EXPEDITION REPORT

Expedition dates: 18 March – 27 April 2012

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Paradise in peril: studying & protecting reefs, sharks, dolphins and turtles of the Pulau Tioman Marine Park, Malaysia

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Biosphere Expeditions

Abstract

Tioman and surrounding islands are a popular tourist destination with visitors being attracted by the abundant marine life. The region, however, is under threat from a number of different impacts, not unlike other regions in the Indo-Pacific Ocean.

Reef health assessments, using the Reef Check methodology, were carried out by a group of volunteers and scientists in March and April 2012. Health was found to be generally fair to good, but there are definite threats to this health status. On-land development, particularly on the mainland, poses the highest risk to the reefs in the South China Sea, because of resulting sedimentation. Widespread illegal fishing, despite clear but unenforced fishing bans in the Marine Park, is also a concern, causing overfishing. The use of fish traps is another concern, causing localised, devastating damage to the reef. Irresponsible diving and snorkelling activity is also an issue, albeit a small one at current levels, but boat anchor breakage is a higher priority. Crown-of-thorns starfish are undoubtedly causing a decline in reef health. However, ambiguity exists on how to manage these predators. Finally, warm water coral bleaching is responsible for a large die-off of corals in the last decade or more.

On the whole, the islands have a very good chance of recovery and increase in health, but only if marine park management and other government authorities prioritise the needs of these financially essential reefs. Fishing needs to be better regulated as does on-land development, both on the island and the mainland. Education of locals and tourists is also key to protecting this unique and beautiful group of islands and their reefs.

Abstrak

Tioman dan pulau-pulau di sekitarnya adalah destinasi pelancong yang popular dengan para pengunjung tertarik dengan kehidupan marin yang banyak. Rantau ini, bagaimanapun, adalah di bawah pelbagai ancaman, serupa rantau lain di Lautan Indo-Pasifik.

Penilaian kesihatan terumbu, menggunakan kaedah Reef Check, telah dijalankan oleh sekumpulan sukarelawan dan saintis pada bulan Mac dan April 2012. Kesihatan terumbu secara amnya berada dalam keadaan sederhana ke baik, tetapi terdapat ancaman yang jelas terhadap status kesihatan ini. Pembangunan, terutamanya di tanah besar, merupakan risiko tertinggi terhadap terumbu di Laut China Selatan, disebabkan oleh pemendapan. Penangkapan ikan secara berleluasa di Tioman dan undang-undang yang tidak dikuatkuasakan menyebabkan penangkapan ikan berlebihan. Penggunaan bubu merupakan satu kebimbangan, menyebabkan kerosakan setempat yang teruk kepada terumbu. Aktiviti menyelam dan snorkeling yang tidak bertanggungjawab merupakan satu isu juga, walaupun adalah satu isu yang kecil pada masa kini, tetapi kerosakan yang disebabkan oleh sauh bot adalah lebih besar. Tapak sulaiman mahkota berduri juga menyebabkan kemerosotan kesihatan terumbu. Walau bagaimanapun, wujudnya kekaburan tentang bagaimana untuk menguruskan pemangsa ini. Akhirnya, kelunturan karang disebabkan oleh air suam bertanggungjawab terhadap kematian karang yang banyak dalam satu dekad yang lalu atau lebih.

Secara keseluruhan, Tioman mempunyai peluang yang sangat baik dalam pemulihan dan peningkatan kesihatan terumbu, tetapi hanya jika jabatan taman laut dan pihak berkuasa kerajaan yang lain mengutamakan keperluan dan kepentingan terumbu ini. Aktiviti memancing dan pembangunan perlu dikawal dengan lebih baik, di pulau dan di tanah besar. Pendidikan kepada penduduk tempatan dan pelancong juga penting untuk melindungi keunikan dan keindahan kumpulan pulau-pulau ini dan terumbunya.

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1. Expedition Review

M. Hammer & A. Stickler (editors)
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 18 March to 27 April 2012. 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 a Reef Check EcoDiver.

Pulau Tioman is located 40 km off the east coast of the Malaysian peninsular. 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.

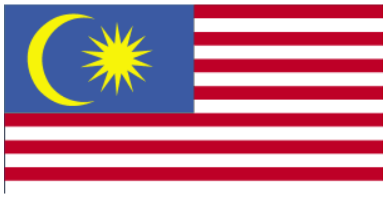

Figure 1.2a. Flag and location of Malaysia and study site.

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 dive sites and conduct surveys at hard-to-reach locations.

1.3. Dates

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

18 – 30 March | 1 – 13 April | 15 - 27 April 2012.

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. 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 posted an expedition diary to www.biosphere-expeditions.org/diary for friends and family to access. Excerpts of the diary with multimedia content such as pictures and video clips also appeared on the Biosphere Expeditions' social media sites such as Facebook, Google+ and the Wordpress blog.

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. There were no serious medical incidences during the expedition. There was one instance of ear infection, which was treated at Tekek clinic and prevented a participant from diving for a few days.

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, diving skills and knowledge of the species.

1.5. Expedition scientist

Katie Yewdall was born in the UK, but has spent more than half her life in Asia. She has a degree in Zoology with Marine Biology from Newcastle University and a Masters Degree in Environmental Monitoring from King's College, London. Katie has worked in conservation, research and the environment since leaving university in many areas of the world, recently focusing on research and conservation of coral reefs in Asia. She works closely with a number of national and international universities as well as the local governmental authorities to improve management of the Pulau Tioman Marine Park, as well as conducting awareness-raising projects in the local villages. Katie is also PADI Divemaster and a Reef Check trainer with over 1500 dives, the majority of them being research dives.

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 – 30 March 2012: Virginie Burck (La Reunion, France), Michael Enders (Germany), Ho Ching Kam (Hong Kong, China), Maarten Ridder (The Netherlands), Frank Volz (Germany). Also Kathy Gill (UK), Biosphere Expeditions' strategy director for part of the group.

1 – 3 April 2012: Gavin Haines (UK), Edzard Hoefig (Germany), Julia Hoefig (Germany), Rebecca Lock (UK).

15 – 27 April 2012: Christine Champneuf (France), Karole Dwyer (UK), Holly Dwyer (UK), Julian Thaler (Switzerland), Georgina Treherne (The Netherlands).

The skipper throughout the expedition was Hyton Hines, a qualified yachtmaster from South Africa, with much experience of ocean crossings and skippering charters.

1.8. Partners

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

Logistical partners were 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 £1390 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	17,065
Expenditure	
Research vessel & accommodation includes all board & lodging on land & sea, ship's crew, fuel & oils, other services	7,579
Equipment and hardware includes research materials & gear or hired purchased in UK & Malaysia	1,282
Staff Includes local and international salaries, travel and expenses	8,186
Administration includes registration fees & sundries	74
Team recruitment Malaysia as estimated % of PR costs for Biosphere Expeditions	6,400
Income – Expenditure	**- 6,456**
Total percentage spent directly on project	**138%***

*This means that in 2012, the expedition ran at a loss and was supported over and above the income from the expedition contributions and grants by Biosphere Expeditions.

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. 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

The importance of coral reefs

Coral reefs are well known to be valuable both in terms of their ecological role and their financial one. They are the oldest natural community on earth and support up to 90% of the marine organisms currently existing (Bryant et al. 1998). Hard corals provide the important structure on and around which the many other reef invertebrates, fish, reptiles and mammals rely. Hundreds of thousands of people living along coastlines also depend on reefs for their survival. The marine environment provides them with ready protein, and for some communities, it is the only protein they have access to. Coral reefs also provide billions of dollars of revenue from the fishing and extraction industry, as well as the tourism industry (Hatziolos et al. 1998). Beach, scuba diving, snorkelling, kayaking and sailing tourism would not exist in their current forms without these vital ecosystems, and potentially, neither would much of the rest of the life in the oceans Bryant et al. 1998). In addition, reefs provide essential protection to 20% of the world's coastline, without which, beach and land erosion would be extensive (Hatziolos et al. 1998). Finally, coral reefs provide huge potential for medical and cosmetic applications (Bryant et al. 1998).

Status of coral Reefs in South East Asia

Coral Reefs in South East Asia are estimated to cover around 100,000 km^2, which is 34% of the oceans' coral reefs. These extensive reefs have 600-800 species of scleractinia corals, the highest coral diversity in the world (Amri et al. 2008, Wilkinson, 2008). The area also has up to 1000 species of marine fish (Allen & Werner 2002). However, overfishing, destructive fishing, pollution and sedimentation mean that close to 90% of the area's reefs are at risk of severe degradation (Burke et al. 2002, Amri et al. 2008). Their loss would have a serious socio-economic impact as communities in the region rely so much upon them for food security, fishing and tourism revenue and costal protection. Loss of revenue may run into millions of dollars.

Malaysia has around 69 coral genera. The reefs around the study site, Tioman Island, have 221 species of hard coral from 14 families (Amri et al., 2008). Published studies indicate fish diversity to be high also at 326 species from 55 families, although research by Blue Ventures Conservation (unpublished), indicates there may be up to 60 species more. In addition, Tioman Island has the highest hard coral cover of the islands along the east coast of the peninsular with Reef Check Malaysia finding 56.3% hard coral cover in Tioman versus 50.2% in Perhentian 38.3% in Redang and 26.4% Aur in 2008 (Reef Check 2008).

Although Malaysia is not quite as economically poor or as biologically rich as other nations in the Coral Triangle, its reefs are still very valuable to its people, with a potential value of US$ 12.7 billion per annum (Wilkinson 2004 & 2008) They are also under just as much pressure as other reefs in the region; threatened by an increasing population and other global coral reefs impacts, such as coral bleaching, climate change and ocean acidification. In fact, Burke et al. (2002) estimate that, along with Indonesia, 85% of Malaysia's reefs are under threat, the main threat in peninsular Malaysia being development on land.

The study site itself, Tioman Island, is a marine park and various rules are in place to protect its reefs. However, the regulations are poorly implemented. Threats to the reefs include overfishing, use of destructive fishing methods, plagues of Crown-of-Thorn starfish, warm water bleaching, irresponsible diving and snorkelling practices and sedimentation from various land development projects. Considering this lack of enforcement, threats to the reef, plus plans in place to develop the island further, means that the area deserves closer inspection and higher levels of protection to ensure it retains its title of healthiest reef in the area.

