EXPEDITION REPORT

Expedition dates: 10 March – 5 April 2013

Report published: November 2014

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

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Abstract

Tioman Archipelago has long been a popular tourist destination, especially among divers and snorkellers that come to visit the coral reefs in this area. However, little is known about the coral reefs that surround the island, particularly along the east coast of Tioman and Pemanggil Islands. In March and April of 2013, two teams of volunteers from Biosphere Expeditions, along with a marine scientist from Reef Check Malaysia, conducted reef health assessments at various sites around the islands, using the Reef Check methodology. This was part of a continuous study first started in 2012 in collaboration with Biosphere Expeditions. Results showed that reefs were in 'good' condition with a total average of 52.50% live coral cover, which is higher than the national average of 46.37% recorded in 2012 (Reef Check Malaysia 2013). However, highly valued seafood such as lobsters and commercial food fish occurred at low densities or were absent during most surveys. Alongside the ever-present illegal fishing, coastal development poses the greatest risk to the reefs. Evidence of coastal runoff, such as sedimentation and high nutrient indicator algae cover, and sewage pollution was observed at a number of sites surveyed. Improved enforcement of Marine Park laws and better coastal development planning are vital in reducing local threats and building resilience of the reefs within the Tioman Archipelago.

Abstrak

Pulau Tioman dan pulau-pulau di rantaunya telah lama menjadi kawasan tarikan pelancong, terutamanya antara penyelam SKUBA yang datang untuk menikmati terumbu karang di kawasan ini. Walaubagaimanapun hanya sedikit diketahui mengenai keadaan terumbu karang terutamanya di sebelah Timur Pulau Tioman dan Pulau Pemanggil. Pada bulan Mac dan April 2013, dua kumpulan sukarelawan daripada Biosphere Expeditions, bersama dengan seorang saintis marin daripada Reef Check Malaysia, telah menjalankan pemantauan terumbu karang di beberapa kawasan di sekitar pulau-pulau tersebut, dengan menggunakan kaedah Reef Check. Ini merupakan sambungan kajian yang pertama kalinya diadakan pada tahun 2012 bersama Biosphere Expeditions. Keputusan menunjukkan bahawa terumbu karang di kawasan tersebut berada dalam keadaan yang 'baik' dengan purata litupan karang hidup sebanyak 52.50% dan melebihi purata negara (46.37%) yang dicatat pada tahun 2012 (Reef Check Malaysia 2013). Akan tetapi makanan laut yang bernilai tinggi seperti Udang Galah dan Ikan Mameng tidak dijumpai di kebanyakan kawasan kajian. Selain daripada masalah penangkapan ikan secara haram, pembangunan pantai yang tidak terancang merupakan ancaman utama kepada terumbu.Buktinya dapat dilihat di beberapa kawasan kajian. Peningkatan penguatkuasaan undang-undang Taman Laut dan pembangunan kawasan pantai yang lebih terancang adalah mustahak untuk mengurangkan ancaman tempatan sambil membina daya ketahanan terumbu dikawasan kepulauan Tioman.

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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, 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 Marine Park, Malaysia Peninsula that ran from 10 March to 5 April 2013. Its aims included: (1) monitoring the health of the Pulau Tioman Marine Park's reefs, its fish and megafauna communities (turtles, sharks, dolphins) 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.

Pulau Tioman is located 40 km off the east coast of the Malaysian Peninsula. The reefs of Pulau Tioman Marine Park are some of the healthiest and most diverse around the peninsula and lie just 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. Pulau 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 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.

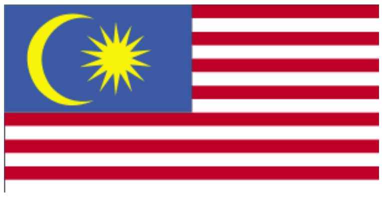


Figure 1.2a. Flag and location of Malaysia and study site.

An overview of Biosphere Expeditions' research sites, assembly points, base camp and office locations is 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.

The expedition started and ended at the Swiss Cottage chalet resort in Tekek village on Pulau Tioman. In each expedition group, there was a land-based, five-day training session followed by a seven-day, yacht-based phase, when the research vessel yacht circumnavigated the main island in the Marine Park, visiting most of the other eight islands and enabling the expedition to reach seldom-visited sites and conduct surveys at hard-to-reach locations.

1.3. Dates

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

10 – 22 March | 24 – 5 April 2013

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

1.4. Local conditions & support

Expedition base

The first five days of each expedition group were based at the Swiss Cottage beach chalet resort on Tioman Island. Expedition participants were divided into pairs and shared twin-bedded rooms for the first six nights.

The next seven days of each group were based on 'Araliya', a Colombia 45 ft sloop rig sailing yacht crewed by a yacht captain, divemaster/field scientist and the expedition leader. The yacht provided the freedom of being able to reach remote parts of the study site, but not the luxury of a hotel or resort. There were two cabins available, one double and one triple and two single berths, mattresses and hammocks.

Weather & water temperature

The climate is tropical and maritime. The average day temperature during the expedition months were 32-40°C. Water temperature during the expedition was 28-31°C.

Field communications

On land, mobile phone reception and Wi-Fi internet connections were available. The yacht was equipped with radio and telephone 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 Tioman island assembly point. From there onwards and back to the assembly point all transport and vehicles 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 serious medical incidences 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 is from Kajang, which is just outside Kuala Lumpur. He has a degree in Marine Science from University Malaysia Sabah and a Masters Degree in the same field from the National University of Malaysia. He started diving when he was still in high school and has since been connected to marine life. In between studies he worked at an Aquarium in Kuala Lumpur and he joined Reef Check Malaysia after finishing his MSc. He is a PADI Divemaster and a Reef Check Course Director.

1.6. Expedition leader

Paul O'Dowd was born in Melbourne, Australia. From the beginning, his primary interests have been natural history and adventure. As a teenager he learned to dive and at 19 years old left Victoria to move to Cairns to work on the Great Barrier Reef in the dive industry. Shortly thereafter he was offered a job managing a dive facility in Papua New Guinea. In PNG Paul became involved in expeditionary and documentary film work. Paul has worked for the BBC's Natural History Unit and various other companies on documentary projects as well as with assorted tourism-based expeditions to places such as the Sepik Basin and the Kokoda Track. Paul also delivers a lecture programme in rainforest ecology, conservation and sustainability for a study abroad programme for American university students. A broad base of scientific literacy and a genuine interest in communication has led to a career in introducing diverse audiences to the natural world. Diving, rock climbing and just about anything that provides a good opportunity to get into nature and help others to do the same is Paul's idea of time well spent.

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 (with country of residence):

18 – 22 March 2013: Hermine Eon (UK), Cathy & Dave Johnstone (Switzerland), Liz McLardy (UK), Gail Zalutsky (USA).

24 – 5 April 2013: Georgie Brown (UK), Janne Gitmark (Norway), Renate & Stefan Plaumann (Germany), Laurence Romeo (UK).

The skipper throughout the expedition was Chris Salter, a qualified Yachtmaster from Australia, with much experience of ocean crossings and skippering charters.

1.8. Partners

On this project Biosphere Expeditions is working with Reef Check Malaysia, the Department of Marine Parks of Malaysia, local dive centres, businesses & resorts, the local community, the National University of Malaysia, University Malaya, as well as sharing data with the Global Coral Reef Monitoring Network (GCRMN).

Our main logistics partner was the Tioman Dive Centre, a well-established SCUBA diving centre based on Tioman Island and managed by Rosie Cotton. Tioman Dive Centre staff were on hand to offer advice and assistance in safety, diving and other local logistical issues.

1.9. Expedition budget

Each team member paid towards expedition costs a contribution of £1470 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., as well as visa and 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	14,593
Expenditure	
Research vessel & accommodation includes all board & lodging on land & sea, ship's crew, fuel & oils, diving & other services	4,526
Equipment and hardware includes research materials & gear hired or purchased in UK & Malaysia	439
Staff Includes local and international salaries, travel and expenses	5,008
Administration includes registration fees & sundries	123
Team recruitment Malaysia as estimated % of PR costs for Biosphere Expeditions	4,472
Income – Expenditure	**25**
Total percentage spent directly on project	**100%**

1.10. Acknowledgements

This study was conducted by Biosphere Expeditions, which runs wildlife conservation expeditions all over the globe. Without our expedition team members (who are 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. Thank you also to Stella Abbas Rowland of Swiss Cottage Chalets who provided accommodation and meals for our volunteers and staff. 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 and Swarovski Optik for their sponsorship support.

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.

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 a vital element of marine ecology.

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; 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 support a vast array of benefits, including cultural, social, biological and economic values, 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 and 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 its role in the carbon cycle, for its 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. Total coral reef area is nearly 100,000 km^2, comprising nearly 34% of the world's total coral reef area (Tun et al. 2004). Southeast Asian coral reefs hold 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. The reefs off the Nusa Tenggara chain in Indonesia; Okinawa, Japan; and Sabah, East Malaysia are also highly threatened (Burke et al. 2002). According to Wilkinson (2004), there are hardly any 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 3600 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).

The Tioman Archipelago

Tioman Island is located some 50 km from Mersing, off the east coast of Pahang, Malaysia. It is the largest island off the east coast of Peninsular Malaysia. The island has five villages, with a total population of approximately 3000, most of whom work in tourism, the main industry on the islands. The islands have been gazetted as a Marine Park since 1994 (Reef Check Malaysia 2012).

Diving and snorkelling are the main tourist activities. The island has long been a popular tourist destination, though in recent years it has been eclipsed by other destinations (particularly Redang and Perhentian). As a result, resort development has been at a slower pace, with no significant new resorts in the last 12 years. There are some 40 resorts on the island, mainly small family-run operations, and 15 dive operators (Reef Check Malaysia 2012).

There is a small power generation station on the island, supplying electricity to all areas. The island has abundant fresh water, and a municipal incinerator was constructed some time ago. The island is served by an airport as well as ferry boat services (Reef Check Malaysia 2012).

Reefs are mainly fringing offshore reefs, with some submerged reefs (Reef Check Malaysia 2012).

Pemanggil Island

Pemanggil Island is approximately 45 km east of Mersing off the east coast of Peninsular Malaysia. The island and its surrounding waters were gazetted as Marine Parks in 1994 under the Fisheries Act 1985 (Amended 1993) (Reef Check Malaysia 2012).

The island is sparsely populated with few villages and has for many years been a frequent stopover point for fishermen. There are also a small number of resorts on the island (Reef Check Malaysia 2012).

Project aims

Various researchers and organisations, including Reef Check Malaysia, have carried out studies in the Tioman Archipelago, but studies 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.

The research objectives of this project were to: (1) monitor the health of the reefs, (2) assess impacts that may be damaging their health, (3) set up baseline surveys that can be continued regularly and well into the future and (4) extend studies to sites that have not yet been studied. The aims of these objectives are 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 was designed to assess the health of coral reefs and focuses on the abundance of particular coral reef organisms that are widely distributed on coral reefs, are easy for non-scientists to identify and provide information about the health of a coral reef.

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, 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.

Reef Check surveys were conducted along two depth contours when 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 5 m, which provides four replicates per transect (8 per complete survey) for statistical analysis.

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

Sites chosen were distributed around the archipelago to get a good representation of the islands. Table 2.2a lists the sites surveyed and Figure 2.2a shows the map of all the sites surveyed. A total of 26 sites were surveyed. Most of the sites were surveyed during the 2012 expedition (Yewdall et al. 2013) with some new sites added during the course of the 2013 expedition.

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 2013.

Island		Site	Coordinates	Depth (m)
Tioman	1.1	Renggis North	02 48.632 N 104 08.176 E	10
	1.2	Juara South	02 46.852 N 104 12.618 E	12
	1.3	Bugis Bay	02 43.899 N 104 13.301 E	6
	1.4	Pasir Munjor	02 45.053 N 104 13.215 E	11
	1.5	Soyak South	02 52.480 N 104 08.810 E	6
	1.6	Soyak North	02 52.560 N 104 08.884 E	10
	1.7	Teluk Dalam	02 52.456 N 104 11.254 E	6
	1.8	Tumuk	02 47.578 N 104 07.343 E	6
	1.9	Batu Malang	02 54.139 N 104 06.143 E	7
	1.10	Batu Nipah	02 43.928 N 104 08.125 E	5
	1.11	Chebeh	02 55.946 N 104 05.814 E	12
	1.12	Fan Canyon	02 54.650 N 104 06.753 E	7
	1.13	Jahat East	02 40.127 N 104 10.518 E	7
	1.14	Jahat West	02 39.687 N 104 09.987 E	7
	1.15	Labas	02 53.318 N 104 03.920 E	7
	1.16	Pasir Penut	02 45.618 N 104 13.227 E	7
	1.17	Sepoi	02 53.883 N 104 03.100 E	12
	1.18	Tekek House Reef	02 48.961 N 104 09.062 E	5
	1.19	Teluk Tambong	02 48.239 N 104 12.589 E	11
	1.20	Teluk Kador	02 54.891 N 104 06.507 E	7
Pemanggil	2.1	Bumphead Bay	02 34.890 N 104 20.119 E	10
	2.2	Lobster Bay	02 34.209 N 104 19.341 E	3
	2.3	Old Man of the Sea	02 34.884 N 104 20.250 E	6
	2.4	Pemanggil Village South	02 34.761 N 104 18.945 E	4
	2.5	Pemanggil Village North	02 34.905 N 104 18.750 E	5
	2.6	Tridacna Bay	02 35.800 N 104 19.635 E	10

Figure 2.2a. Sites surveyed by the expeditions in 2013.
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 before starting the fish visual survey was allowed after tape laying. The waiting period is necessary to allow fishes to resume normal behaviour after being disturbed by the diver laying the transect (Hodgson et al. 2006).

Fish species commonly targeted by fishermen and aquarium collectors 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 (Chaetodontidae), sweetlips (Haemulidae), snappers (Lutjanidae), Barramundi cod (*Cromileptes altivelis*), humphead wrasse (*Cheilinus undulatus*), bumphead parrotfish (*Bolbometopon muricatum*), parrotfish (Scaridae) over 20 cm, moray eel (Muraenidae) and grouper (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 (*Stenopus hispidus*), long-spined black sea urchin or Diadema urchins (*Diadema* spp.), pencil urchin (*Eucidaris* spp.), collector urchin (*Tripneustes* spp.), sea cucumber species *Thelenota ananas*, *Stichopus chloronotus*, *Holothuria edulis*, lobster (all edible species), triton (*Charonia tritonis*) and crown-of-thorns starfish (*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).

Substrate line transect

Starting from 0 m, at every 0.5 m 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 with fish recording being conducted just before invertebrate and substrate recording, using the same transect tape.

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. The substrate line transect data were converted to mean percentage cover of each substratum category. Anthropogenic data were represented by mean abundance of each impact.

2.3. Results

Status of Reefs within the Tioman Archipelago

The results from all 26 surveys were compiled to provide an overview of the status of coral reefs within the Tioman Archipelago. Results showed that reefs were in 'good' condition (based on the Coral Reef Health Criteria developed by Chou et al. 1994) with a total average of 52.50% live coral (hard coral, HC + soft coral, SC) cover (Fig. 2.3a). This average is higher than the national average of 46.37% recorded in 2012 (Reef Check Malaysia 2013).

