimum land clearing and proper mitigation measures are in place. If properly managed, such developments should not have a significant impact on the reefs.

Divers and snorkellers visiting Tioman can have a variety of physical impacts on the reefs, including touching, standing on corals, littering and boat anchoring. Boat anchor and trash damage was recorded at Labas South, which is commonly visited by divers, and which recorded the highest level of RB during surveys in 2016. It is recommended that awareness campaigns are implemented to educate all reef users on correct reef etiquette to minimise their impacts. These campaigns should be targeted both directly at tourists and at tourist operators. It is also recommended that the Department of Marine Parks Malaysia provide adequate mooring buoys at sites frequently visited by tourists in order to avoid anchoring on reefs.

Illegal fishing

There are regular reports of illegal fishing inside the MPA and during training dives at Renggis and surveys at Labas, Chebeh and Juara, illegal fishing was observed by the expedition.

Incursions often occur early in the morning and late in the evening, when there are fewer tourists at the sites. Discarded fish nets were also observed during surveys, but were found at secluded sites such as Labas North, Labas South, Batu Malang and Teluk Kador. We believe illegal fishing within the MPA is the main reason for the low abundance of fish observed during surveys. MPA rules must be enforced by the Department of Marine Parks Malaysia and locals must be made aware of why a no-take area is important for ensuring fish stocks survive. They must also be made aware of the benefits of no-take areas to their community and the important role reef fish play in maintaining the balance of a healthy and resilient coral reef ecosystem.

Solid waste disposal

The high number of tourists visiting Tioman generates a large amount of waste, putting significant strain on waste collection and disposal systems. There is an incinerator at the main village, but this cannot handle the amount of waste currently being generated. There is a need to promote waste segregation among resorts and to enable easier recycling of waste for local villagers, as well as composting of organic waste and separation of hazardous and toxic wastes (such as used engine oil and batteries). Though solid waste was not commonly witnessed on reefs during surveys, the amount of trash witnessed on the shore along beaches and roads was high. Waste segregation and recycling will reduce the load on the incinerator, as well as instil a sense of caring for the environment within the community. Education and awareness campaigns should be implemented to promote better waste management and reduce littering, particularly among the village communities, as well as resort operators. Local town councils should also provide facilities to promote recycling on the island. The government must put in place laws that tax resorts in order to free up funds for waste disposal systems.

Sewage treatment

High levels of NIA recorded at some sites indicate that there are excess nutrients in the water, most likely originating from land. Most resorts and households on the islands rely on septic tanks to treat their sewage. However, many are not correctly designed and maintained and these overflow, releasing sewage effluent into the sea. It is recommended that the state governments establish a system for regular de-sludging of septic tanks to ensure that they operate effectively. This will be a lower cost and less disruptive solution than the construction of large-scale, centralised sewage treatment facilities. It should also be mandatory that all resorts are fitted with septic tanks that meet the required specifications.

The threats mentioned above are local threats that could be solved with the cooperation of state and federal government agencies. Reducing these threats is vital in improving the resilience of reefs around Tioman, thus increasing their ability to recover from large-scale global threats such as bleaching. The loss of reefs around Tioman would have a catastrophic impact on biodiversity, the local economy and the way of life for the local community

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Appendix I: Expedition diary and reports

A multimedia expedition diary is available at https://biosphereexpeditions.wordpress.com/category/expedition-blogs/malaysia-2016/

All expedition reports, including this and previous expedition reports, are available atwww.biosphere-expeditions.org/reports.