Figure 2.1a. Location of the Tioman group of islands. Image taken from Google Earth.

The Tioman group of islands and threats to its reefs

The main island of Tioman is the most developed with a small airport, 5 km of paved road, a large school development, one large resort and a number of smaller chalet operators and diving schools. Most of the development is focused on the north-west coastline. The east and south coast of the island, as well as surrounding islands such as Pulau Permangil, are less developed and, therefore, the communities rely more heavily on fishing. Many islands, such as Tulai, Seri Buat, Jahat and Sepoi have no inhabitants at all.

The main impacts acting upon reefs in this region appear to be: Tourism and coastal development leading to pollution and sedimentation, illegal fishing activities and destructive fishing practices, Crown-of-Thorn starfish populations explosions and warm water bleaching.

Tourism and coastal development

Locals recall how Times Magazine once voted Tioman Island into the top ten most beautiful islands in the world. This accolade was apparently bestowed in the 1970s and many, in part, explains the stream of tourists coming to visit the island. Tourist numbers have been fairly stable over the last 10 years, ranging from a high of 249,025 in 2004 to a low of 172,787 in 2003 with the most recently available figure of 194,392 in 2009 (Tioman Development Agency Data). Tourists come to enjoy the beach, to go swimming, kayaking, snorkelling and/or diving. Although there are no data to support this, it is safe to say that the island's current economy is based heavily on marine tourism revenue and that a loss of the clear waters and aesthetically pleasing marine environment would result in the loss of this revenue.

Tourism itself can sometimes bring about the degradation of the natural systems that underpin it. Irresponsible tourist activities such as collecting marine souvenirs, breaking fragile corals, touching and harassing marine life, feeding marine creatures, oil and fuel spills from boats and littering, if done on a large enough scale, all contribute to the problem.

Development on the island is slow compared to islands in a number of other nations on the continent, such as Thailand, but what development there is seems to be carried out without much consideration of its environmental impact. For example, a new marina was built, crushing a fringing reef system, just a few years ago. Many villages have an oversized concrete jetty. The new ferry terminal building, right on the edge of the coastal zone, has just been completed, as well as an extensive school complex. A beach regeneration program and waterfront promenade has also been completed in the last few years, all for an island of just 37 km long and a community of just 3300 people. There are plans for a new and bigger airport; plans that suggested a 2 km runway built out into the ocean, development of a more extensive road system and a new land reclamation project 30 km away on the mainland peninsula.

On land development and deforestation cause soil and minerals to leach from the land surface, run into rives and finally the ocean. Scleractininia corals suffer when exposed to high levels of sedimentation as a layer of silt prevents both light from permeating through to the polyps, as well as preventing tentacles from filtering food from the water column.

In addition, further development and an increase in tourists will lead to an increase in sewage and solid waste, which, if not properly managed, will further degrade and harm the environment.

Fishing and destructive fishing practices

Fishing used to provide the main source of income and subsistence for villagers on the islands, before tourism became established. No data exist to quantify fishing. However, visitors and divers regularly report rod and line fishing from small boats and jetties around the island. Many local people still own fishing boats and fishing gear such as gill nets, seine nets and fish traps and fishermen are regularly seen fishing with these within the marine park area. They mainly target reef fish, pelagic fish and squid. The most popular form of fishing within the shallower marine park area, and potentially the most physically destructive in this case, are the fish traps. Large cages around 3 m long by 1.5 m wide are dropped from boats onto reef habitats and left for a few days.

Fishermen return and tow a small weighted anchor along the sea-bed in the vicinity of the drop site until it hooks onto the cage. The cage is then pulled up onto the boat. The method at least prevents juvenile fish from being caught, but the physical damage caused to the bottom composition is extensive and lasting.

This fishing activity is despite a ban on all forms of fishing as per the Department of Marine Parks of Malaysia rules. Many individuals around Tioman and surrounding islands consider themselves fishermen, especially outside of the north-west coastal villages of the main island. It is not known how much of an effect this illegal fishing has on the health of the reefs or how much of a 'hang-over' effect the previously more intensive fishing activity has left. With 'fishing villages' being small, populations of just 100 – 300 people (Tioman Development Agency data), potentially fishing levels are low enough to not have a substantial effect on the health of the reefs, but there are no data to support this conjecture.

Crown-of-thorn starfish (COTS)

COTs are known to be highly destructive (Saloman et al. 2011, Richmond and Wolanski, 2011) and tend to appear suddenly in very large numbers, or outbreaks. COT populations can reach levels where their numbers overwhelm entire coral reefs. Outbreaks are thought to occur due to a lack of predators (Uthike et al. 2009) including *Charonia tritonis*, the triton shell, which is highly valuable curio item and has become almost extinct due to collection for sale. and/or an increase of nutrients in the water to feed their planktonic young (Birkland 1982). Nutrients in the water are usually caused by sewage or fertiliser run-off from human developments. Both these effects are caused by anthropogenic impacts. However, another school of thought is that COT plagues are natural and are simply following cyclical predator/prey dynamics (Vine 1971, Morgan et al. 1986). As the prey, *Acropora* sp. coral, increases in abundance, a bounty of food allows the COT predators to grow and reproduce rapidly. In time, prey species will decline due to heavy predation. A lack of food for predators will lead to a COTS population crash and prey species can once again flourish. It is thought that this natural cycle, as COTs mainly target *Acropora*, controls the growth of fast-growing corals, allowing slower species to colonise. Therefore, Vine (1971) and Morgan et al. (1986).argue, outbreaks actually increase diversity in the long run.

A lack of definitive research in this area means that managers are uncertain of how to react when COTs move in. The natural predator/prey cycle could take many decades to play out, with local reefs going through a long period of unattractive bad health that leaves the island's tourism operators without a product to sell. Tioman's park managers, as well as a number of dive centres, attempt to control COTs numbers by removing or poisoning individuals, following best practice advise from a number of experts. However, not enough is known about whether this could be damaging the diversity in the long term.

Warm water bleaching

Bleaching can occur when scleractinina corals come under thermal stress (Brown et al. 1997). Zoozanthellae inside the coral polyps are ejected when water temperatures vary just one or two degrees outside of the natural range for the area. Without zoxanthallae, corals lose 80% of their energy source as they consume amino acids produced via photosynthesis by these algae (Brown et al. 1997, Gates et al. 1992).

Bleaching has been seen on a large scale a number of times with mass events being recorded in South East Asia in 1998 and again in 2010. It is thought that cycles of water warming is naturally occurring, along with the El Nino weather phenomenon and once temperatures reduce, corals are able to recover. However, it can lead to massive hard coral loss that, coupled with other impacts, can be irreparable.

Figure 2.1b. Bleaching on a Tioman Island reef, May 2010.

Reef Check survey

Reef Check's survey method uses simple techniques to collect scientifically robust data. This methodology is specially designed for recreational divers that might not have scientific background, so training has to be precise, rapid and understandable in order to guarantee that organism identification is accurate (Hodgson et al. 2006).

To understand the health of a coral reef, Reef Check bases its data collection on "indicator organisms" that are defined as organisms that reflect the conditions of the ecosystem. These indicators can be individual species or even a family. The important thing is that each of these indicators has an economic or ecological value, is sensitive to anthropogenic impacts and easy to identify. A Reef Check team collects four types of data (Hodgson et al. 2006): Site description referring to environment, socio-economic and human impact conditions; fish indicator species count; invertebrate indicator species count; recording different substrate types (including live and dead coral).

Site description data are collected prior and after the dive and all other data are collected along a 100 metre transect, at two depth contours, between 2 to 5 metres and between 6 and 12 metres (Hodgson et al. 2006).

Aims of this research

Various researchers and organisations, including Reef Check Malaysia, have carried out studies in the area, but studies have mainly been limited to sites within easy access of the dive centers fringing the north west coast of the island. In addition, a few (except 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 are 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) add to work already done and to extend studies to sites that have not yet been studied. The aims of these objectives are to (1) gain a fuller understanding of the Tioman group of islands' reefs, (2) feed this information back to park management and (3) disseminate ecological information to the scientific community.

2.2. Methods

Reef Check methodology

The Reef Check coral reef survey method is a standardised, simple methodology that allows data to be collected by volunteers with no previous experience of ecological study. By allowing anyone to be trained to collect the data, Reef Check increases the amount of data that are collected. The standardised nature of the method allows large amounts of data to be compared across the globe, leading to a fuller, more rounded understanding of what is occurring across the planet's oceans. Reef Check surveys serve as an early warning mechanism and a baseline data set that can be built upon by more specialised scientists. They also encourage an increased awareness in the general public of the issues facing the marine environment, with the hope that more people will become actively involved in the protection of it.

All data were collected by team members that passed through an intensive Reef Check training and testing procedure. A project scientist and an expedition leader coordinated team members on the expedition. The primary responsibilities of both were to train 13 team members in Reef Check methodology and also to coordinate and supervise the subsequent surveys and data collection.

Site selection and transect placement

The Reef Check survey protocol utilises two transects at depths between 2 - 5 metres (shallow dive) and 6 - 12 metres (medium dive), chosen for practical reasons of dive duration and safety. Along each depth interval, shallow and medium, four 20 metre long line transects are surveyed with a 5 metre space interval between transects. The distance between the start of the first transect and end of the last transect is, therefore, 95 metres.

An ideal Reef Check team includes six members (three buddy pairs, each pair responsible for fish, invertebrate and substrate data collection respectively) plus support crew, each with different specialties and experience.

The Reef Check methodology is adapted by region and the area used for this expedition was the Indo-Pacific region. Full details of the methodology and regular updates can be found on the Reef Check website www.reefcheck.org.

Sites chosen were roughly evenly distributed around the islands and included sites with varying proximity to settlements and river mouths. By choosing sites distributed around this group of islands, the localised, varying effects of impacts could be assessed, as well as getting a more rounded picture of what is happening in the region as a whole. Only coral-dominated communities were chosen and focus was on sites with fairly flat, even reef surfaces, which are best suited to this type of survey method. Table 2.2a lists the sites surveyed and the geographical location group of the site. Figure 2.2a shows a map of all the sites chosen.