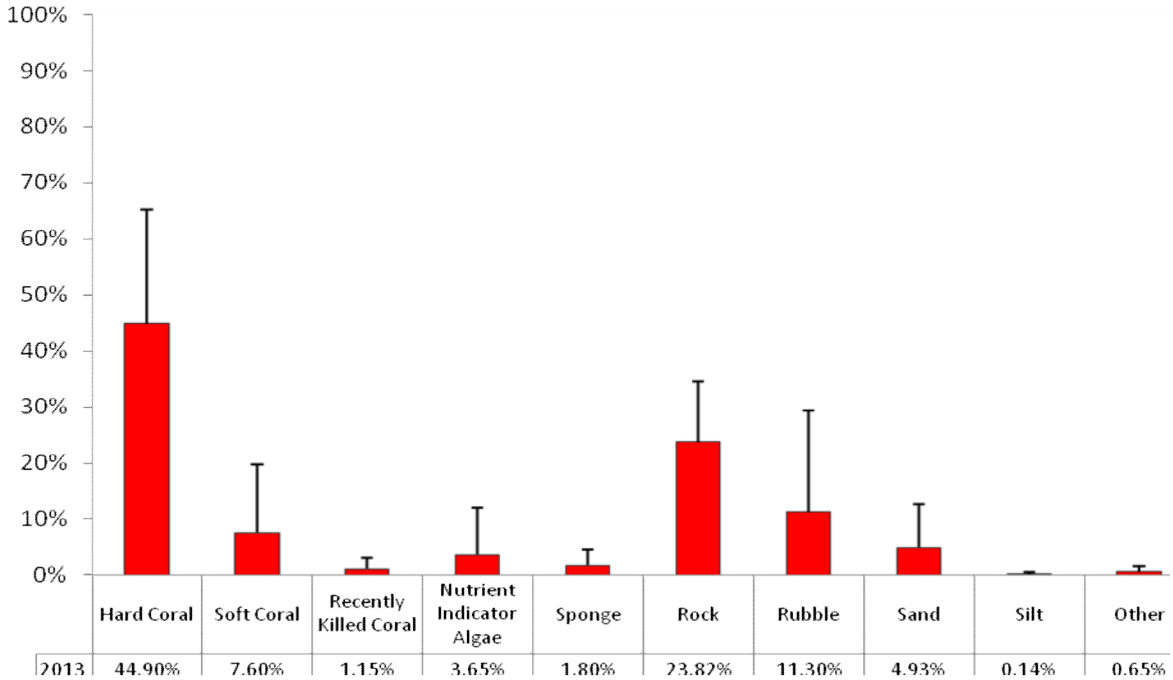


Figure 2.3a. Average percentage of substrate cover per 100 m within the Tioman Archipelago

At 3.56% (Fig. 2.3a), a higher amount of nutrient indicator algae (NIA) was recorded compared to the findings of the 2012 expedition (3.18%) (Yewdall et al. 2013) and the national average of 2.71% (Reef Check Malaysia 2013). This amount is considered manageable and not an immediate cause of concern. However, if NIA levels show increasing trends in the coming years, more attention must be paid to its causes.

Recently killed coral (RKC) results from a variety of natural and human impacts were recorded at a low level (1.15%), while Rock (RC), which is critical for reef recovery, regeneration and extension, is considered normal at 23.82% (Fig. 2.3a). The average level of rubble (RB) recorded on reefs in 2013 (11.30%) was similar to the national average in 2012 (11.85%) (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 (4.93%) is within normal range. Sponge (SP), another natural component of reefs and an indicator of nutrient input, appears normal at 1.8% (2.11% in 2012). The average level of silt (SI) on reefs within the archipelago is low at 0.14% and the average level of other (OT) was 0.65% (Fig. 2.3a).

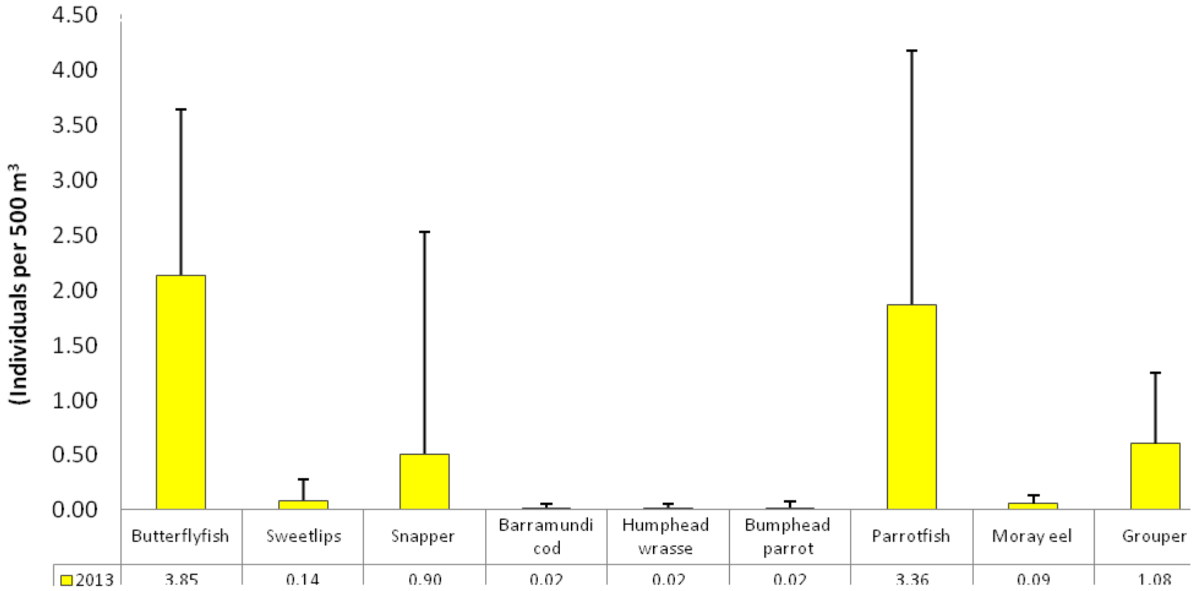


Figure 2.3b. Average number of individuals per 500 m^3 within the Tioman Archipelago

Abundance of several fish that are targeted for food is low in most of the areas where surveys have been conducted (Fig. 2.3b), with abundance of many being below 1 individual per 500 m^3 survey transect (including sweetlips, snappers, Barramundi cod, humphead wrasse, bumphead parrotfish and moray eel).

Groupers above 30 cm in length are considered high value food fish and were present in very low numbers (1.08 individuals per 500 m^3 survey transect). Equally important are healthy butterflyfish and parrotfish populations, but both were present in low numbers (3.85 and 3.36 individuals per 500 m^3 survey transect respectively).

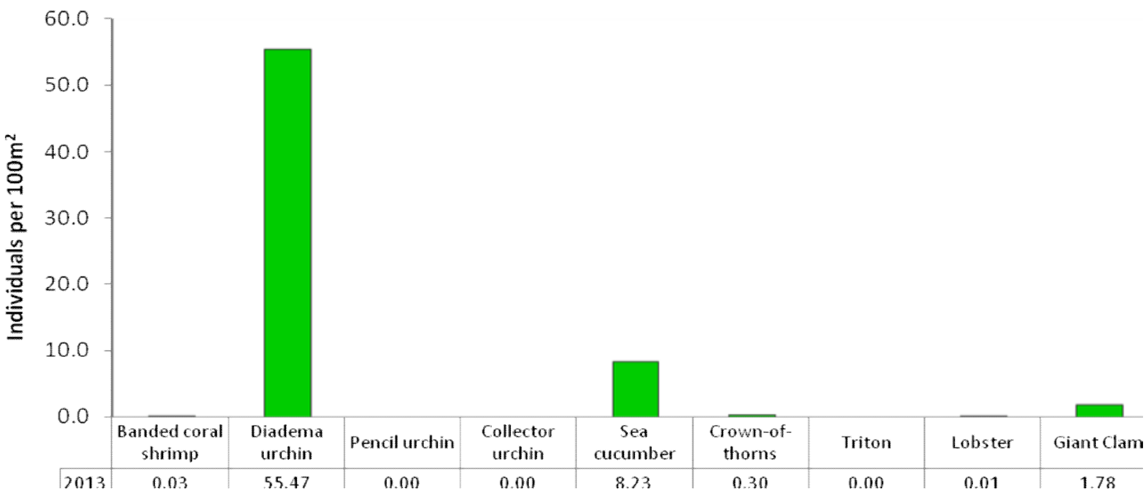


Figure 2.3c. Average number of individuals per 100 m^2 within the Tioman Archipelago

Tritons, pencil urchins and collector urchins were absent during all surveys (Fig. 2.3c). Lobsters, which are a favourite seafood among tourists, were also absent during most surveys, with an average of only 0.01 individuals per 100 m^2 survey transect. However, sea cucumber numbers were high, with an average of 8.23 individuals per 100 m^2 compared to the national average of only 1.56 individuals per 100 m^2 in 2012. Giant clams were rarely seen, with an average of 1.78 individuals per 100 m^2 (Fig. 2.3c).

Diadema urchin numbers were exceptionally high (55.47) compared to the national average of 35.36 individuals per 100 m^2. However, their numbers have decreased in Tioman compared to 2012 (70.97). 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 (0.3 per 100 m^2) is at the higher end of this range, suggesting that COT numbers are at the border of acceptable limits. These numbers are also higher than the national average in 2012 (0.21 per 100m$^{2)}$, yet lower than those recorded in the 2012 surveys (0.46) by Yewdall et al. (2013).

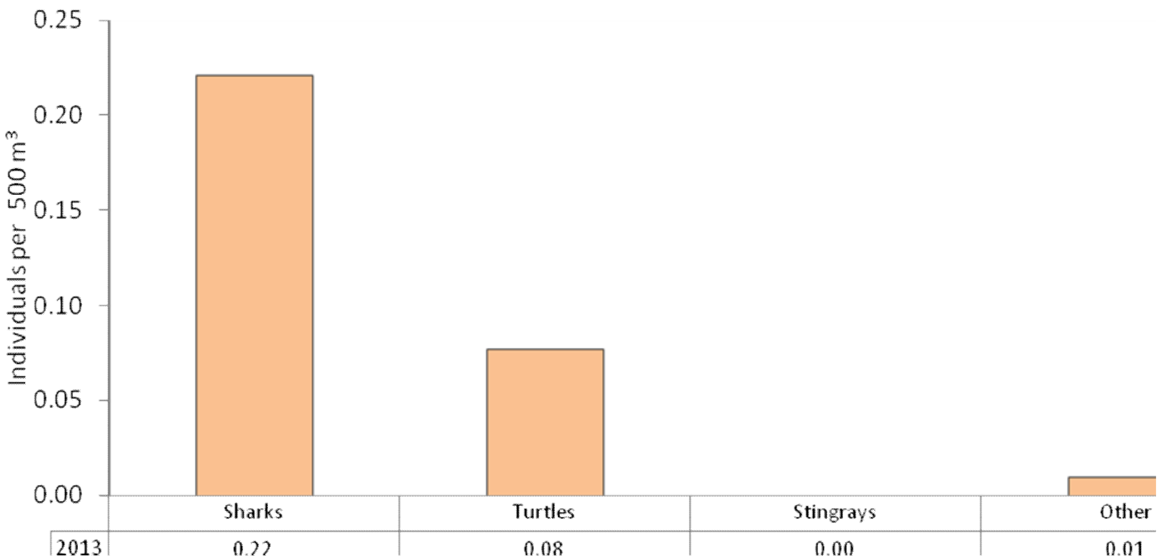


Figure 2.3d. Average number of individuals per 100 m^2 within the Tioman Archipelago

Sharks, turtles, stingrays (excluding the bluespotted stingray *Neotrygon kuhlii*), sea snakes and marine mammals are considered rare and their occurrences were recorded when observed during surveys. No stingrays were spotted during the surveys, while sharks, turtles and sea snakes were recorded in low numbers.

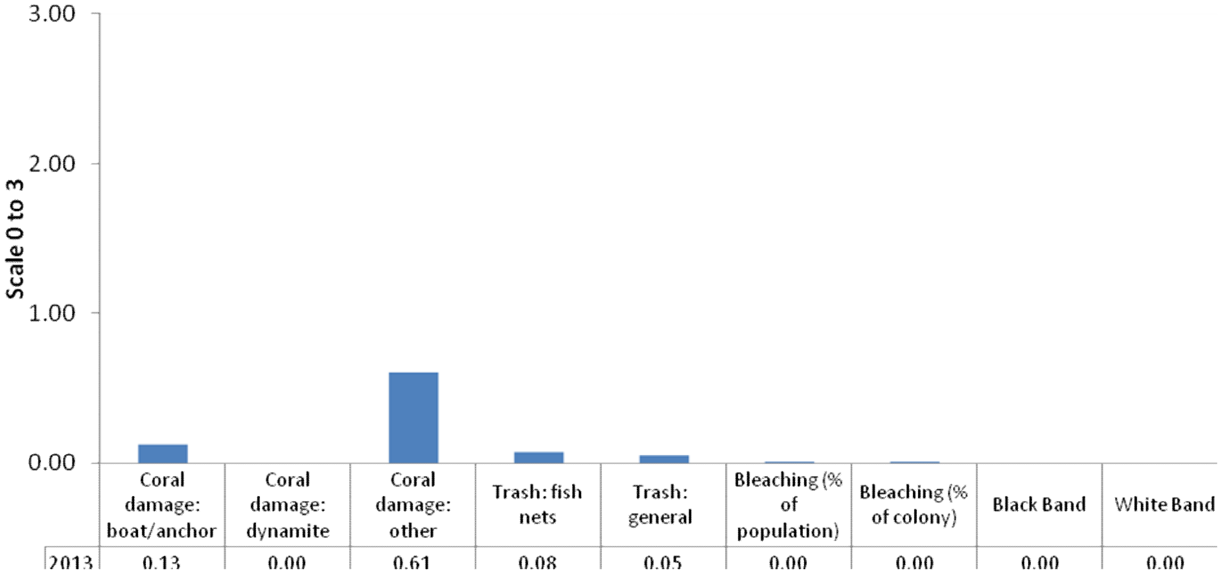


Figure 2.3e. Average coral damage on a scale of 1 to 3 (3 being worst) in Tioman Archipelago

Visible coral damage caused by human and non-human impacts was also recorded during surveys and results showed that the main cause of damage was non-human impacts, which included storms, COT outbreaks and *Drupella* outbreaks (both under coral damage : other). Discarded fish nets and trash were present on the reef, but in very small amounts (Fig. 2.3e).

Below are details of substrate characteristics, fish populations and invertebrates from all sites visited individually. *For all graphs, data are averaged from the four replicates at all survey depths combined and error bars are Standard Error. Codes for this and all other substrate graphs below: 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.

Renggis North

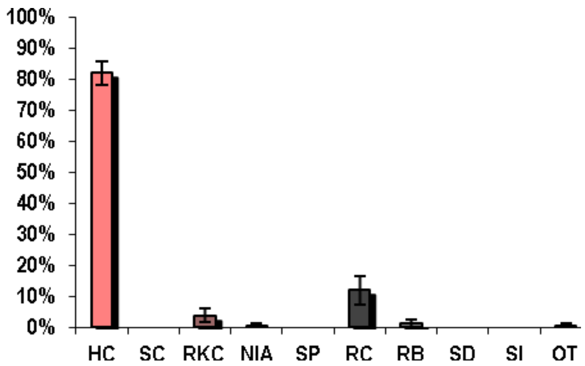


Figure 2.3f(i). Substrate cover for Renggis North*.