21 sites were surveyed on this expedition, some with one, some with two survey transects, resulting In a total of 35 100 m transects, each made up of four surveys. Group 1 surveyed 7 sites, with 14 transects, Group 2 surveyed 7 sites with 12 transects, Group 3 surveyed 4 sites with 6 transects and Group 4 surveyed 3 sites with 3 transects.

Many of these sites were pilot surveys and the suitability of the sites for future surveys was also assessed. For this reason, the method of placing transects randomly within homogeneous areas was chosen. An element of known bias was introduced to ensure areas chosen were representative of coral reef habitat as a whole, not a sandy, rubble or sea grass habitat.

One 100 m tape was used as the transect reference. The first buddy team to enter the water attached the beginning of the tape to a randomly chosen non-living substrate. The tape was laid along the surface of the reef, ensuring the depth remained constant. Four 20 m surveys were carried out along the tape with a gap of 5 m between each one to yield four independent samples.

Table 2.2a. Sites surveyed by the expedition, depths of transects and location grouping.

Site surveyed	Depth of surveys	Group
Batu Malang	5m and 9m	2
Bugis Bay	4m and 7m	1
Bumphead Bay (our name), Permangil Island	4m and 11m	3
Chebeh Island	5m and 10m	2
Jahat Island	5m and 11m	1
Juara Bay South, Tioman Island	5m and 8m	1
Juara rocks, Tioman Island	4m and 5m	1
Labas Rocks	8m and 9m	2
Lobster Bay (our name), Permangil Island	4m	3
Old Man of the Sea (our name) Permangill Island	4m and 11m	3
Pirate Reef, Tioman Island	11m	2
Renggis Island, north	5m and 9m	2
Rock 'n' Roll bay (our name), bay south of Telok Dalam, east side of Tioman	4m and 7m	1
Sepoi Island	4m and 8m	2
Seri Buat east island, Mangrove Inlet,	4m	4
Seri Buat east island, Outer reef,	5m	4
Seri Buat, east island, Between Islands	5m	4
Slasher Beach (our name), Permangil Island	7m	3
South of Lanting lighthouse, Tioman Island	4m and 7m	1
Telok Dalam, Tioman Island	5m and 9m	1
Tumuk, Tioman Island	7m	2

Figure 2.2a. Sites surveyed around Tioman and surrounding islands. Group 1 sites are marked in pink, group 2 sites are yellow, group 3 sites are green and group 4 sites are red. Image taken from Google Earth. Inset images not to scale.

Site description

A description of the site was written according to observations made during and after the survey and from previous knowledge of the 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 estimates of the distance to the nearest settlement and nearest river were made and a GPS point was taken.

After data collection, it was noted that sites in the same geographical location had similar impacts acting upon them (as recorded by the site description data). Sites were grouped according to these geographical proximities and impact similarities for a number of analyses. Grouping sites together increases the repetition of sampling within that location, which makes the data more meaningful and robust. It also allows for the effects of the various impacts to be assessed.

Fish belt transect

Four segments of 5 meters height, 5 m width by 20 m length (centred on the transect line) were sampled for fish that are typically targeted by fishermen or aquarium collectors and that are sensitive to impacts. In the Indo-Pacific these species and families are any grouper (Serranidae) over 30 cm, sweetlips (Haemulidae), snappers (Lutjanidae), parrotfish (Scaridae) over 20 cm, butterflyfish (Chaetodontidae) and moray eel (Muraenidae). Quantitative counts were made of each species/family. Three more species are counted in the Indo-Pacific Reef Check, but were not taken as species to look for since they do not exist in the area: the Barramundi cod (*Cromileptes altivelis*), the humphead wrasse (*Cheilinus undulates*) and the bumphead parrotfish (*Bolbometopon muricatum*).

The same four 5 m wide by 20 m long transects (centred on the transect line) were also sampled for invertebrate taxa typically targeted as food species or collected as curios. The taxa counted were: banded coral shrimp (*Stenopus hispidus*), long-spined black sea urchins (*Diadema* spp.), pencil urchin (*Eucidaris* spp.), collector urchin (*Tripneustes* spp.), three edible sea cucumbers species (*Thelenota ananas*, *Stichopus chloronotus*, *Holothuria edulis*), lobster (all edible species) and triton shell (*Charonia tritonis*). Quantitative counts were made of each species/family.

During the invertebrate survey, anthropogenic impacts were also assessed. These included coral damage by anchors, dynamite, or ‘other’ factors, and for trash. Trash is divided by type, i.e. fishing nets or simply ‘other’. Divers valued the damage caused by each factor 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 measured along each 20 m transect.

Substrate line transect

Four 20 m long transects were point sampled at 0.5 m intervals to determine the substratum types on the reef. The categories recorded at 50 cm intervals 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).

Impact Assessment

Also within the same 5 m by 20 m belt transect used for invertebrate sampling, an impact assessment was done. A number of impacts were identified and a rating for each impact was given. The ratings ranged from 0 (none) to 3 (high). Impacts were: coral damage - boat/anchor; coral damage – dynamite; coral damage – other (inclusive of predation); trash – fish nets; trash – general.

Bleaching and incidence of disease was also recorded, but a percentage for the whole transect was given for these categories: bleaching of population (% affected by bleaching); bleaching of colonies (average % of each colony that is bleached); white band disease (% of population affected by disease); black band disease (% of population affected by disease).

Data analysis

All data were entered on underwater slates and subsequently transferred onto Reef Check Excel sheets. Belt transect data were used to calculate the mean abundance of each fish and invertebrate taxa. 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.

The data was averaged across the whole area to give an idea of the status of the reefs across the region. It was then grouped according to location and again a mean for that group was calculated. The non-parametric Kruskal-Wallis test was used to determine the significance of differences between the location groups. This allowed the data to reveal if the different impacts acting upon that location were causing an effect.

Note on statistical conventions: the results of statistical tests are given by showing the 'p' (probability) value of the test. Results that are significant at the p <.05 level are commonly considered statistically significant and p <.005 or p <.001 levels are often called "highly" significant

2.3. Results

Fish community (regional)

The fish most often encountered on the fish surveys were butterflyfish and parrotfish, with snappers and groupers being the other notable sighting. Few sweetlips, barramundi cod, bumphead parrotfish and moray eels, and no humphead wrasse were seen. Figure 2.3a shows the average counts per 20 m sample area.

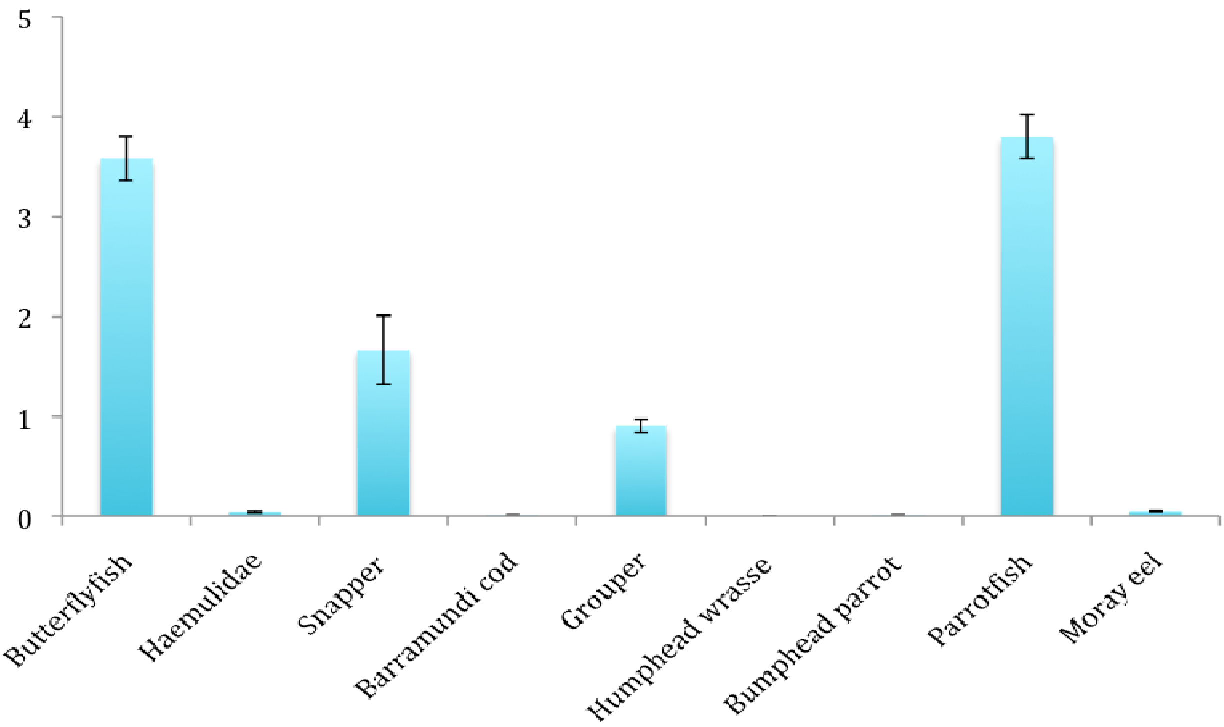

Figure 2.3a. Mean abundance of fish indicator species found per 20 m belt transect transect across all sites in the Tioman group of Islands.

The number of groupers counted in each size class across the entire region was shown to be significantly varied ($p < 0.01$). Figure 2.3b shows significantly more smaller groupers than larger ones, on average, counted per 20 m fish belt.

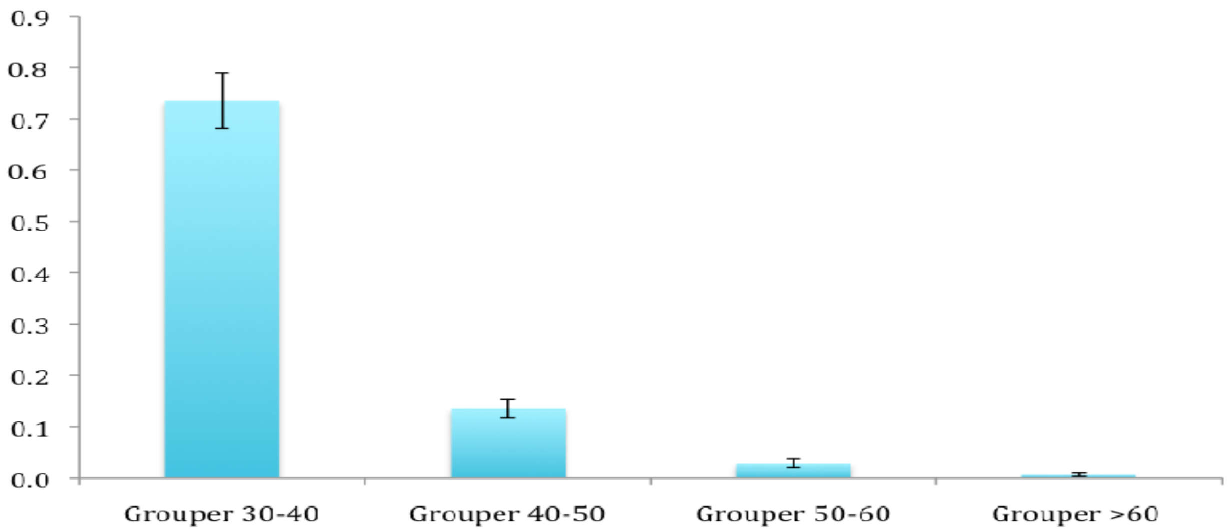

Figure 2.3b. Mean abundance of groupers per 20 m belt transect in each size category across the Tioman island area.

Comparing geographic locations

Figure 2.3c shows the average abundances of indicator fish broken down by geographically located groups of sample sites. The abundance of individuals were not found to be significantly different for butterflyfish ($p = 0.83$), sweetlips ($p = 0.12$), snappers ($p = 0.54$), barramundi cod ($p = 0.18$), bumphead parrotfish ($p = 0.18$) or moray eels ($p = 0.81$) when comparing data across the four locations. However, grouper abundance was statistically different across the four groups ($p = 0.01$), as was parrotfish abundance ($p = 0.03$). Group 2 and 3 recorded most groupers and group 1 most parrotfish.

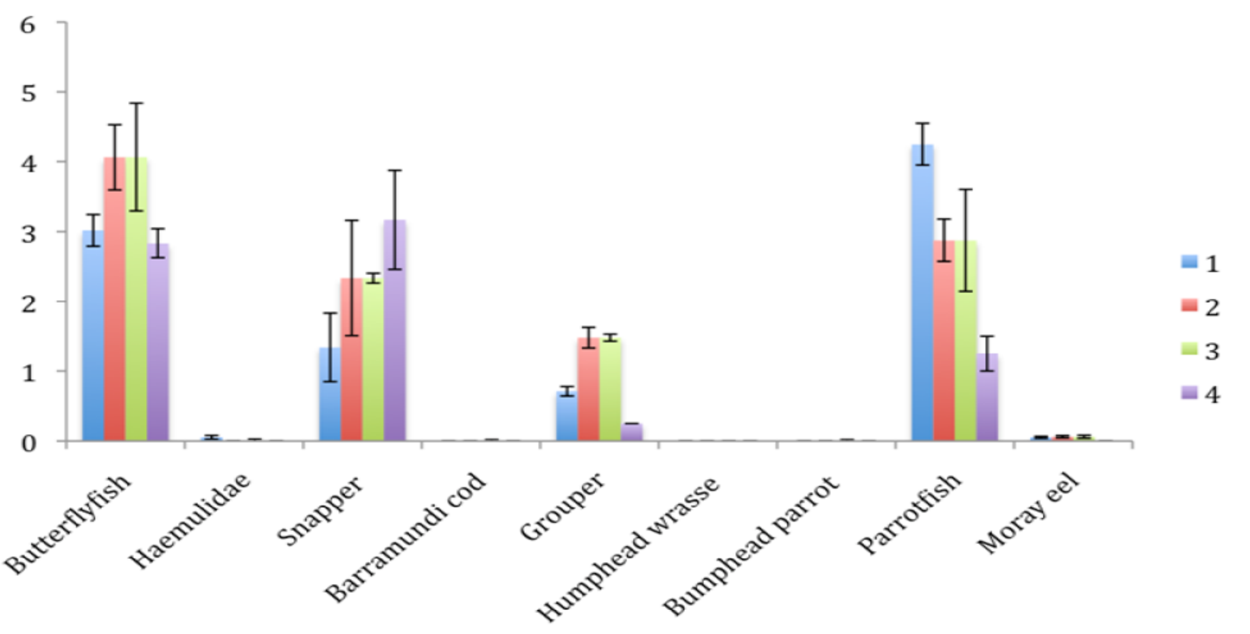

Figure 2.3c. Mean abundances of fish indicator species found per 20 m belt transect within each of the four geographic locations in the Tioman group of islands.

The abundance of groupers of size class 30-40 cm is significantly different between the four groups ($p < 0.05$) with group 2 having the most groupers of this size, as shown in figure 2.3d. The abundance of groupers of other sizes between the four groups is not statistically different ($p > 0.5$).

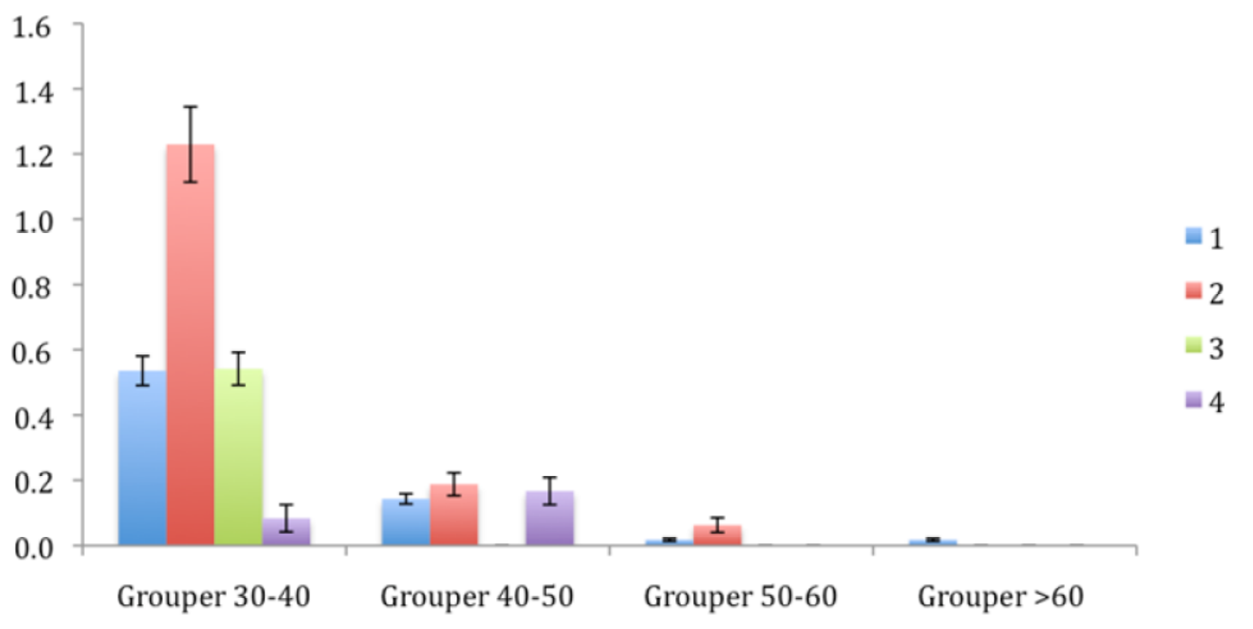

Figure 2.3d. Mean abundance of groupers in increasing 10 cm size categories per 20 m survey in each of the four geographic locations.

Invertebrate community (regional)

Across the region, no pencil urchins (*Cidaroida* sp.), collector urchins (*Tripneustes* sp.), triton shells (*Charonia tritonis*) or lobster were seen. In addition very few banded coral shrimp (*Stenopus hispidus*), an average of 0.04, and not many COTs starfish (*Acanthaster planci*), an average of 0.34, were recorded per 20 m survey. *Diadema* sp. sea urchins were the most abundance invertebrate seen with an average of 59.7 counted per 20 m belt transect and sea cucumbers (various species) coming next with an average of 4.1 (Figure 2.3e).

The number of giant clams (*Tridacna* sp.) found was also low. These were divided into size categories. Figure 2.3f shows the distribution of individuals counted across these size categories.

There is a significantly different number of giant clams in each size category ($p < 0.01$) with smaller clams more abundant.