The reef surveyed at Renggis North was in excellent condition with live coral cover of 81.9% (Fig. 2.3f(i)), the highest of all sites surveyed in Tioman. Substrate cover did not change much compared to 2012 (Yewdall et al. 2013) except for a drop in sponge cover and a small increase of 0.63% in NIA level.

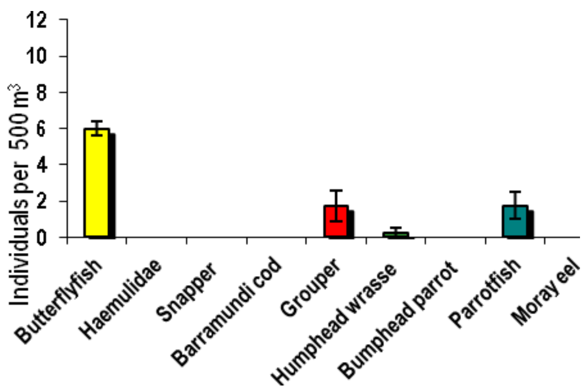


Figure 2.3f(ii). Fish abundance for Renggis North.

Four indicator fish were recorded within the 500 m^3 water column surveyed, including butterflyfish (6 individuals per 500 m^3), humphead wrasse (0.25), grouper (1.75) and parrotfish (1.75) (Fig. 2.3f(ii)). Highly prized food fish such as sweetlips, Baramundi cod and bumphead parrotfish were absent. Yewdall et al. (2013) showed similar results. Two blacktip reef sharks were also observed at the site during the survey.

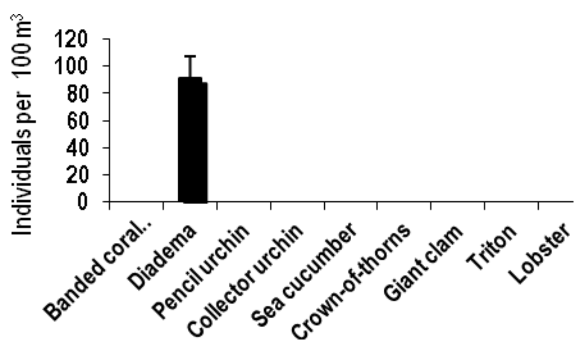
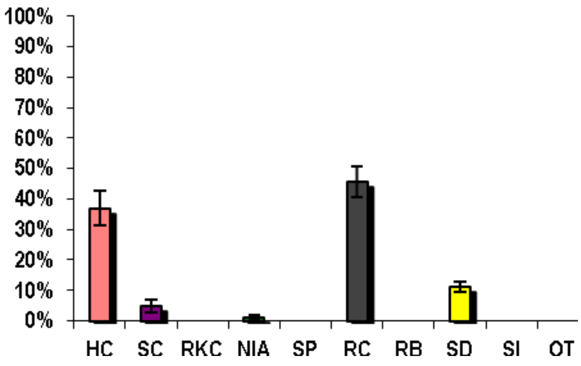


Figure 2.3f(iii). Invertebrate abundance for Renggis North.

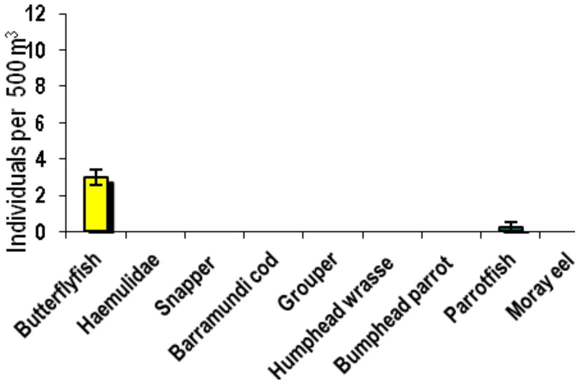
The Diadema urchin (91.75 individuals per 100 m^2) was the only indicator invertebrate recorded during the survey at Renggis North (Fig. 2.3f(iii)). During the 2012 expedition (Yewdall et al. 2013) giant clam was also recorded in addition to Diadema urchin.

Juara South



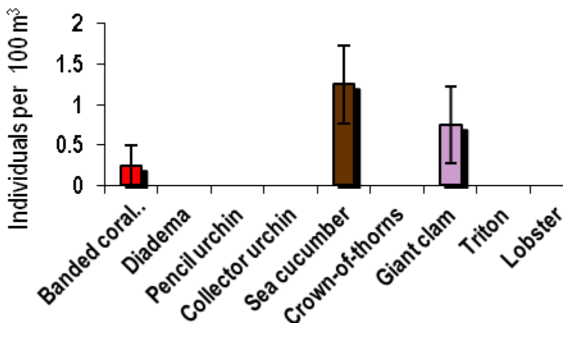
The reef at Juara South was in fair condition, with 41.88% of live coral cover (HC 36.88% and SC 5.88%) (Fig. 2.3g(i)). RC cover was high at 45.53%, reflecting the rocky nature of the coastline; rock is a good substrate for possible coral recruits to settle and grow on. The low level of NIA (1.25%) is a good indication that the reefs are free from nutrient pollution. Survey results of 2012 mirrored those of 2013, an indication that no drastic change had occurred within the last year.

Figure 2.3g(i). Substrate cover for Juara South.



Only butterflyfish (3 individuals per 500 m^3) and parrotfish (0.25) were observed at this site (Fig. 2.3g(ii)). In 2012, snappers, groupers and moray eel were observed, but in low abundance. Therefore their absence during this year's surveys was not cause for concern.

Figure 2.3g(ii). Fish abundance for Juara South.



Banded coral shrimp (0.25 individuals per 100 m^2), sea cucumber (1.25) and giant clam (0.75) were the only three indicator invertebrates found within the 100 m^2 area surveyed (Fig. 2.3g(iii)). All other target species were absent.

Figure 2.3g(iii). Invertebrate abundance for Juara South.

Bugis Bay

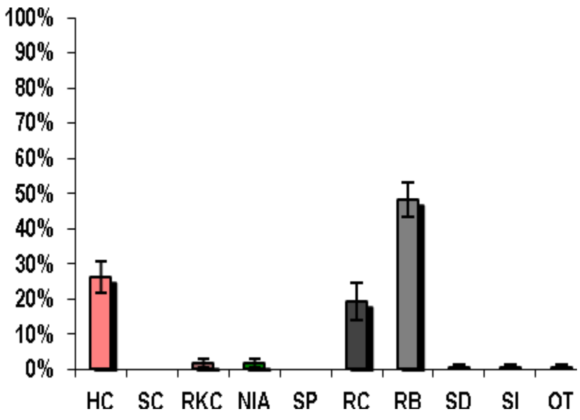


Figure 2.3h(i). Substrate cover for Bugis Bay.

The section of reef surveyed at Bugis Bay consisted mainly of RB (48.13%) and RC (19.38%) (Fig. 2.3h(i)) with corals mainly boulder and encrusting. This is a reflection of the impact that this reef has to endure every year during the monsoon season. Strong waves are generated at this side of the island, which is exposed to the open South China Sea. The status of the reefs at this site was just slightly above poor condition, with 26.25% live coral cover (similar to 2012), the second lowest recorded in Tioman.

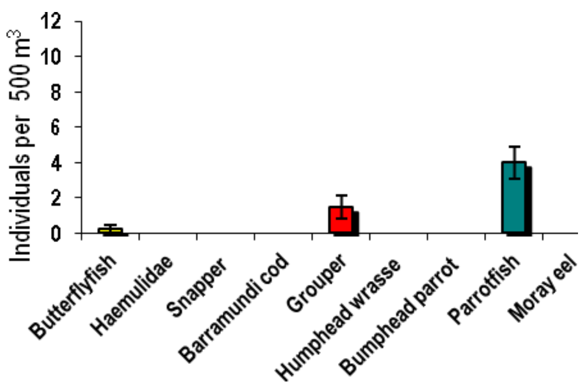


Figure 2.3h(ii). Fish abundance for Bugis Bay.

Butterflyfish (0.25 individuals per 500 m^3), groupers (1.5) and parrotfish (4.0) were the only three indicators recorded at this site during the survey (Fig. 2.3h(ii)). Results from fish surveys conducted in 2012 were similar. One green turtle was observed during this 2013 survey.

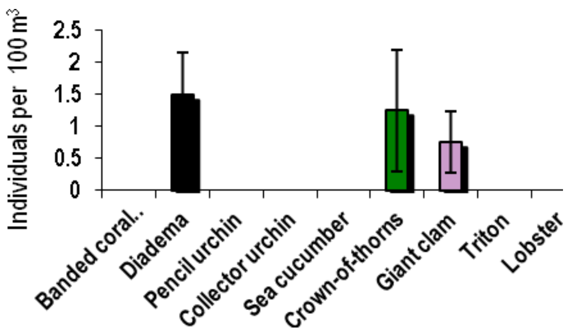


Figure 2.3h(iii). Invertebrate abundance for Bugis Bay.

Most of the indicators were absent from the surveys (banded coral shrimp, pencil and collector urchin, sea cucumber, triton and lobster) (Fig. 2.3h(iii)). For the three indicators observed during the surveys, abundance was generally very low (Diadema 1.5 individuals per 100 m^2, COTs 1.25 and Giant Clams 0.75).

Pasir Munjur

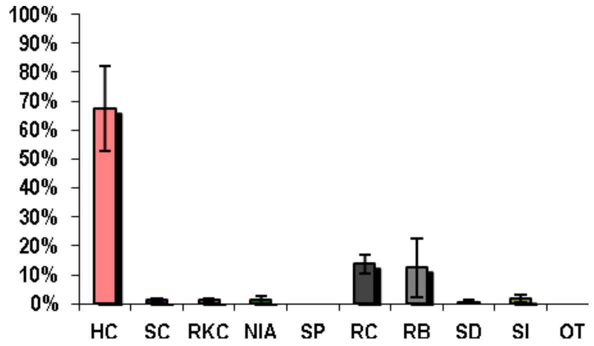


Figure 2.3i(i). Substrate cover for Pasir Munjur.

Pasir Munjur was one of the new sites surveyed this year. This fringing reef is located just off Munjur beach, which is an important turtle nesting site. The reef is in good condition with live coral cover of 68.75% (67.5% HC and 1.25% SC) (Fig. 2.3i(i)). RC (13.75%) and RB (12.50%) were the other major components of the reef and there was little recent damage to the reef (RKC 1.25%).

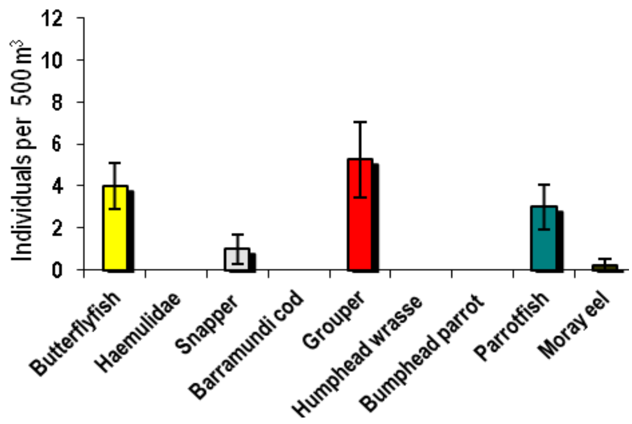


Figure 2.3i(ii). Fish abundance for Pasir Munjur.

Butterflyfish (4 individuals / 500 m^3), snappers (1), groupers (5.25), parrotfish (3) and moray eel (0.25) were the indicator fish recorded during the surveys (Fig. 2.3i(ii)). The number of grouper recorded at this site was the highest for Tioman and this is mainly due to the fact that this site is secluded and fishing is rarely conducted here.

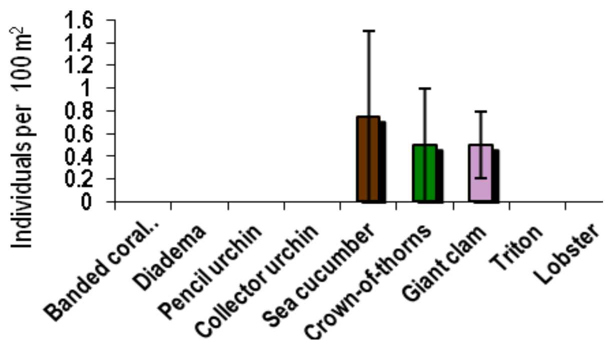


Figure 2.3i(iii). Invertebrate abundance for Pasir Munjur.

Most of the indicators were not recorded in the surveys (Fig. 2.3i(iii)). Only sea cucumber (0.75 individuals per 100 m^2), COTS (0.5) and giant clams (0.5) were recorded.

Soyak South

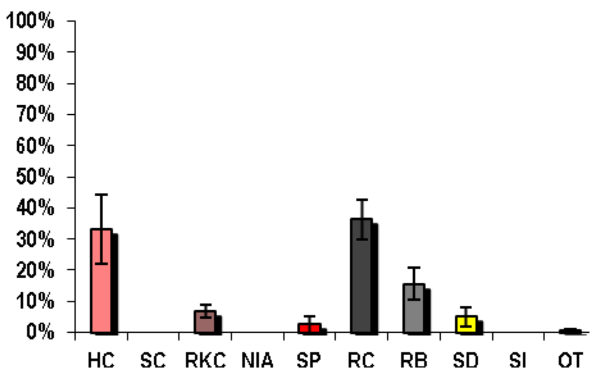


Figure 2.3j(i). Substrate cover for Soyak South.

Soyak South was not surveyed during the 2012 expedition. The reef south of Soyak Island was in fair condition with 33.13% live coral cover. RC (36.25%), RB (15.63%) and RKC (6.88%) covered most of the survey area (Fig 2.3j(i)). This side of the island is exposed to sea and suffers damage every monsoon resulting in the high level of non-living substrate on the reef. Anchor reef damage was also observed at this site.

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

Three indicator species were completely absent from the surveys (Barramundi cod, bumphead parrotfish, and moral eel). butterflyfish abundance (10.25 individuals per 500 m^3) was the highest of all sites surveyed in Tioman (Fig 2.3j(ii)). Abundance of other indicators was generally low (sweetlips 0.25, snapper 0.75, humphead wrasse 0.25, parrotfish 6 and groupers 1.75).

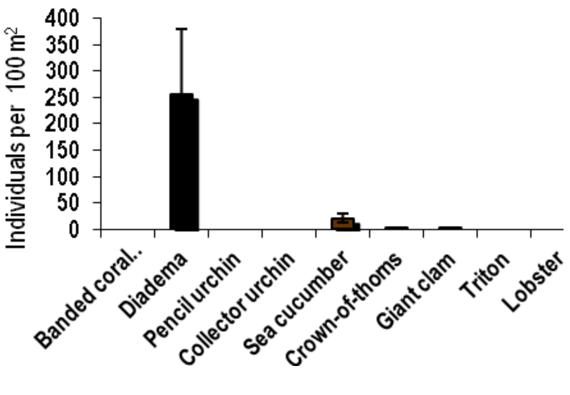
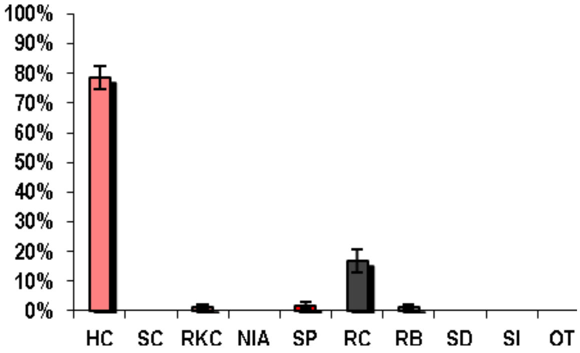


Figure 2.3j(iii). Invertebrate abundance for Soyak South.