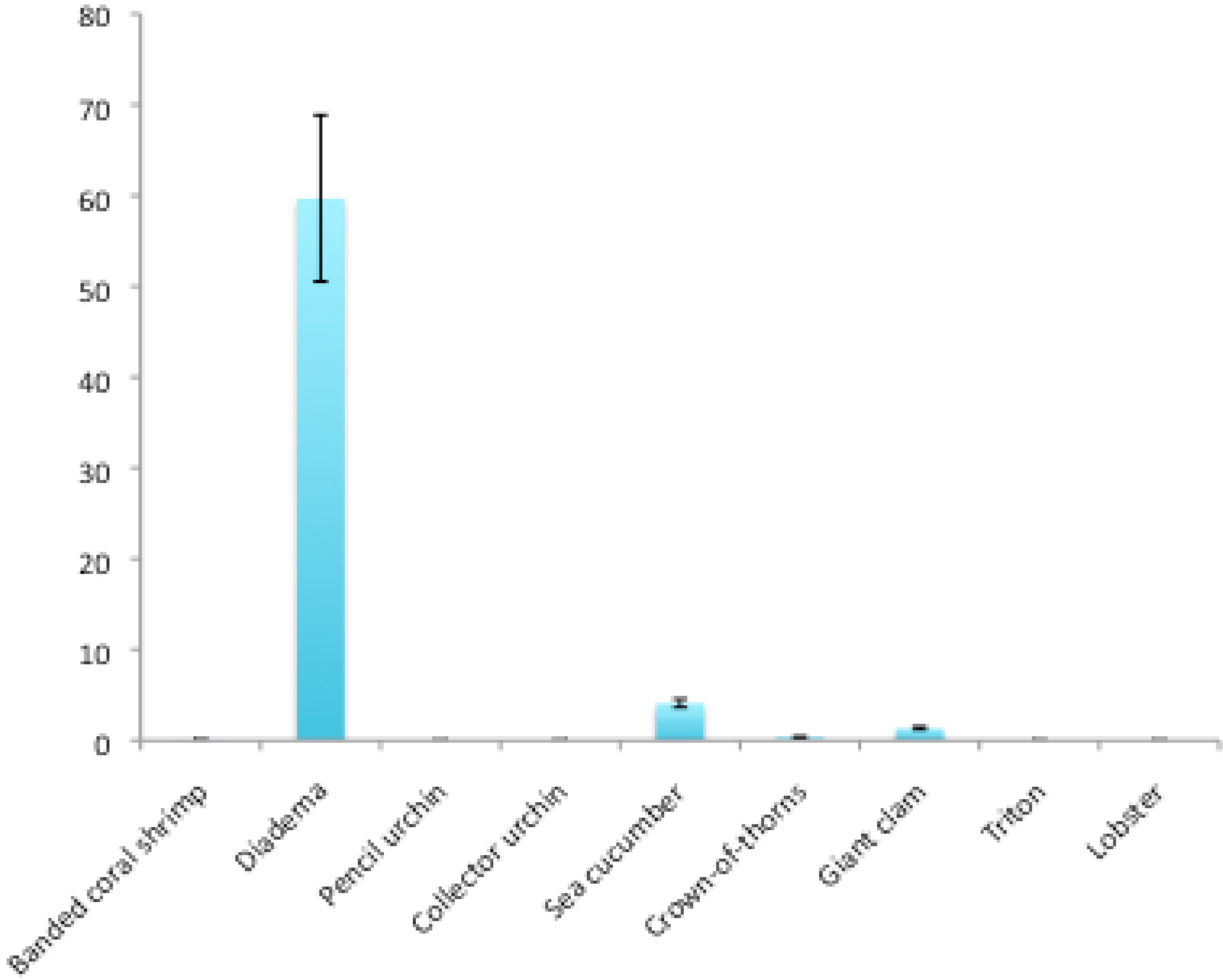

Figure 2.3e. Mean abundance of indicator invertebrates seen per 20 m belt transect across the region surveyed.

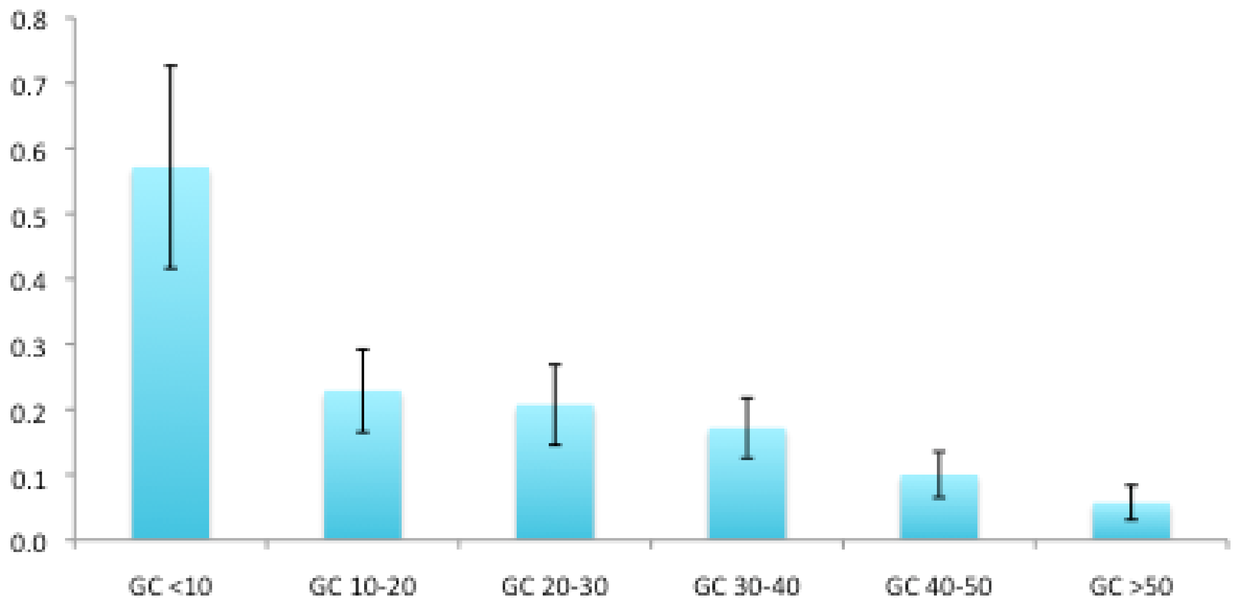

Figure 2.3f. Mean distribution of giant clams seen in 10 cm size categories across Tioman and surrounding islands.

Comparing geographic locations

Figure 2.3g shows the distribution of invertebrates (except *Diadema* urchins) across the four locations. There is no significant difference in the abundance of banded coral shrimp (p = 0.39) between the different sites and triton shells, pencil urchin, collector urchins and lobster were absent in all four of the geographic locations.

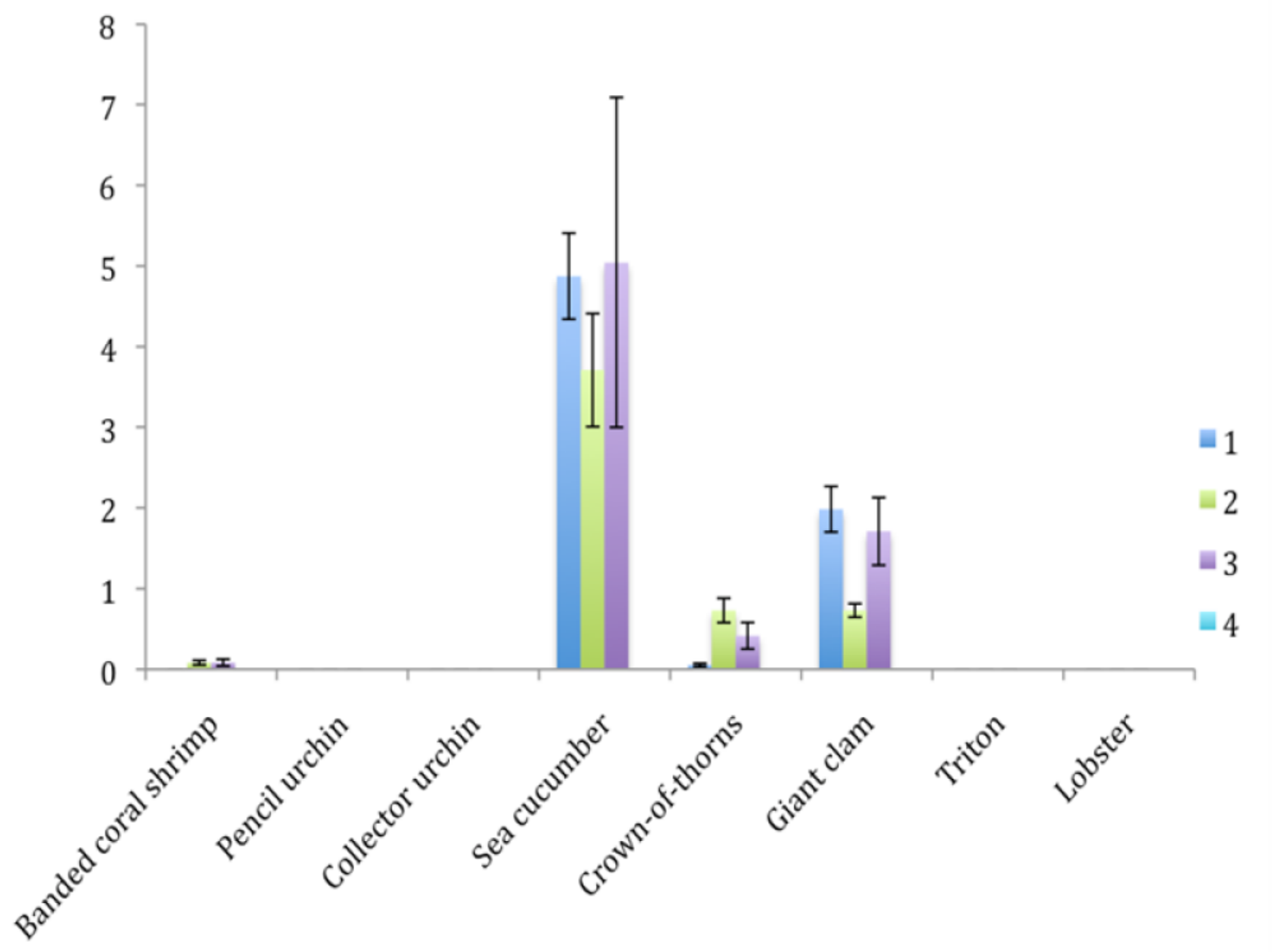

Figure 2.3g. Average abundance of indicator invertebrates counted per 20 m belt transect in each geographic location.

The difference in sea cucumber abundance between locations is almost significant (p = 0.07) and the abundance of COTs was just significantly different (p = 0.05), with group 2 sites having the highest number of these invertebrates.

In contrast, the *Diadema* abundance is highly significantly different across the geographic locations (p < 0.01). Figure 2.3h shows group 2 sites to have many more *Diadema* than any of the other sites. Group 4 has the second highest number with group 3 sites having none at all.

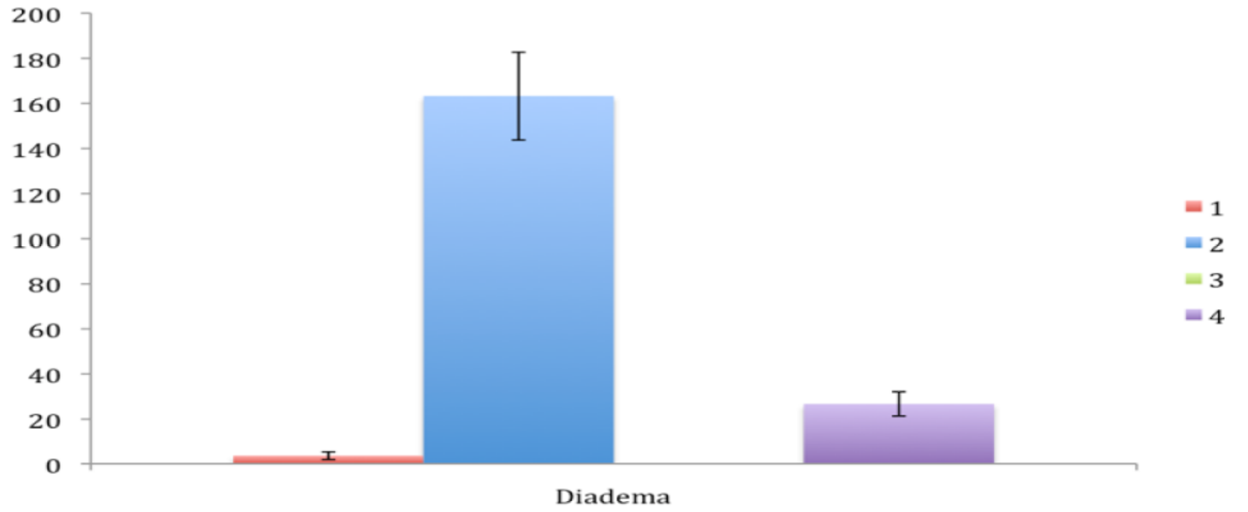

Figure 2.3h. Average *Diadema* sp. urchin numbers counted per 20 m belt transect at each of the four geographic locations.

Total giant clam abundance across the sites is significantly different (p = 0.03), but the size of them was varied in relevance. Groups 1 and 3 had the most giant clams and group 3 had none. The abundances of giant clams sized 20-30 cm, 40-50 cm, and 50cm were found to be not significantly different in the four locations (p = 0.16, p = 0.33, p = 0.30, respectively), but the abundance of giant clams of sizes 10-20 cm, 30-40 cm were (p = 0.02, p = 0.02, respectively) was significantly different. Giant clams of 0-10 cm had almost significant abundance differences between the grouped sites (p = 0.06).

Within group 1, the numbers of giant clams in each size category is not significantly different (p = 0.12) from each other, neither is it in group 2 (p = 0.15) or group 3 (p = 0.08). There were no giant clams found in sites in group 4.

Figure 2.3i shows the distribution of giant clam sizes over the four groups and although there does seem to be a trend towards a higher abundance of smaller clams in groups 1 and 3, statistics show that the size differences within each location are not significantly different (group 1 – p = 0,12, group 3 – p = 0.08). Group 2 sites show a random distribution of sizes that are not significantly different (p = 0.15).

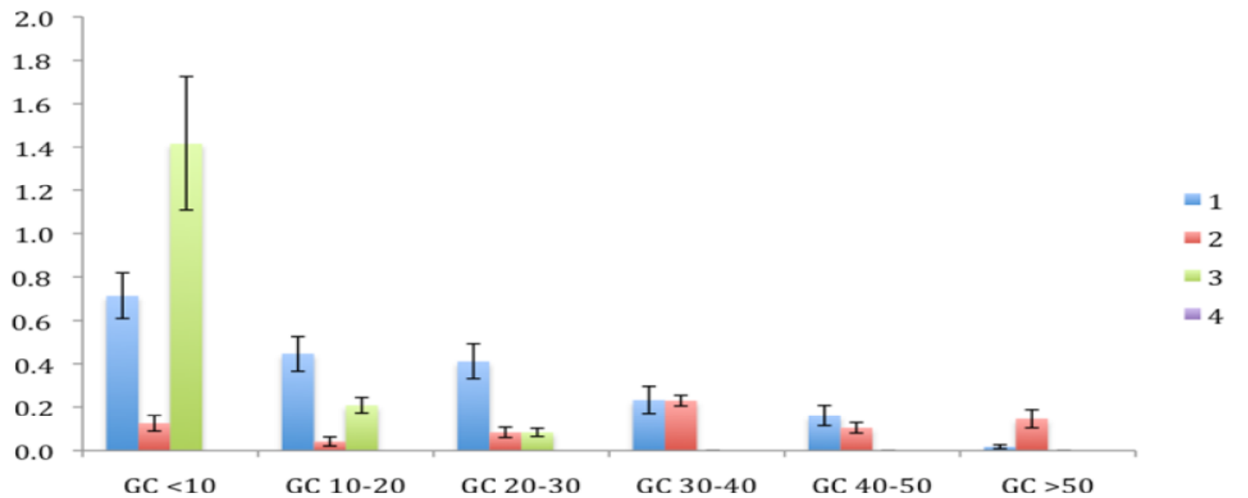

Figure 2.3i. Mean size distribution of giant clams per 20 m survey across the four different locations.

Substrate cover (regional)

Figure 2.3j shows the substrate results for the entire Tioman region. The total hard coral cover for the Tioman area was found to be 33.3% and the soft coral cover was found to be 5.7%. Total coral cover therefore is 38.9%, which puts the region into the 'Fair' category according to Chou et al. (1994).

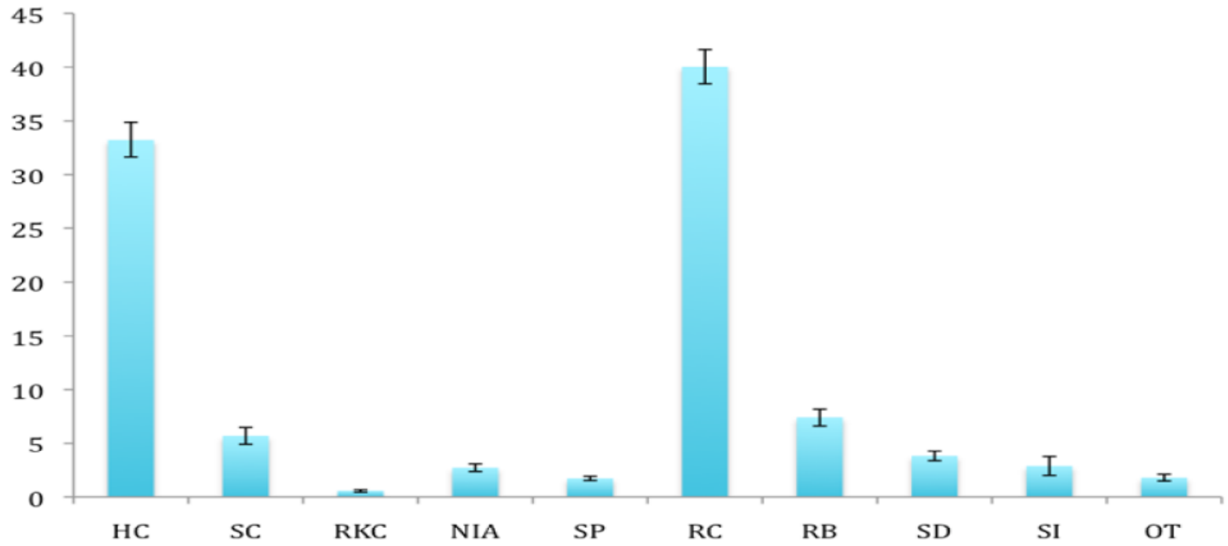

Figure 2.3j. Average percentage cover of each substrate category per 20 m transect across the Tioman Island region.

Rock was the predominant substrate recorded (40.0%), which represents a large amount of unoccupied coral-suitable substrate, as well as indicating a sizable disturbance that has caused healthy hard coral to be killed off.

Rubble cover was low at 7.4%, as was recently killed coral at 0.6%. Other living organisms, not otherwise categorised, represent 1.8% of the cover. Sponge was also low at 1.8%. Silt was recorded at 2.9% and nutrient indicator algae was 2.7%.

Living substrate cover (excluding nutrient indicator algae) was found to be 42.5% and non-living substrate cover was found to be 54.7% in the area (figure 2.3k).

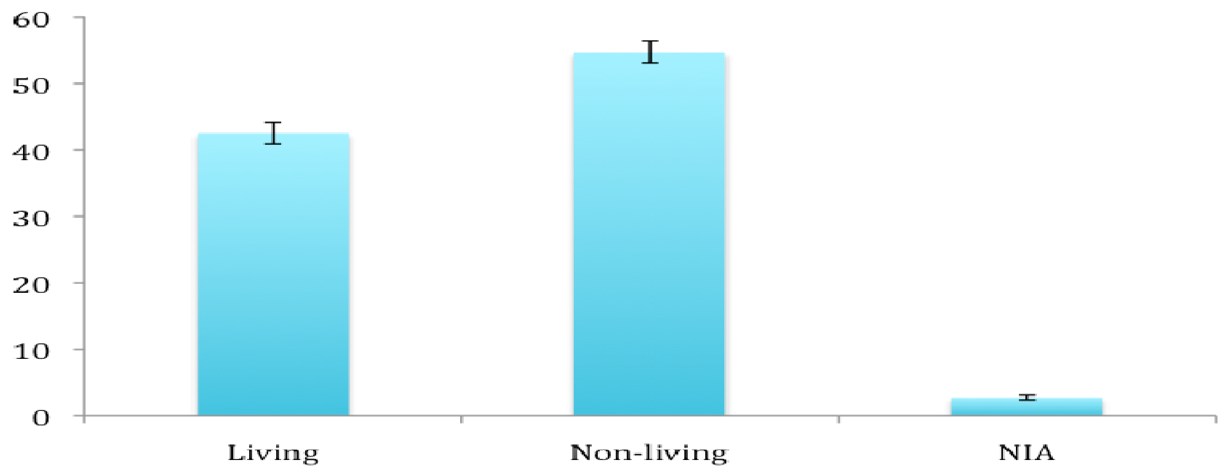

Figure 2.3k. Percentage of living substrate cover (excluding nutrient indicator algae) versus non-living cover in the entire Tioman Island region.

Comparing geographic locations

Hard coral is not significantly different between the geographic locations (p = 0.14). However, hard coral cover was highest in sites in group 3 (Table 2.3a). Group 2 had two sample sites that were very much outliers with coral cover at 6% and 9% (Table 2.3b). Without these two sites, the average hard coral cover for group 2 would be 46%.

Table 2.3a. Average percentage hard coral cover per 20 m in each group of sites.

Group	% hard coral cover
Group 1	24.7
Group 2	39.2
Group 3	44.3
Group 4	27.3
Total region	**33.3**

Table 2.3b. Percentage hard coral cover per 20 m survey at survey sites in group 2.