Diadema (255 individuals per 100 m^2) were the most abundant invertebrate recorded at this site Fig 2.3 (iii). This very high abundance probably reflects the ample amount of food noted at the site, turf algae, which grows on RC and RB.

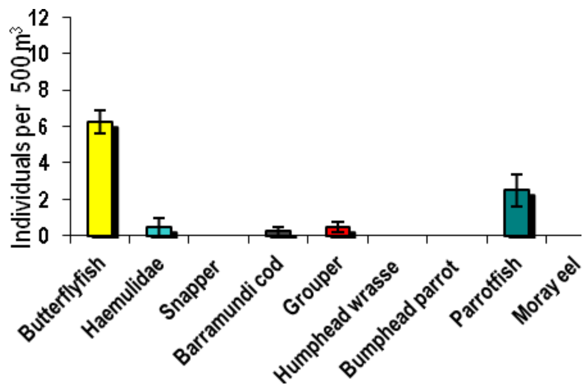
Apart from Diadema, sea cucumbers (20.25) were the most abundant invertebrate recorded at this site (Fig 2.3j(iii)) with COTs (1.25) and giant clams (1.75) present in lower numbers.

Soyak North



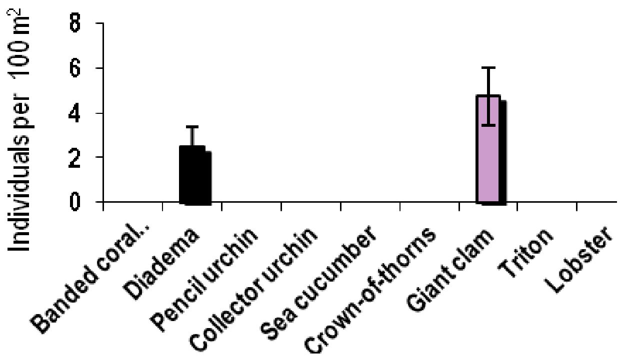
The reef on the northern sheltered side of Soyak Island was in excellent condition with 78.75% live coral cover (Fig 2.3k(i)). RC was the second highest substrate cover (16.88%) at this site, which indicates that there is suitable substrate for more coral recruits to settle and expand the reef. Compared to Soyak South, the northern reef had very low RKC (1.25%) and RB (1.25%).

Figure 2.3k(i). Substrate cover for Soyak North.



Only four indicator species were present during surveys: butterflyfish (6.25 individuals per 500 m^3), sweetlips (0.5), grouper (0.5) and parrotfish (2.5) (Fig 2.3k(ii)). This site was also one of the two sites where Barramundi cod was recorded (0.25). A single green turtle was also recorded during the survey at this site.

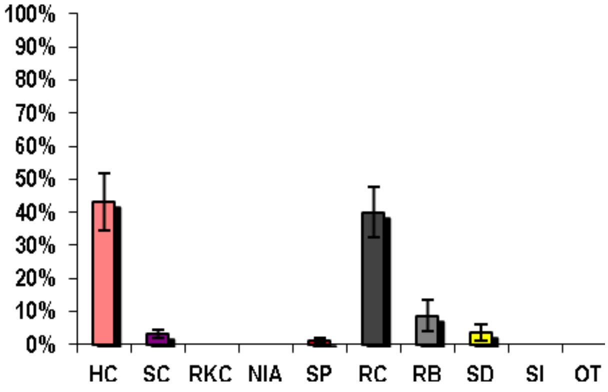
Figure 2.3k(ii). Fish abundance for Soyak North.



Giant clam (4.75 individuals per 100 m^2) and Diadema urchin (2.5) were the only two indicator invertebrates recorded (Fig 2.3k(iii)). There were many fewer Diadema urchins recorded on the northern side of the island compared to the southern side.

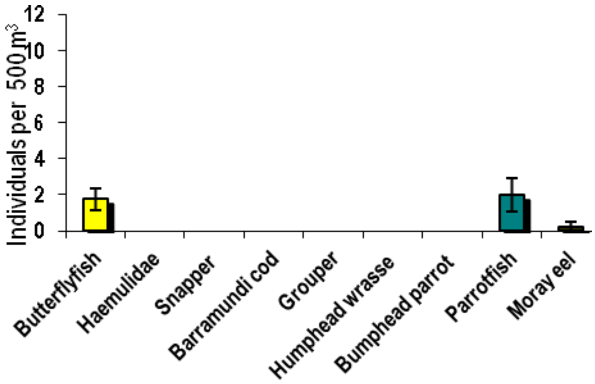
Figure 2.3k(iii). Invertebrate abundance for Soyak North.

Teluk Dalam



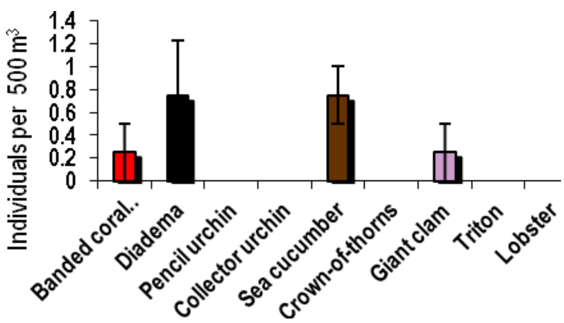
Teluk Dalam reef is considered to be in a good state with live coral cover of 46.26% (43.13% HC and 3.13% SC) (Fig 2.3l(i)). There were large amounts of RC (40%) and RB (8.75%) due to storm damage in the past. However, the lack of RKC is a good sign that there has not been much recent damage in the area. Large numbers of new coral colonies were observed during the surveys and this was reflected in the data, as live coral cover had increased from the 33% recorded in 2012.

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



Only three indicator species were recorded during the surveys: butterflyfish (1.75 individuals per 500 m^3), parrotfish (2.0) and moray eel (0.25) (Fig 2.3l(ii)). Fishing is common at this bay and this is reflected in the absence of sweetlips, snappers, groupers, Barramundi cod and humphead wrasse.

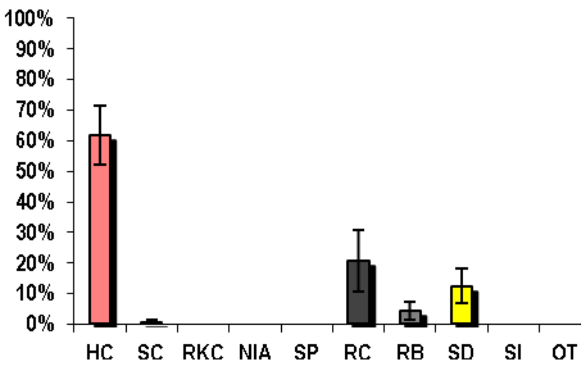
Figure 2.3l(ii). Fish abundance for Teluk Dalam.



Four indicator invertebrates (banded coral shrimp 0.25 individuals per 100 m^2, Diadema urchin 0.75, sea cucumber 0.75 and giant clam 0.25) were recorded during the surveys. However, these indicators were all present in small numbers (Fig 2.3l(iii)).

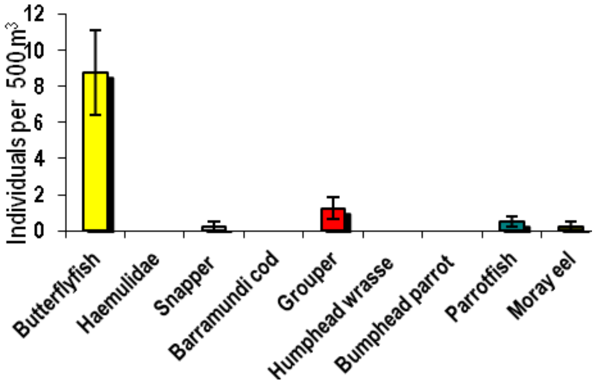
Figure 2.3l(iii). Invertebrate abundance for Teluk Dalam.

Tumuk



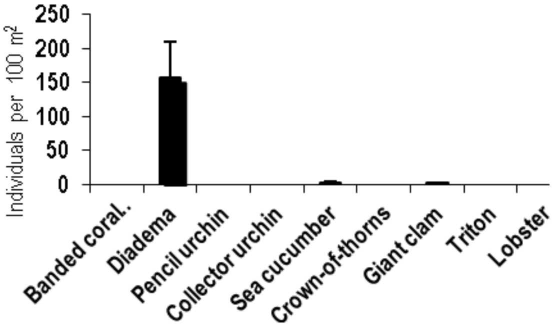
The reef at Tumuk was in good condition with 62.51% live coral cover (HC 61.88% and SC 0.63%) (Fig. 2.3m(i)). The site also recorded 20.63% RC and only 4.38% RB. Tumuk is another new site surveyed this year that was not covered in 2012.

Figure 2.3m(i). Substrate cover for Tumuk.



Butterflyfish (8.75 individuals per 500 m^3), snapper (0.25), parrotfish (0.5), moray eel (0.25) and groupers (1.25) were recorded within the 500 m^3 survey water column at Tumuk (Fig. 2.3m(ii)). However, commercially important food fish such as sweetlips, Barramundi cod, humphead wrasse and bumphead parrotfish were absent.

Figure 2.3m(ii). Fish abundance for Tumuk.



Sea cucumbers (3.5 individuals per 100 m^2), giant clams (1.5) and Diadema urchins (157.5) were the only invertebrate indicators found at Tumuk (Fig. 2.3m(iii)). The high number of urchins may be due to the large sand patches in between the reef and it is known that Diadema can aggregate to make defensive structures against predators (Solandt, pers. com.).

Figure 2.3m(iii). Invertebrate abundance for Tumuk.

Batu Malang

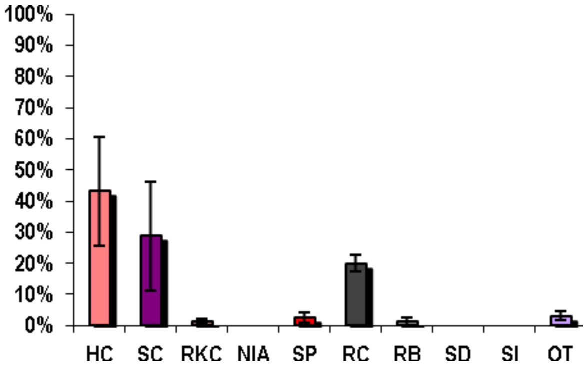


Figure 2.3n(i). Substrate cover for Batu Malang.

Live coral cover was 71.98% (HC 43.13% and SC 28.75%) at Batu Malang (Fig. 2.3n(i)), placing it in the good reef condition category. The percentage of live coral cover at this site was the third highest of all sites surveyed in Tioman. Levels of other substrate categories are low (NIA 0%, RB 1.25% and SI 0%), indicating few recent disturbances at Batu Malang. Compared to 2012, the amount of RC has reduced and SC has increased.

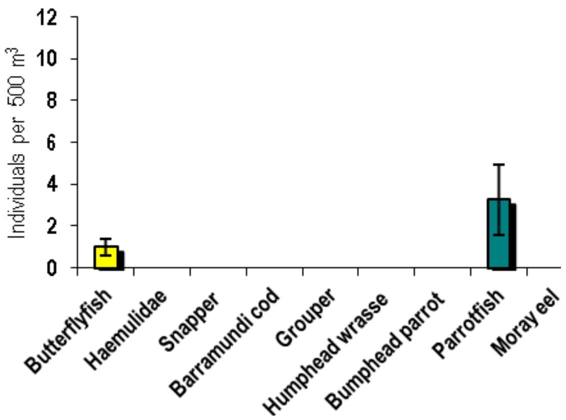


Figure 2.3n(ii). Fish abundance for Batu Malang.

Only two indicator fish (butterflyfish 1 individual per 500 m^3 and parrotfish 3.25) were present at Batu Malang (Fig. 2.3n(ii)). Prized food fish such as Barramundi cod, humphead wrasse and bumphead parrotfish and important food fish such as grouper and snapper were absent during the surveys. On a more positive note, one green turtle was observed at this site.

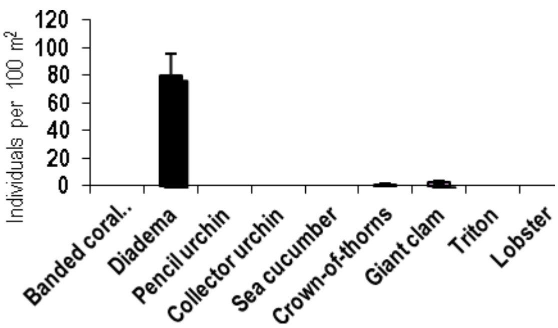
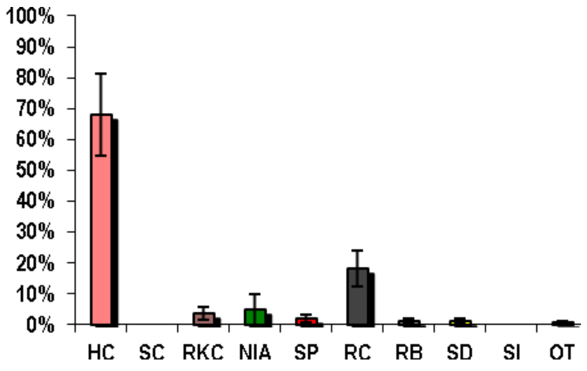


Figure 2.3n(iii). Invertebrate abundance for Batu Malang.

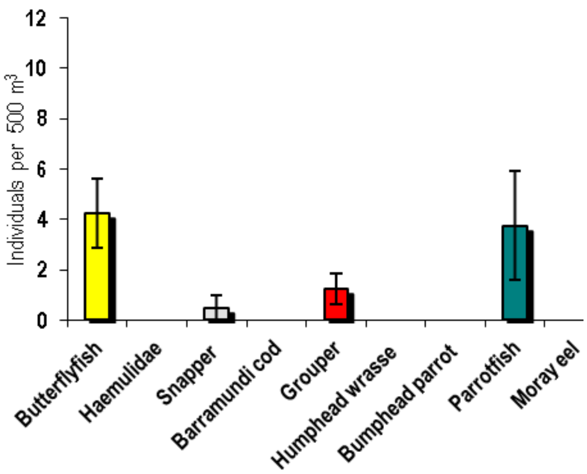
Most of the indicators were absent from the surveys. Only three indicator invertebrates, giant clam (2.5 individuals per 100 m^2), COTS (0.5) and Diadema urchin (79.75), were present at Batu Malang (Fig. 2.3n(iii)).