Site name	% hard coral cover
Batu Malang (D)	43
Batu Malang (S)	38
Chebeh (D)	21
Chebeh (S)	6
Labas (D)	25
Labas (S)	9
Pirate Reef	51
Renggis North (D)	84
Renggis North (S)	79
Sepoi (D)	39
Sepoi (S)	24
Tumuk	50

S = shallow site, D = deep site

Figure 2.3l shows the percentage cover of each of the categories in each geographic location. Soft coral, recently killed coral, sponge, sand and other cover were also not significantly different between the four locations ($p = 0.11$, $p = 0.15$, $p = 0.15$, $p = 0.28$, $p = 0.51$ respectively).

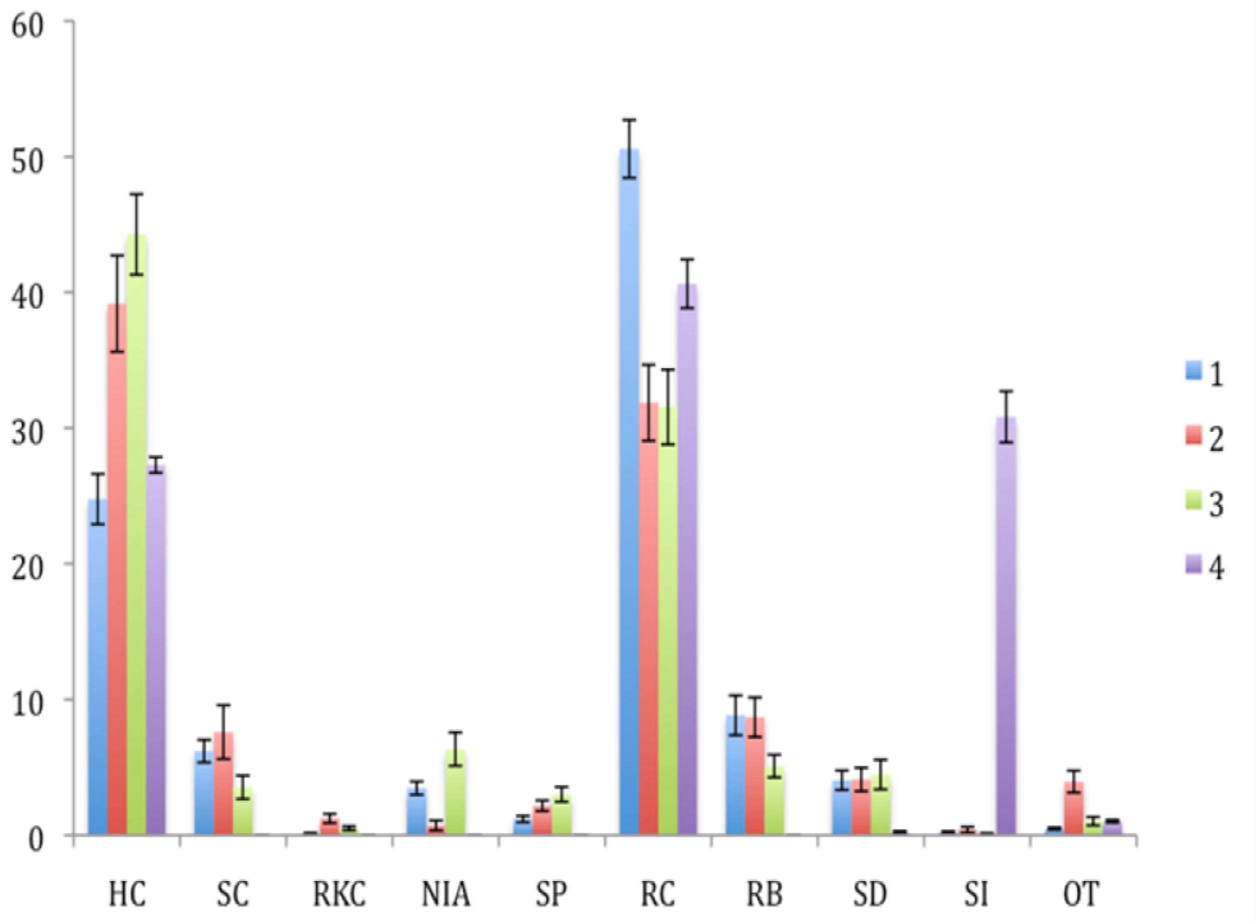

Figure 2.3l. Mean percentage cover of each substrate category per 20 m survey for each geographic location.

Rubble was close to being significantly different ($p = 0.08$), sites in group 4 being the most different with no rubble recorded on the surveys.

Nutrient indicator algae were found to vary highly significantly between the groups ($p < 0.01$) with group 3 having the most, group 1 having the second most and group 4 having none (figure 2.3l).

Rock was variable between the sites too ($p = 0.05$) with group 1 having the most (50.6%) and groups 2 and 3 having the least (31.9% and 31.6% respectively).

Finally, silt was highly variable between the four locations ($p < 0.01$) with sites in group 4 having much more silt that the others (Figure 2.3l).

Figure 2.3m shows the difference between nutrient indicator algae, living and non-living substrate within each group of sites. Group 1 has significantly more non-living than living substrate cover ($p < 0.01$), as does group 4 ($p < 0.01$). The difference between the two categories is not significant for groups 2 and 3 ($p = 0.4$ and $p = 0.08$ respectively).

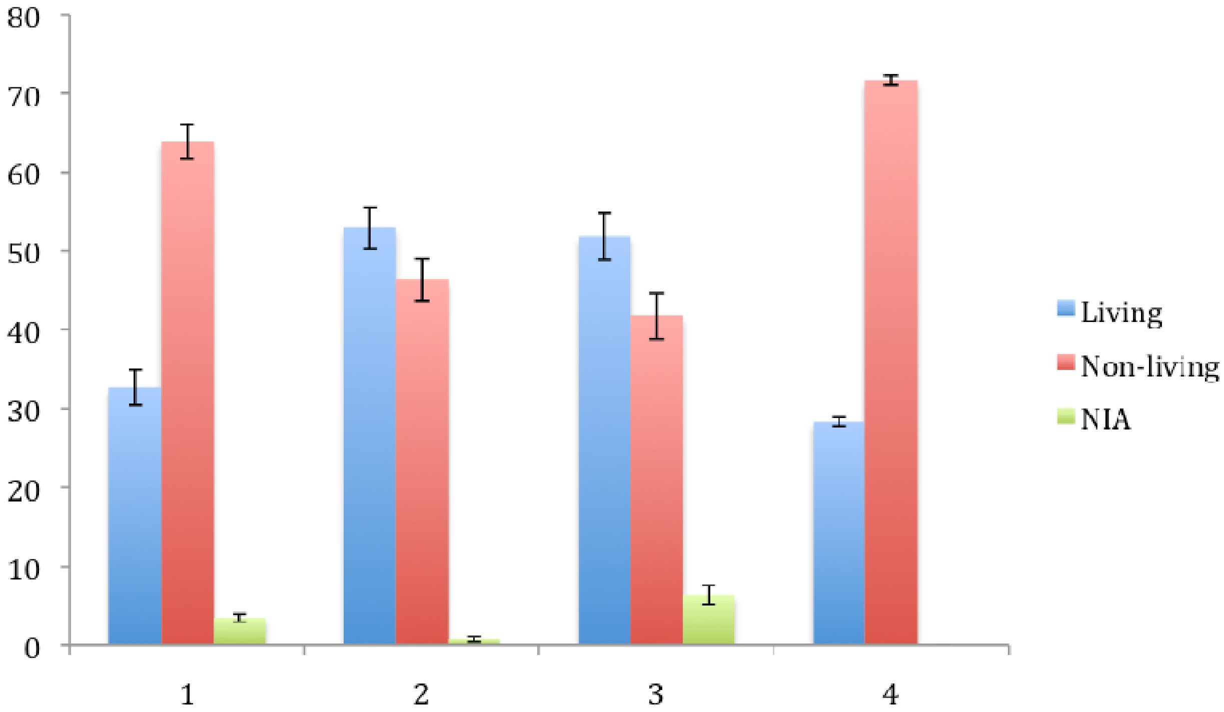

Figure 2.3m. Comparison of percentage cover of nutrient Indicator algae, living substrate (excluding nutrient indicator algae) and non-living substrate per 20 m survey in each of the four geographic locations.

Impact (regional)

Figure 2.3n shows 'other coral damage' to be the main impact across the region. This category represents, COTs damage, *Drupella* sp. snails and other stressors that may impact coral health. Physical boat and anchor damage is the next most prominent impact, with trash, then fish net garbage following. Only one incidence of suspected dynamite fishing was noted on all 35 transects. However, no impacts obtain an average rating of over 1, therefore, these impacts are all fairly low.

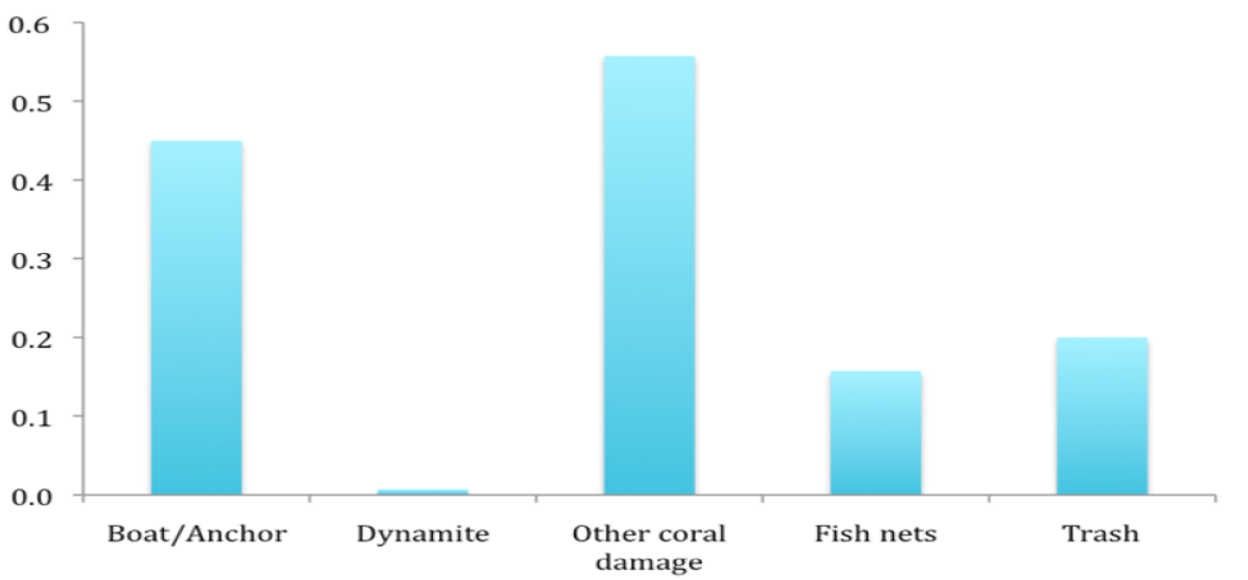

Figure 2.3n. Average rating of impacts measured across the Tioman islands area. Units are based on a ratings system of 0 (no incidence) -3 (high incidence) averaged over the 35 samples.