Batu Nipah



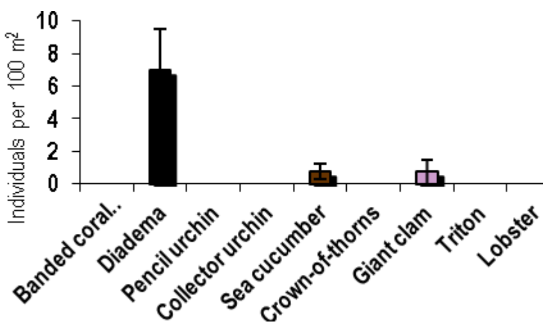
Reefs at Batu Nipah were found to be in good condition with 68.13% live coral cover (Fig. 2.3o(i)). However, the amount of NIA (5%) on the reef was above the regional average level (3.65%). The high amount of RC (18.13%) can provide good surface for recruitment of new corals, provided NIA levels do not increase.

Figure 2.3o(i). Substrate cover for Batu Nipah.



Highly prized food fish such as Barramundi cod, humphead wrasse and bumphead parrotfish were absent (Fig. 2.3o(ii)). Other indicators were present in low numbers, including butterflyfish (4.25 individuals per 500 m^3), snapper (0.5), parrotfish (3.75) and groupers (1.25). A blacktip reef shark was also recorded during the surveys.

Figure 2.3o(ii). Fish abundance for Batu Nipah.



Most of the indicator species were absent (banded coral shrimp, pencil and collector urchin, COTs, triton and lobster). Abundance of other indicator species was low (Diadema urchin 7 individuals per 100 m^2, sea cucumber 0.75 and giant clam 0.75) (Fig. 2.3o(iii)).

Figure 2.3o(iii). Invertebrate abundance for Batu Nipah.

Chebeh

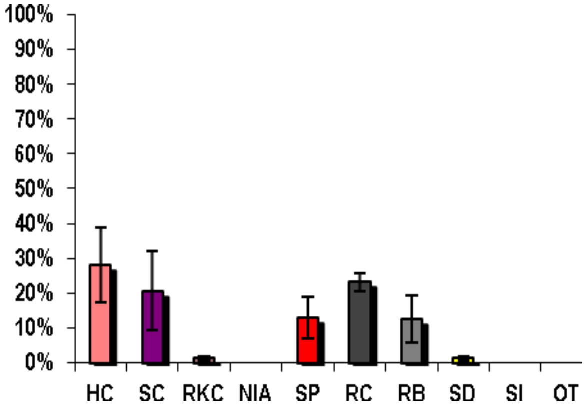


Figure 2.3p(i). Substrate cover for Chebeh.

Live coral cover at Chebeh was 48.76% (28.13% HC and 20.63% SC), which puts it in the fair category (Fig. 2.3p(i)). RC was the second main component of the reef (23.13%) and 12.5% of substrate cover consisted of RB. In 2012 RB was 33.13%, but soft corals have started to grow on much of the rubble, which is reflected in the increase in SC compared to 2012. At this site zooanthids were the dominant soft coral species

Figure 2.3p(ii). Fish abundance for Chebeh.

Butterflyfish (3 individuals per 500 m^3), sweetlips, snapper (0.25), grouper (1) and parrotfish (0.75) were observed during the surveys (Fig. 2.3p(ii)). Even though Chebeh is located far from the villages on Tioman, highly prized food fish such as Barramundi cod and humphead wrasse were absent.

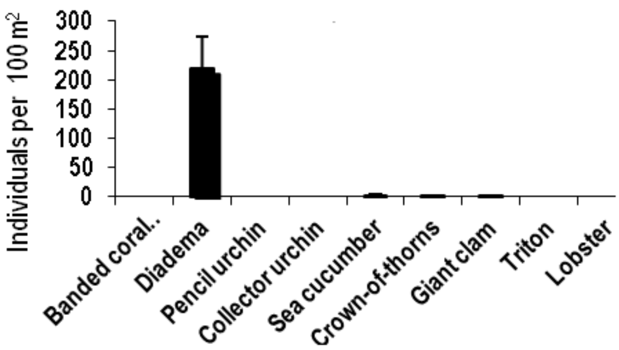
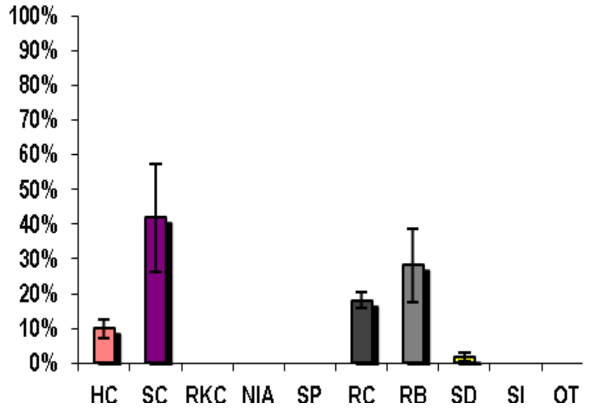


Figure 2.3p(iii). Invertebrate abundance for Chebeh.

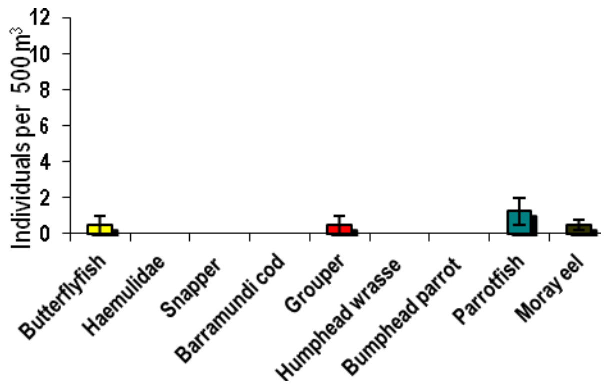
Several indicator species were absent, including banded coral shrimp, pencil and collector urchin, triton and lobster. The number of Diadema urchins (219.25 individuals per 100 m^2) was high, which may be related to the low levels of NIA at this site. Abundance of giant clams (1.75), COTs (0.25) and sea cucumber (2.25) was low (Fig. 2.3p(iii)).

Fan Canyon



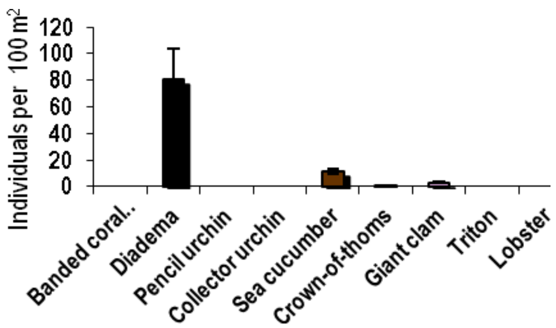
The reef at Fan Canyon was categorised as good with live coral cover of 51.88% (HC 10% and SC 41.88%) (Fig. 2.3q(i)). The amount of RB was high at this site, covering 28.13% of the reef surveyed. There were no obvious signs of recent reef damage and this site was not surveyed in 2012. Many coral reefs (particularly in areas of strong current) can be dominated naturally by soft corals. The amount of rubble suggests that the site is considerably disturbed.

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



Only four indicator fish species were present during the surveys and they were in low number: butterflyfish (0.5 individuals per 500 m^3), groupers (0.5), parrotfish (1.25) and moray eels (0.5) (Fig. 2.3q(ii)).

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



For invertebrate surveys, only Diadema urchin (80.5 individuals per 100 m^2), sea cucumber (11.5), COTS (0.25) and giant clams (3) were observed at the site (Fig. 2.3q(iii)).

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

Jahat East

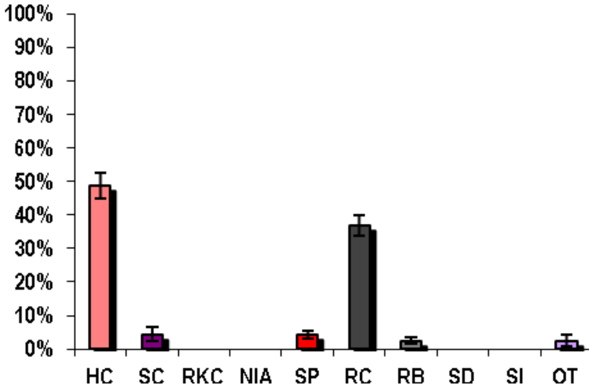


Figure 2.3r(i). Substrate cover for Jahat East.

The reef to the east of Jahat Island is a new survey site and was considered to be in good condition with 53.13% live coral cover (48.75% HC and 4.38% SC) (Fig. 2.3r(i)). This reef also consists of large amounts of RC (36.88%), providing ample substrate for coral recruits to settle on. There was little RB (2.50%) and this was most likely caused by storm damage in the past.

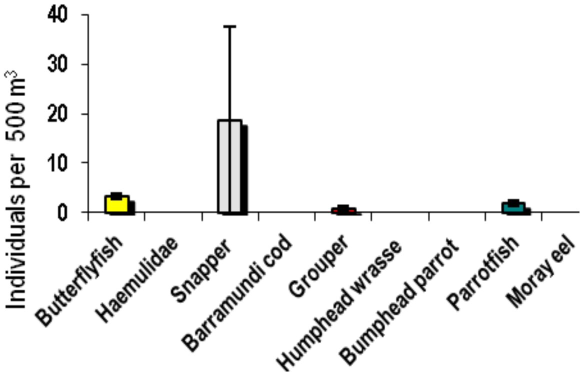


Figure 2.3r(ii). Fish abundance for Jahat East.

Four indicator fish species were recorded at this site: butterflyfish (3.25 individuals per 500 m^3), snapper (18.75), grouper (0.75) and parrotfish (2) (Fig. 2.3r(ii)). Many blacktip reef sharks (on average 4.5 per 500 m^2) were seen and this site recorded the highest number of snapper of all sites surveyed in Tioman. Jahat Island is rather secluded and isolated, yet highly prized food fish such as the humphead wrasse and barramundi cod were absent.

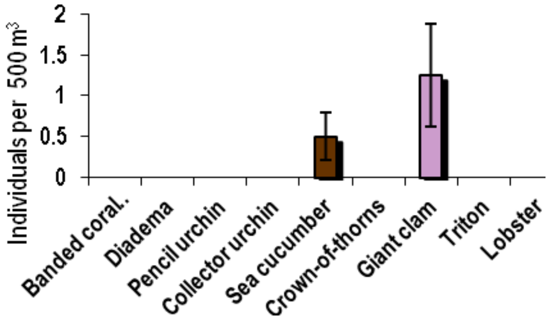


Figure 2.3r(iii). Invertebrate abundance for Jahat East.

Most of the indicator species were absent from the surveys (banded coral shrimp, diadema, pencil and collector urchin, COTs, triton and lobster). Only sea cucumbers (0.5 individuals per 100 m^2) and giant clams (1.25) were seen during surveys and they were present in low number (Fig. 2.3r(iii)). The absence of diadema could perhaps correlate with less fishing pressure and therefore more predation on the species.

Jahat West

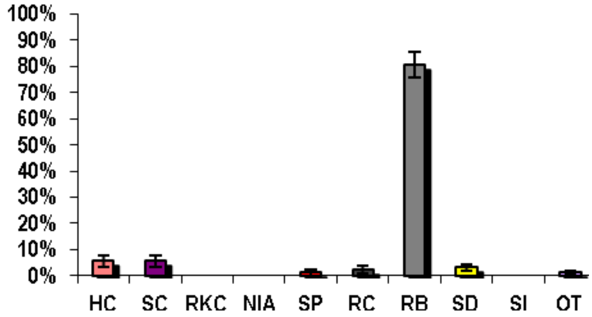


Figure 2.3s(i). Substrate cover for Jahat West.

The reef to the west of Jahat Island is also a new survey site and was in poor condition with only 11.25% live coral cover (5.63% HC and 5.63% SC) (Fig. 2.3s(i)), the lowest of all sites surveyed in Tioman. This site is exposed to the open sea and will always be impacted by storms during the monsoon season. Therefore it is not surprising that this site is covered mostly by RB (80.63%). There is no evidence or history of blast fishing around Tioman.

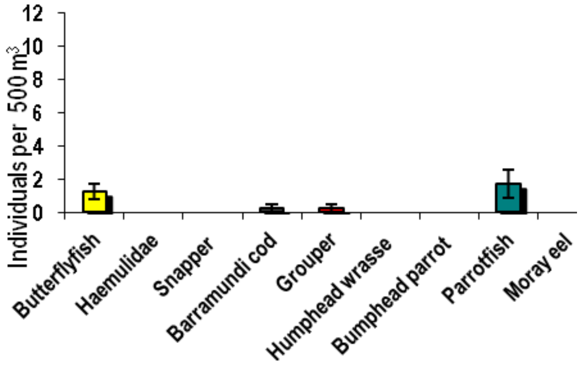


Figure 2.3s(ii). Fish abundance for Jahat West.

Only four indicator fish species were observed during the surveys and they were in low number: butterflyfish (1.25 individuals per 500 m^3), Barramundi cod (0.25), parrotfish (1.75) and grouper (0.25) (Fig. 2.3s(ii)). Jahat West was one of the two sites where Barramundi cod was observed during the surveys.

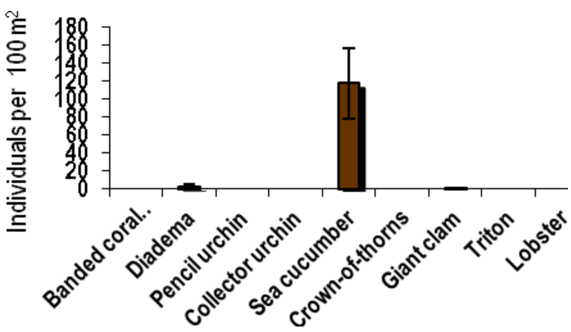
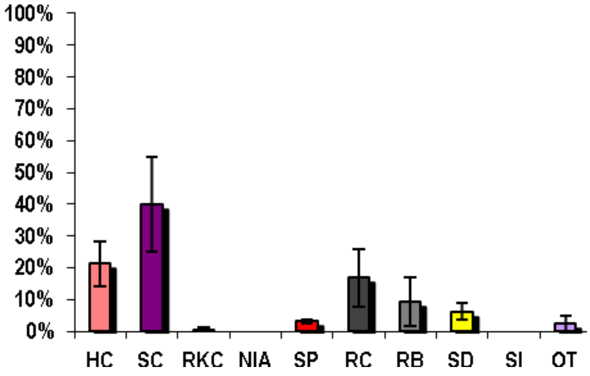


Figure 2.3s(iii). Invertebrate abundance for Jahat West.

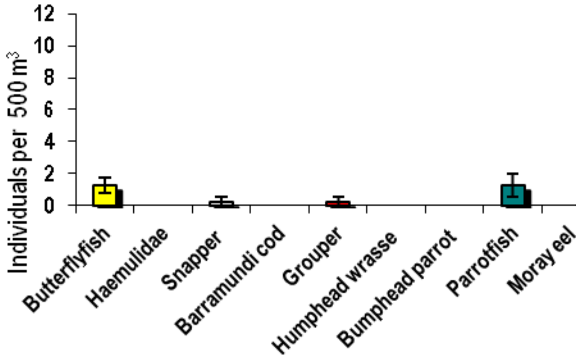
Most of the indicator species were absent, including banded coral, pencil and collector urchin, COTs, triton and lobster. Sea cucumber (117.5 individuals per 100 m^2) was the most abundant invertebrate recorded at this site and of all sites surveyed in Tioman. Other indicator species were present in low numbers, including Diadema urchin (2.5) and giant clam (0.5) (Fig. 2.3s(iii)).

Labas



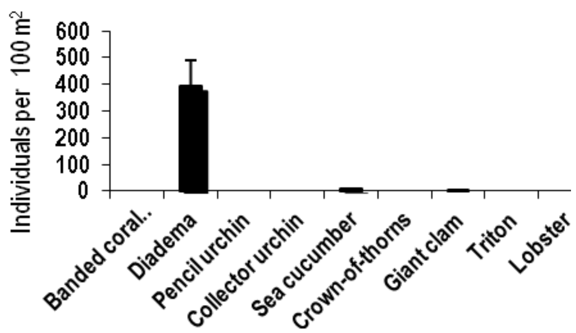
Reefs at Labas were found to be in good condition with 61.25% live coral cover (21.25% HC and 40% SC) (Fig. 2.3t(i)). The high live coral cover is due to the high amount of soft coral. Level of NIA and SI did not change from last year (both remain at 0%) and the level of RB was lower compared to last year, indicating fewer and lesser recent disturbances at Labas.

Figure 2.3t(i). Substrate cover for Labas.



Only four indicator fish species were observed during the surveys and they were in low number: butterflyfish (1.25 individuals per 500 m^3), snapper (0.25), parrotfish (1.25) and grouper (0.25) (Fig. 2.3t(ii)).

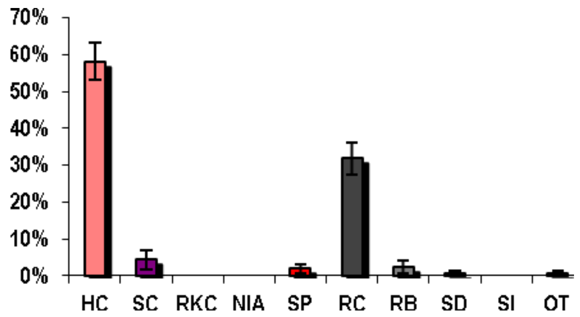
Figure 2.3t(ii). Fish abundance for Labas.



Labas had the highest number of Diadema urchins of all sites surveyed in Tioman, recording as many as 392.5 individuals per 100 m^2 (Fig. 2.3t(iii)). The other two indicator species observed were sea cucumber (7.5) and giant clam (2.25).

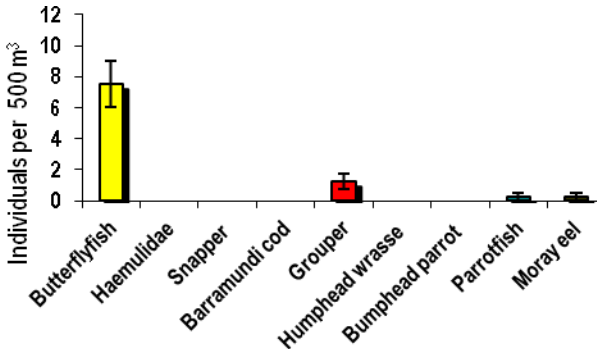
Figure 2.3t(iii). Invertebrate abundance for Labas.

Pasir Penut



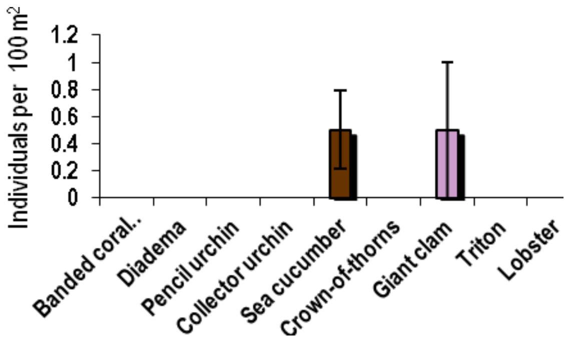
Pasir Penut is a new site surveyed this year and the reefs were in good condition with 62.50% live coral cover (Fig. 2.3u(i)). The high live coral cover was attributed to the high amount of HC (58.13%) which is responsible for building the reefs. Recent disturbances at this site were low, as indicated by the low level of RB (2.5%) and the absence of NIA and SI.

Figure 2.3u(i). Substrate cover for Pasir Penut.



Five fish indicator species were absent from surveys (sweetlips, snapper, Barramundi cod, humphead wrasse and bumphead parrotfish) and abundance of other indicators was low (parrotfish 0.25 individuals per 500 m^3, moray eel 0.25 and grouper 1.25) (fig. 2.3u(ii)). Butterflyfish was the most abundant indicator at this site with 7.5 individuals per 500 m^3. A single green turtle was also observed during the surveys.

Figure 2.3u(ii). Fish abundance for Pasir Penut.



Most of the invertebrate indicator species were absent, including banded coral shrimp, diadema, pencil and collector urchin, COTs, triton and lobster. Only two indicator species were observed in very low numbers (sea cucumber 0.5 individuals per 100 m^2 and giant clam 0.5) (Fig. 2.3u(iii)).

Figure 2.3u(iii). Invertebrate abundance for Pasir Penut.

Sepoi

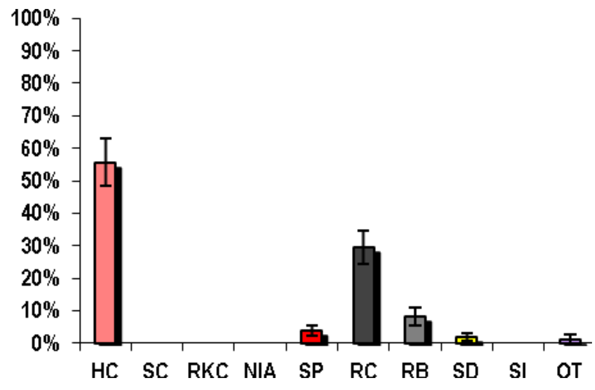


Figure 2.3v(i). Substrate cover for Sepoi.

With 55.63% live coral cover (Fig. 2.3v(i)), reefs at Sepoi fall into the good condition category. The high level of RC (29.38%) provides good surface for recruitment of new corals, provided that NIA is kept in check and herbivore populations are protected. The level of NIA (0%) and SI (0%) at this site was low and the same as recorded in 2012, indicating few recent disturbances at Sepoi and no deterioration from 2012.

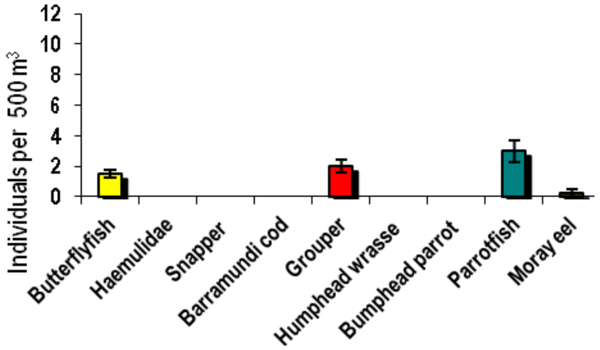


Figure 2.3v(ii). Fish abundance for Sepoi.

Only four fish indicator species were recorded during the surveys and their abundance was very low (butterflyfish 1.5 individuals per 500 m^3, parrotfish 3, moray eel 0.25 and grouper 2) (Fig. 2.3v(ii)). Prized food fish such as Barramundi cod, bumphead parrotfish and humphead wrasse were absent. One blacktip reef shark was observed at this site during surveys.

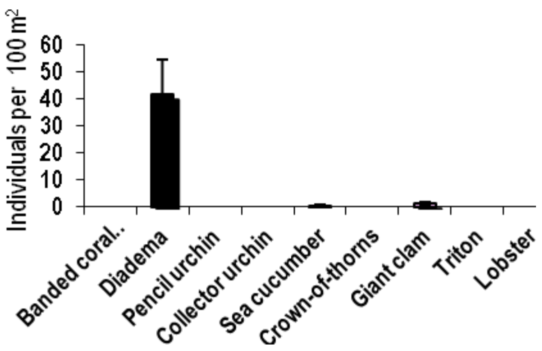


Figure 2.3v(iii). Invertebrate abundance for Sepoi.

Several invertebrate indicator species were absent, including banded coral shrimp, pencil and collector urchin, COTs, triton and lobster. The number of Diadema urchins was high (41.75 individuals per 100 m^2) while the number of sea cucumber (0.5) and giant clam (1.25) was low (Fig. 2.3v(iii)).

Tekek

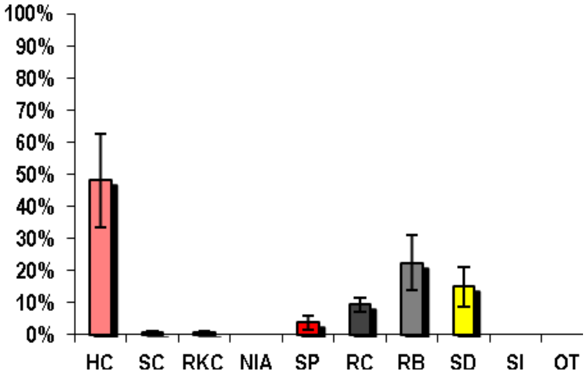


Figure 2.3w(i). Substrate cover for Tekek.

The reef at Tekek was in fair condition with 48.75% live coral cover (48.13% HC and 0.63% SC) (Fig. 2.3w(i)). The amount of RB at this site was high at 22.5%. This site is highly frequented by divers and snorkellers and therefore receives high levels of tourist impacts.

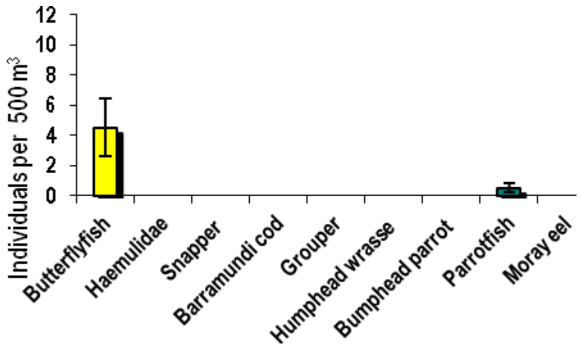


Figure 2.3w(ii). Fish abundance for Tekek.

Most of the fish indicator species were not observed during the surveys (sweetlips, snapper, Barramundi cod, humphead wrasse, bumphead parrotfish, moray eel and grouper) (Fig. 2.3w(ii)). Only two indicator species were present, butterflyfish (4.5 individuals per 500 m^3) and parrotfish (0.5).

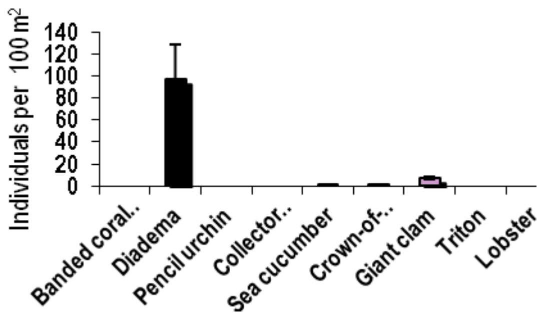


Figure 2.3w(iii). Invertebrate abundance for Tekek.

Diadema urchin was the most abundant invertebrate indicator species recorded at this site. Diadema can cause bioerosion, but is also likely to play a role in controlling NIA at this site, as the level of NIA recorded was low at 0%. The number of giant clam (7.25 individuals per 100 m^2) recorded at Tekek (Fig. 2.3w(iii)) was highest of all sites surveyed in Tioman.

Teluk Tambong

Teluk Tambong is a new site surveyed this year and the reefs were in fair condition with 29.38% live coral cover (18.75% HC and 10.63% SC) (Fig. 2.3x(i)),. NIA level was the highest in this region. The survey site is located near to a river mouth and mangroves and the number of algae grazers was low. However, it is not clear whether the high level of NIA is due to their natural existence at this site or due to pollution. Yearly monitoring at this site will give a clearer picture.

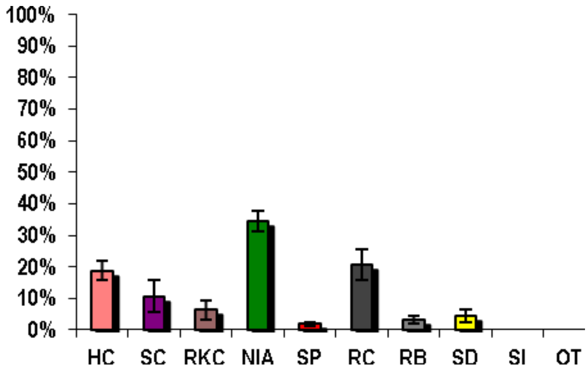


Figure 2.3x(i). Substrate cover for Teluk Tambong.

Only three fish indicator species were observed during surveys and their numbers were low (butterflyfish 4.5 individuals per 500 m^3, parrotfish 0.25 and grouper 0.5) (Fig. 2.3x(ii)). Other indicators such as sweetlips, snapper, Barramundi cod, humphead wrasse, bumphead parrotfish and moray eel were not seen.

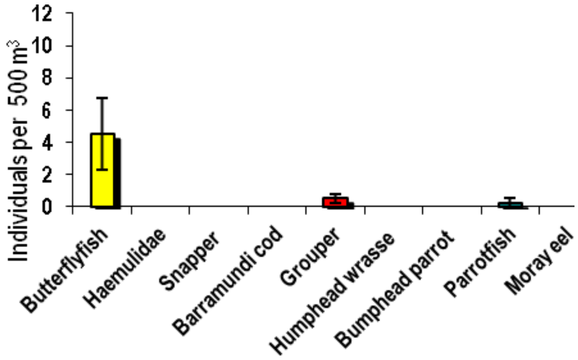


Figure 2.3x(ii). Fish abundance for Teluk Tambong.

Only two invertebrate indicator species were recorded and they were in very low abundance (sea cucumber 1.75 individuals per 100 m^2 and giant clam 0.75) (Fig. 2.3x(iii)). Other indicators such as banded coral shrimp, diadema, pencil and collector urchin, COTs, triton and lobster were not recorded.

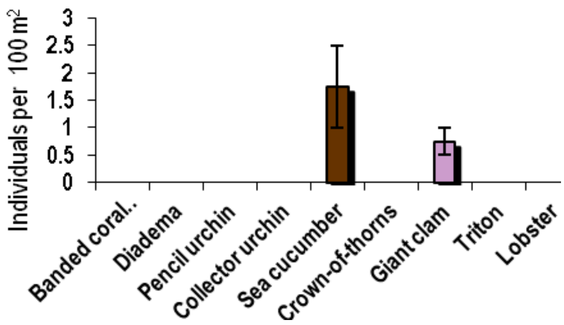


Figure 2.3x(iii). Invertebrate abundance for Teluk Tambong.

Teluk Kador

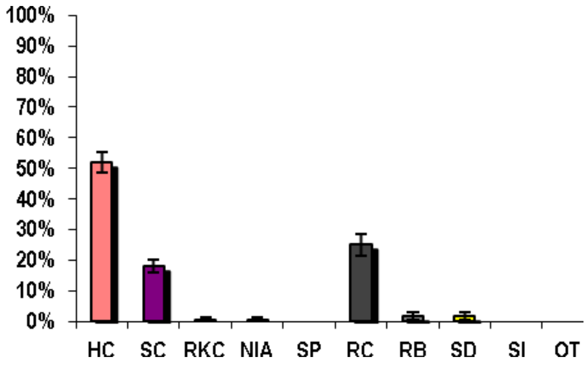


Figure 2.3y(i). Substrate cover for Teluk Kador.

Live coral cover at Teluk Kador was 70% (Fig. 2.3y(i)), placing the reefs under good condition. The level of other substrate categories was low (e.g. RKC 0.63%, NIA 0.63% and SI 0%), indicating few recent disturbances at this site. This is another new site surveyed.

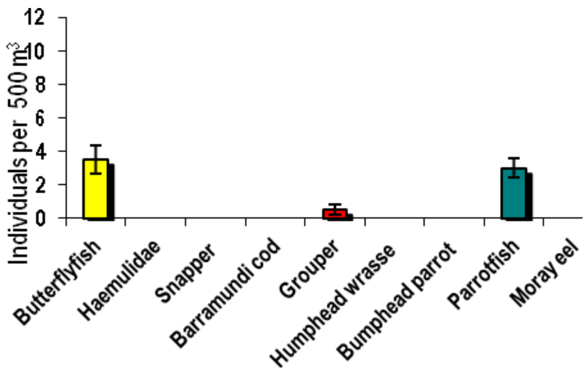


Figure 2.3y(ii). Fish abundance for Teluk Kador.

Most of the fish indicator species were absent during the surveys (sweetlips, snapper, Barramundi cod, humphead wrasse, bumphead parrotfish and moray eel). Only three indicator species were present: butterflyfish (3.5 individuals per 500 m^3), parrotfish (3) and grouper (0.5) (Fig. 2.3y(ii)). One blacktip reef shark was also observed during the survey.

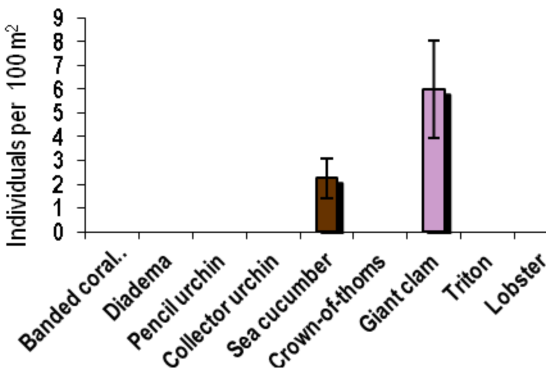
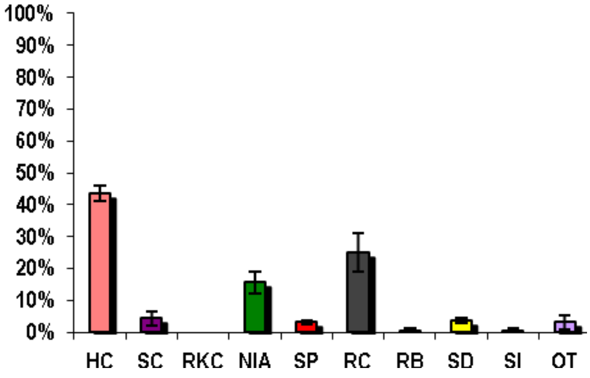


Figure 2.3y(iii). Invertebrate abundance for Teluk Kador.

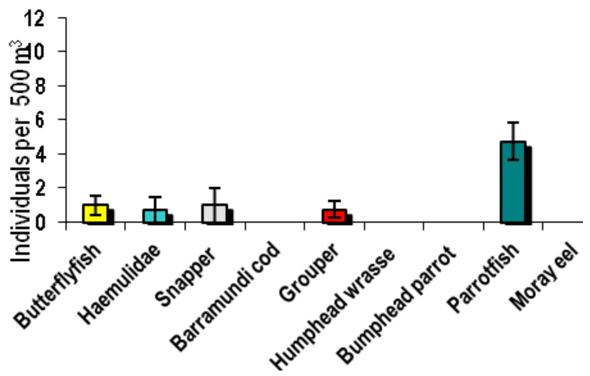
Only two indicator invertebrate species were present during the surveys, sea cucumber (2.25 individuals per 100 m^2) and giant clam (6) (Fig. 2.3y(iii)). Banded coral shrimp, diadema, pencil and collector urchin, COTs, triton and lobster were absent.

Bumphead Bay



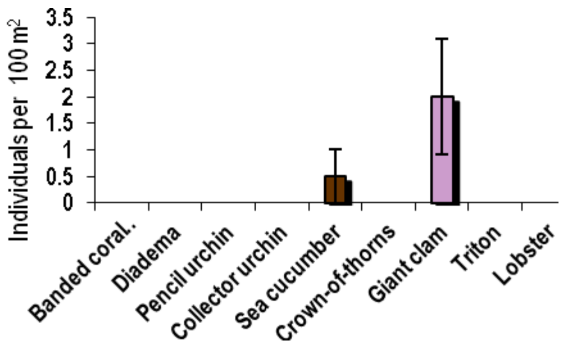
The reefs at Bumphead Bay were considered to be in fair condition with 48.13% live coral cover (43.75% HC and 4.38% SC) (Fig. 2.3z(i)). Although the NIA level was high at 15.63%, this is not cause for concern, as the amount was similar to what was recorded in the previous year. The high amount of RC (25%) reflects the rocky nature of this site.

Figure 2.3z(i). Substrate cover for Bumphead Bay.



Prized food fish such as Barramundi cod, humphead wrasse and bumphead parrotfish were not observed during the surveys. Moray eel was also not observed during surveys. The abundance of most other indicators was low (butterflyfish 1 individual/500 m^3, sweetlips 0.75, snapper 1, parrotfish 4.75 and grouper 0.75) (Fig. 2.3z(ii)).

Figure 2.3z(ii). Fish abundance for Bumphead Bay.



Only two indicator invertebrates species were observed during the surveys and their numbers were low (sea cucumber 0.5 individuals per 100 m^2) and giant clam 2) (Fig. 2.3z(iii)).

Figure 2.3z(iii). Invertebrate abundance for Bumphead Bay.

Lobster Bay

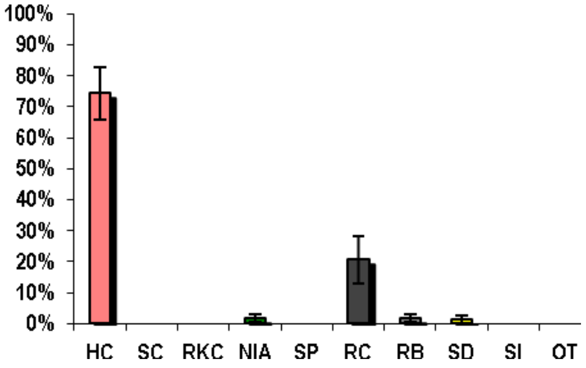


Figure 2.3aa(i). Substrate cover for Lobster Bay.

The reefs at Lobster Bay were very close to being placed in the excellent condition category, with 74.38% live coral cover (Fig. 2.3aa(i)). The high live coral cover was attributed to the high amount of HC. The high amount of RC (20.63%) reflects the rocky nature of this site. Levels of other substrate categories are low (NIA 1.88%, RB 1.88% and SI 0%), indicating few recent disturbances at Lobster Bay.

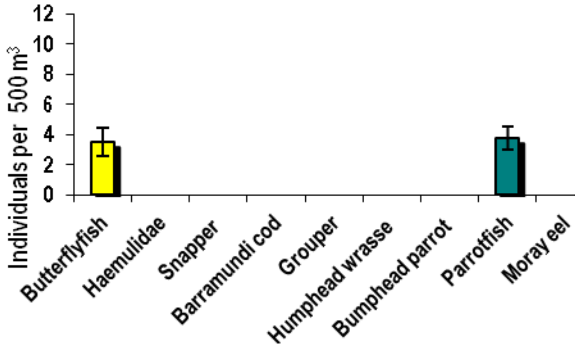


Figure 2.3aa(ii). Fish abundance for Lobster Bay.

Most of the fish indicator species were absent during the surveys (sweetlips, snapper, Barramundi cod, humphead wrasse, bumphead parrotfish and grouper). Only three indicator species were present: butterflyfish (3.5 individuals per 500 m^3), parrotfish (1.69) and moray eel (0.06) (Fig. 2.3aa(ii)).

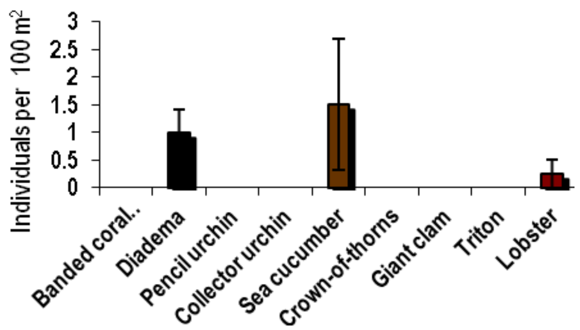


Figure 2.3aa(iii). Invertebrate abundance for Lobster Bay.

Only three indicator invertebrate species were present during the surveys: Diadema urchin (1 individuals per 100 m^2), sea cucumber (1.5) and lobster (0.25) (Fig. 2.3aa(iii)). Banded coral shrimp, pencil and collector urchin, COTs, giant clam and triton were absent.

Old Man of the Sea

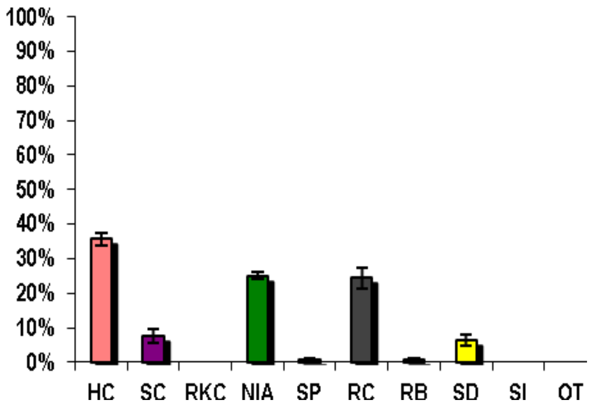


Figure 2.3ab(i). Substrate cover for Old Man of the Sea.

The reefs at Old Man of the Sea were in fair condition with 43.13% live coral cover (35.63% HC and 7.5% SC) (Fig. 2.3ab(i)). The high amount of RC (24.38%) reflects the rocky nature of this site. The amount of NIA is very high at 25%, the highest of all sites surveyed in Pemanggil, and has increased from 12.5% in 2012. However, it is not clear whether the high level of NIA is due to their natural existence at this site or due to pollution (there is no resort or population in the bay). Yearly monitoring at this site will give a clearer picture.

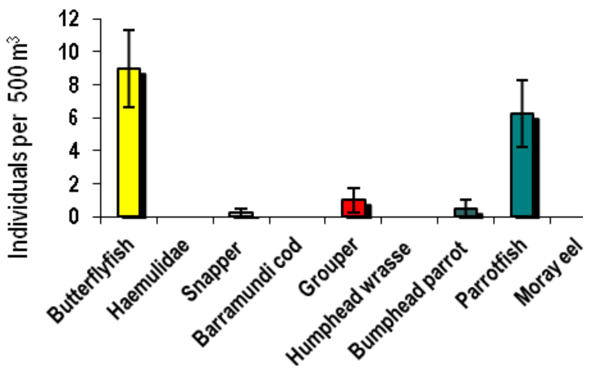


Figure 2.3ab(ii). Fish abundance for Old Man of the Sea.

Five fish indicator species were recorded: butterflyfish (9 individuals per 500 m^3), snapper (0.25), bumphead parrotfish (0.5), parrotfish (6.25) and grouper (1) (Fig. 2.3ab(ii)). Butterflyfish was the most abundant species recorded at this site, and bumphead parrotfish was observed only at this site out of all sites surveyed in Pemanggil.

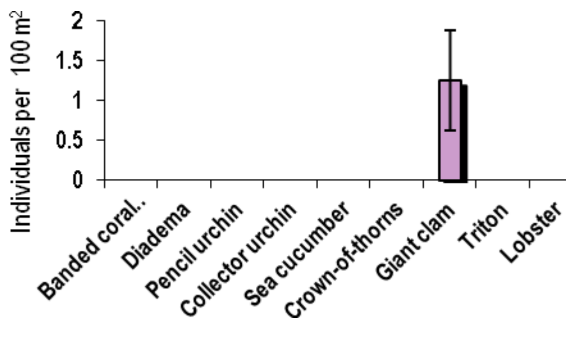
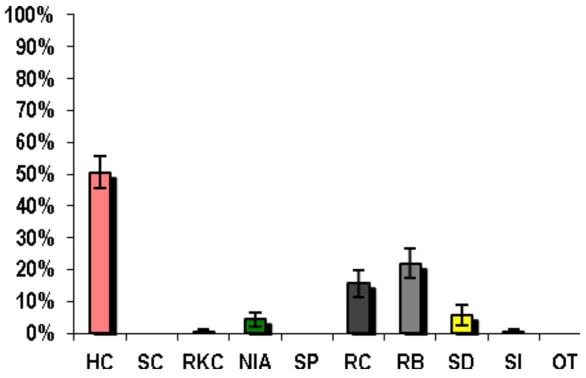


Figure 2.3ab(iii). Invertebrate abundance for Old Man of the Sea.

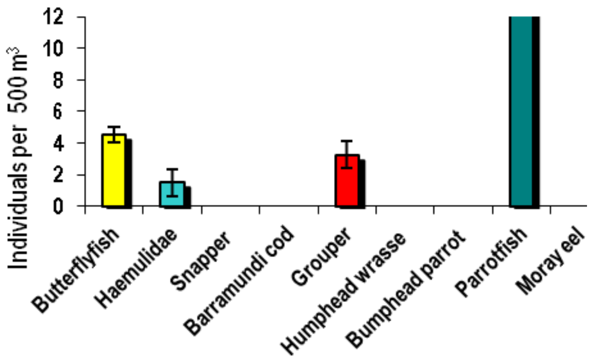
Only one indicator invertebrate species was present during the surveys, giant clam (1.25 individuals per 100 m^2) (Fig. 2.3ab(iii)). Banded coral shrimp, diadema, pencil and collector urchin, sea cucumber, COTs, triton and lobster were absent.

Pemanggil Village South



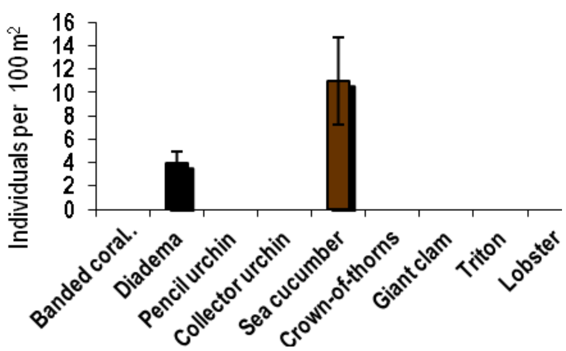
The reef south of Pemanggil Village is a new site surveyed and the reefs were in good condition with 50.63% live coral cover (Fig. 2.3ac(i)). The high live coral cover was attributed to HC. The amount of RB is very high at 22.5%, the highest of all sites surveyed in Pemanggil. This high amount of RB indicates many recent disturbances at the site, which is backed up by the impact surveys where fish trap, boat anchor damage and storm damage were observed.

Figure 2.3ac(i). Substrate cover for Pemanggil Village South.



Only four indicator fish species were observed during the surveys: butterflyfish (4.5 individuals per 500 m^3), sweetlips (1.5), parrotfish (13.5) and grouper (3.25) (Fig. 2.3ac(ii)). Snapper, Barramundi cod, humphead wrasse, bumphead parrotfish and moray eel were absent.

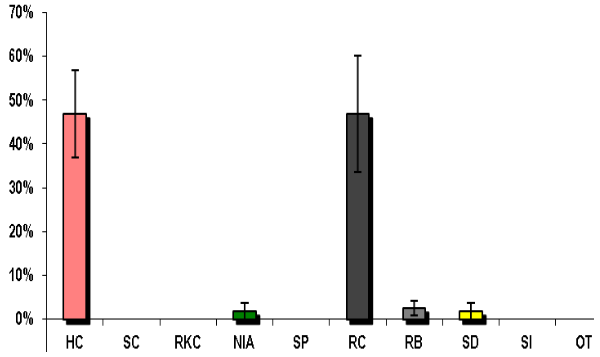
Figure 2.3ac(ii). Fish abundance for Pemanggil Village South.



Most indicator species were absent, including banded coral shrimp, pencil and collector urchin, COTs, triton, lobster and giant clam. The two indicator species present were sea cucumber (11 individuals per 100 m^2) and Diadema urchin (4) (Fig. 2.3ac(iii)).

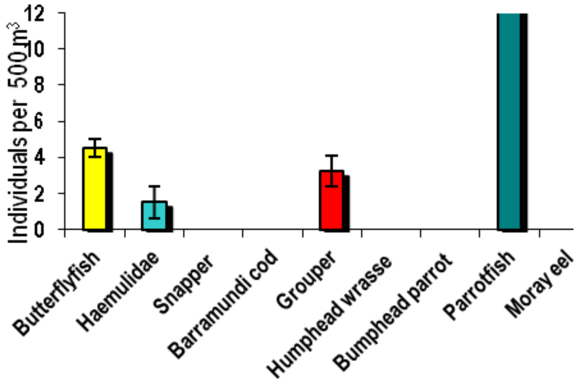
Figure 2.3ac(iii). Invertebrate abundance for Pemanggil Village South.

Pemanggil Village North



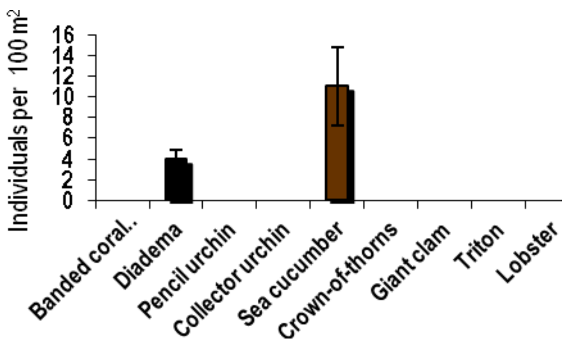
The reef north of Pemanggil Village is a new site surveyed and the reefs were in fair condition with 46.88% live coral cover (Fig. 2.3ad(i)). The high live coral cover was attributed to the high amount of HC. The amount of RC is very high at 46.88%, a significant proportion of which is dead coral. Levels of other substrate categories were low (NIA 1.88%, RB 2.5% and SI 0%), indicating few recent disturbances at Pemanggil Village North.

Figure 2.3ad(i). Substrate cover for Pemanggil Village North.



Four indicator fish species were absent: snapper, Barramundi cod, humphead wrasse and bumphead parrotfish. Parrotfish (18.75 individuals per 500 m^3) was the most abundant species at this site (Fig. 2.3ad(ii)) and had the highest abundance here of all sites surveyed in Pemanggil. Other indicators were present in low numbers (butterflyfish 2.5, sweetlips 0.5 and moray eel 0.25). One hawksbill turtle was also observed during the surveys.

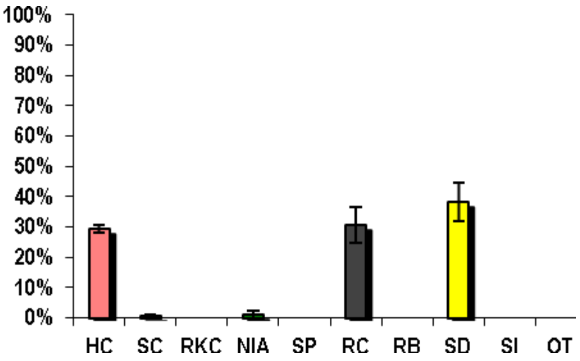
Figure 2.3ad(ii). Fish abundance for Pemanggil Village North.



Three indicator species were observed: Diadema urchin, sea cucumber and COTs. The abundance of sea cucumber (28.75 individuals per 100 m^2) was the highest of all sites surveyed in Pemanggil. Other indicators (banded coral shrimp, pencil and collector urchin, triton, lobster and giant clam) were absent (Fig. 2.3ad(iii)).

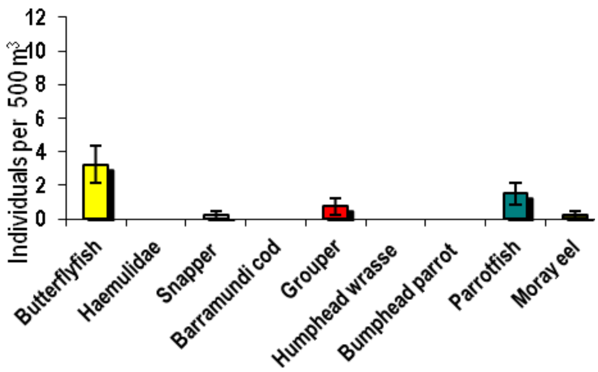
Figure 2.3ad(iii). Invertebrate abundance for Pemanggil Village North.

Tridacna Bay



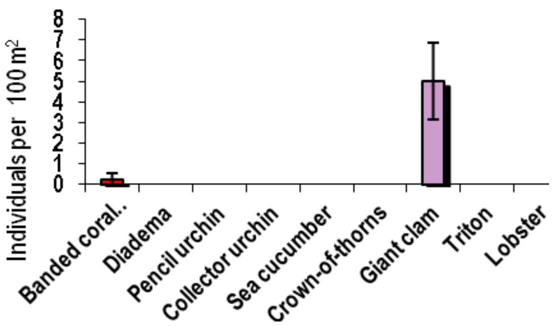
Tridacna Bay is a new site surveyed and the reefs were in fair condition with 30% live coral cover (29.38% HC and 0.63% SC) (Fig. 2.3ae(i)), the lowest of all sites surveyed in Pemanggil. Corals were typically of sheltered, bay-like conditions (i.e. branching and brain/massive colonies). This site had very high SD (38.13%) and RC (30.63%) levels. The low levels of NIA (1.25%) and the absence of RB and SI indicated that recent disturbances were low.

Figure 2.3ae(i). Substrate cover for Tridacna Bay.



Four fish indicator species were absent from surveys: sweetlips, Barramundi cod, humphead wrasse and bumphead parrotfish. Abundance of other indicator species was generally low (butterflyfish 3.25 individuals per 500 m^3, snapper 0.25, parrotfish 1.5, moray eel 0.25 and grouper 0.75) (Fig. 2.3ae(ii)).

Figure 2.3ae(ii). Fish abundance for Tridacna Bay.



Only two indicator invertebrates were observed: banded coral shrimp and giant clam. Banded coral shrimp (0.25 individuals per 100 m^2) was only recorded at this site out of all sites surveyed (Fig. 2.3ae(iii)).

Figure 2.3ae(iii). Invertebrate abundance for Tridacna Bay.

2.4 Discussion & conclusions

Substrate cover

Average live hard coral cover for Tioman Island was 52.50%, indicative of ‘good’ condition and healthy reefs. Most of the sites surveyed (46.15%) were in good condition and 7.69% were in excellent condition. Only 3.85% were in poor condition and the remaining 42.31% were in fair condition. Data from this study compare favourably to previous surveys done by Chou et al. (1994) who reported that only 11.4% of Malaysian reefs were in excellent condition, barely more than half (52.8%) were in good condition and 27.5% were in fair condition. The remaining 8.3% of the reefs were classified as poor. Reef Check surveys in 2012 also showed that reefs in Tioman were just below the “Good” Category with 48.82% live coral cover (Reef Check Malaysia 2013).

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 fish bombing 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 80.63% on one site. Since fish bombing is not practiced in Tioman Archipelago, this suggests that the sites were badly affected by storms. A general trend was noticeable: rubble corals were relatively more abundant at the more exposed sites, such as Jahat West. This is in contrast to the more protected sites, such as Tridacna Bay, where more sand substrates dominated.

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, algae can smother corals by cutting off the sunlight they need for photosynthesis and eventually killing them. This leads to a phase shift from coral- to algae-dominated reefs, which are much less productive than coral-dominated reefs. The level of NIA at most surveyed sites was zero, which could either suggest and herbivory was high and/or that the concentration of nutrients at the study area was not excessive. The low cover of algae may reflect high grazing intensity by herbivorous fishes on these reefs, since grazing pressures control algal abundance, production and distribution in coral reef communities (Carpenter 1988; Paddack et al. 2006). However, this is not the case for Tioman as the herbivorous fish population is low. The possible reason for low NIA is the high density of Diadema urchin. 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).

Recently Killed Coral (RKC) results from a variety of impacts, including bleaching, predation (e.g. by crown-of-thorns starfish and *Drupella* snails) and other local stressors (e.g. sedimentation), while 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 and it indicates few recent impacts on reefs.

Rock (RC) comprises both bare natural rock and dead consolidated coral that has not disintegrated into rubble, nor been colonised by algae or invertebrates. 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 2013 level of 23.82% is within normal range. 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. Similiarly to NIA, sponge will compete for space with corals and can outgrow the slower growing corals, eventually killing them. At 1.8%, the level of SP does not appear to be a threat.

Fish abundance

Butterflyfish, which are used as bioindicators of reef health (Hodgson et al 2006, Koh et al. 2002), were present in low numbers. Though research has shown that the abundance of these fish could be directly correlated with the distribution and abundance of the 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 sign of reef health. For this reason, the low numbers of butterflyfish recorded by this expedition do not mean that the reefs were in poor condition. However the lack of butterflyfish can indicate fishing pressure as they are highly sought after for the aquarium trade (Hodgson et al. 2004).

Though the Tioman Archipelago is protected as a Marine Park, illegal fishing clearly still occurs within its waters and this is reflected in fish abundance. Besides butterflyfish, parrotfish numbers were also low at most sites (average of 3.58 individuals per 500 m^3). Food fish such as grouper, snappers and sweetlips were mostly absent or occurred in low abundance. It is likely that they are being overfished. Illegal fishing activities and fish traps were observed throughout the expedition at various sites

Three species greatly valued for the live fish trade, the Barramundi cod (also for the aquarium trade), bumphead parrotfish and humphead wrasse, were hardly sighted throughout the surveys. These findings are predictable as the absence or low number of these species is a common finding in many studies since the advent of this fishery, and the increasing over-fishing related to human population expansion. According to Hodgson et al. (2004), the absence of these three fish implies that they were or are heavily exploited. Exploitation in the past and current illegal fishing has inhibited population recovery even after more than 19 years of protection on paper.

The lack of target fish and the presence of illegal fishing within the Tioman Archipelago were also reported by Yewdall et al (2013). Greater protection (including enforcement of Marine Park regulations) will be necessary to aid recovery of populations of these species, and ongoing monitoring will help to track their recovery.

Invertebrate abundance

High number of Diadema urchins can result in high bioerosion rates of coral reef substrate and low topographic complexity of reefs (McClanahan & Shafir 1990), causing long-term detrimental effects on their structure and ecology. However, they are also likely to play a major role in controlling NIA (see section above). In the absence of fish grazers, loss or removal of urchins may cause reefs to be dominated by fleshy algae that can outcompete hard corals for light and space (McClanahan et al. 1996). The presence of Diadema urchin in Tioman Archipelago is therefore very important in keeping the reef ecosystem in balance. Their numbers are concentrated around certain sites corroborating the findings of Yewdall et al. (2013) and Reef Check Malaysia (2013), and indicating that predation on small Diadema is not controlling patchy areas of dense populations of the species (McClanahan & Shafir 1990).

Commercially important edible sea cucumbers and giant clam were in low abundance. They are consumed locally and in the past were harvested at a commercial scale 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 (COTS) was present in low number and its scarcity indicates no COTS population outbreaks (Hodgson et al. 2004). Considerable efforts have been made by Marine Park authorities and local dive centres to control COTS numbers by organising regular COTS 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) (Yewdall et al. 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) and their number in Tioman are higher compared to all other islands in the region (Reef Check Malaysia 2013). It appears (from recent research on the Great Barrier Reef) that population explosions of the species are linked to increased levels of nutrients making planktonic survival and settlement more successful.

2.5. Summary & recommendations

Reef health

The reefs around the Tioman Archipelago were generally in good, healthy condition, with 52.50% live coral cover (44.90% HC and 7.60% SC). 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 relatively 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). .

Impacts damaging reef health and suggestions for management

Storm damage

Quite a few factors could have contributed to damage on the reefs of the Tioman Archipelago. Based on the results gathered during the expedition, storm disturbance emerged as the most common 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 in tourists visiting the island each year has resulted in an increase in infrastructure construction. Some of these constructions are poorly planned and do not have appropriate mitigation measures to protect the environment (for example no sewage treatment). This can then result in sedimentation and nutrification of nearby reefs. Infrastructure development should be strictly monitored to ensure minimum land clearing and proper mitigation measures are in place. If properly managed, such developments will not have significant impacts 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 damage was recorded at Soyak South, Tumuk, and Tekek House Reef, which are all sites commonly visited by snorkellers, divers and yachts. It is recommended that awareness campaigns are implemented to educate all reef users on correct reef etiquette to minimise their impacts. These 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 to avoid anchoring on reefs.

Illegal fishing

There are regular reports of illegal fishing inside the 2 nm (nautical miles) protected area and a few instances were observed during the expedition. These often occur early in the morning and late in the evening when there are fewer tourists at the sites. Fish nets and traps were also observed during surveys, but were generally found at isolated sites. Illegal fishing within the MPA is likely to be one of the main reasons for the low abundance of fish observed during surveys. MPA rules must be enforced and locals must be made aware of why a no-take area is important in ensuring fish stocks survive. They must also be made aware of the benefits of no-take areas to their community.

Solid waste disposal

The high number of tourists visiting Tioman generates a huge amount of waste, putting significant strain on waste collection and disposal systems. There is an incinerator at the main village, but it is not the ideal solution, as the incinerator cannot handle the amount of waste currently being generated. There is a need to promote waste segregation among resorts and the local villagers, to allow easier recycling of wastes, composting of organic wastes 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 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 the facilities to promote recycling on the island. Government must put in 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, so 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 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.

Future expeditions

It is recommended that in the future Pulau Tengah, Pulau Besar and Pulau Kecil are included in the survey sites. These islands were not covered in past expeditions and the conditions of their reefs are unknown. However, new sites should only be added if all the old sites can also be monitored. Although it is important to understand the condition of reefs at as many sites as possible, Reef Check data makes most sense when it is continuous and repeated over long periods of time.

There is also a need for more sites to be surveyed along the east of Tioman. Currently most of the sites surveyed are located to the west of Tioman. Covering more sites to the east will give a better representation of the island's reefs.

It is also advised that more permanent transects need to be placed to ensure monitoring of the same reef areas, which will then give more accurate data on changes occurring on the reef.

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Appendix I: Expedition diary and reports

A multimedia expedition diary is available at http://biosphereexpeditions.wordpress.com/category/expedition-blogs/malaysia-2013/.

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