Bleaching was recorded at just one site during the entire survey period, leaving the percentage of bleaching of the population within a 20 by 5 m belt transect across the region at just 0.6%, a negligible amount. In addition, white band disease was only noted on one transect out of the 35, resulting in an average of just 0.3%, as seen in Figure 2.3o.

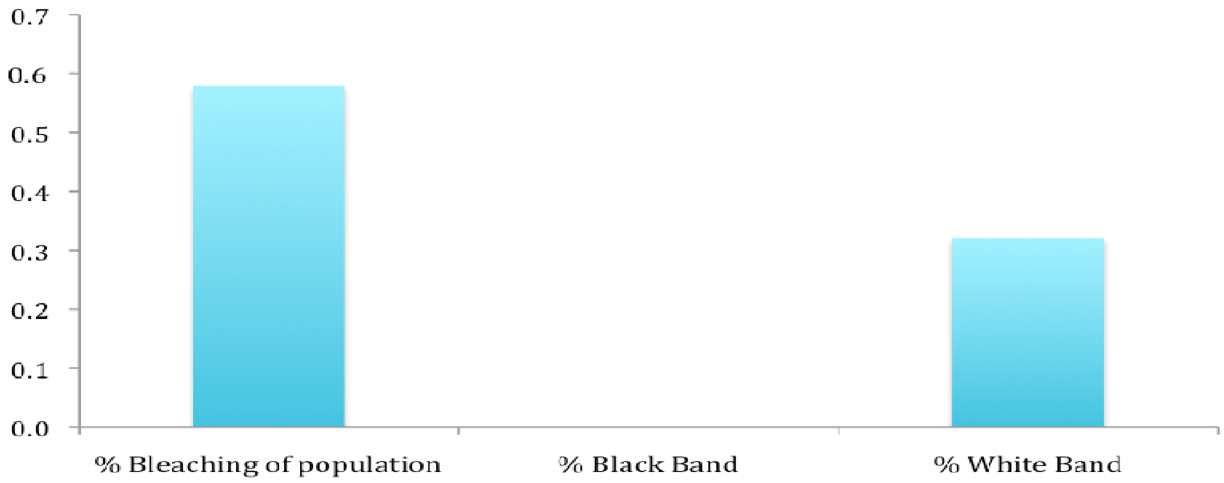

Figure 2.3o. Mean percentage of bleaching and disease of the hard coral population per 20 m belt transect across the region.

Comparing geographic locations

Boat and anchor damage differed significantly between the four groups (p = 0.03) with sites in group 2 showing the most damage (figure 2.3p). Fish net trash was also significantly different between the four sites with group 4 sites being the most affected (p = 0.04).

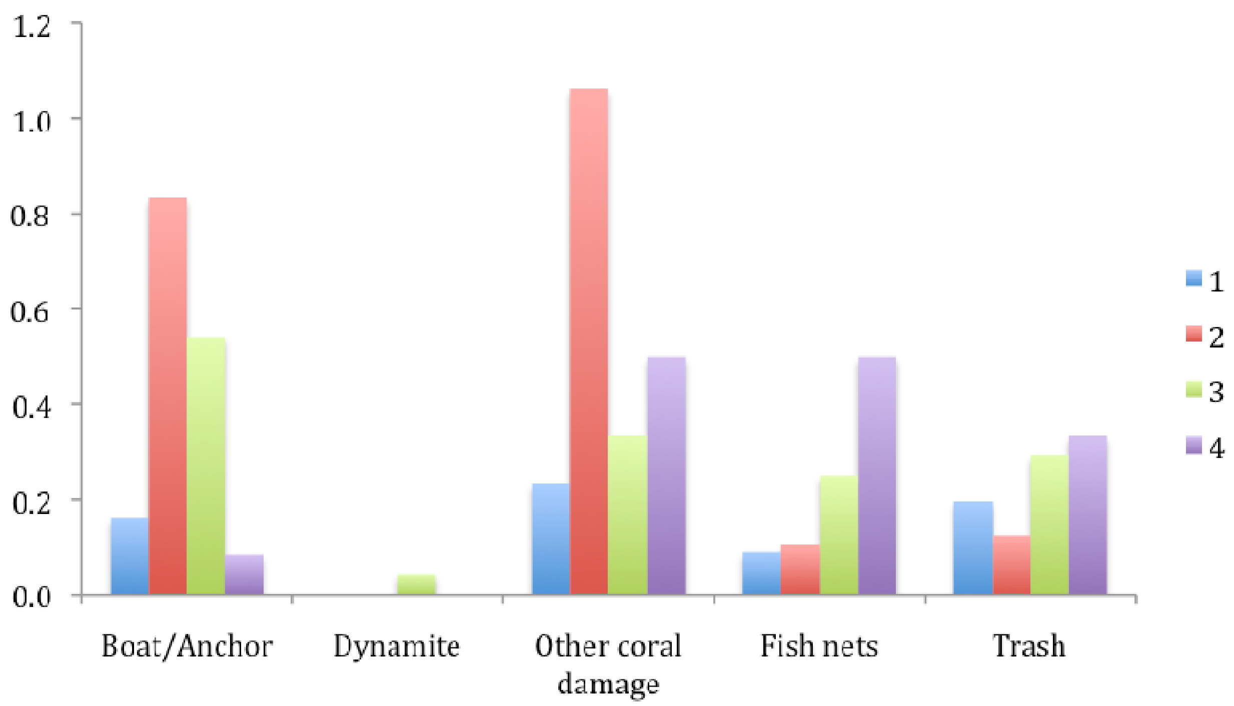

Figure 2.3p. Average rating of impacts measured in each geographic location. Units are based on a ratings system of 0 (no incidence) -3 (high incidence) averaged over the 35 samples.

The incidence of other damage was close to being statistically different with sites in group 2 being the most affected (p = 0.06).

Dynamite fishing and incidences of general trash were not statistically significant (p = 0.18, p = 0.20 respectively).

Bleaching was seen on just one transect at one of the sites in group 3 (Figure 2.3q). This one incidence was found to be not significant (p = 0.18) when compared to samples in other groups. White band disease, however, was found in each of the three samples in group 4, making the incidence of this disease highly significant (p < 0.001).

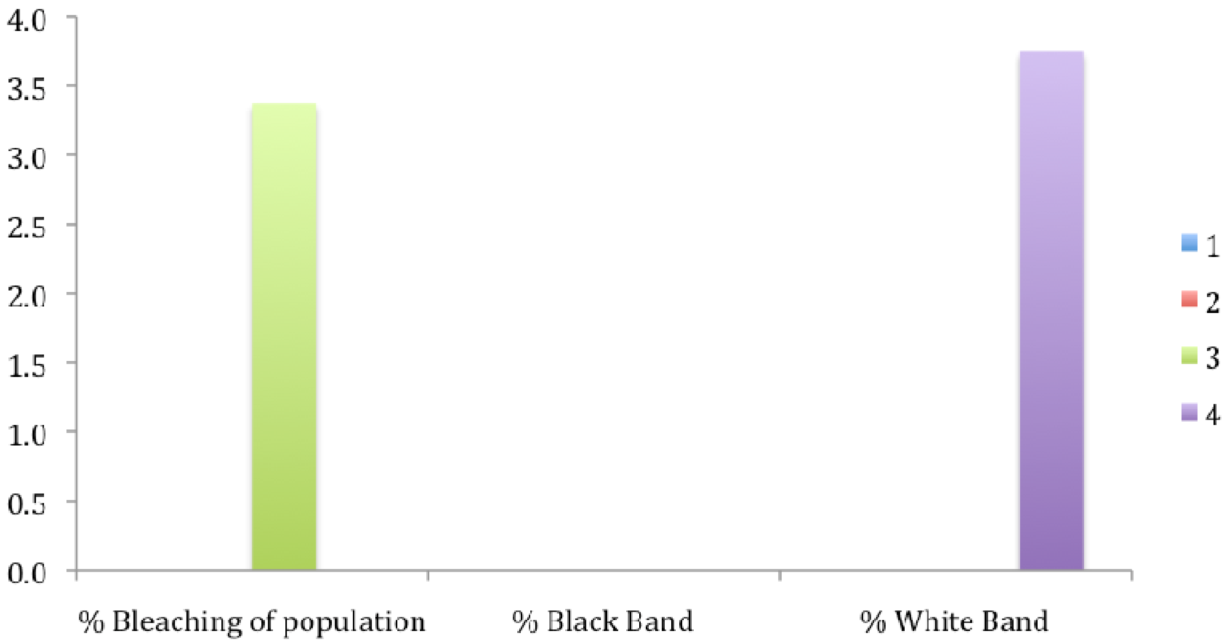

Figure 2.3q. Mean percentage of bleaching and disease of the hard coral population per 20 m belt transect in each location.

Description of sites – observations of potential impacts results

During data collection, a description of each site was made that included observations of the potential factors that may impact the reef. These were ranked from none (0), low (1), medium (3) and high (5). These rankings were averaged within the location groups and analysed.

Regional

Figure 2.3r shows the percentage share of average ranking for factors that could affect the reef across the region. The biggest threat across the whole survey area was artisanal fishing followed by commercial fishing. Tourist diving and snorkelling, sewage pollution and siltation were the next biggest threats to the reefs.

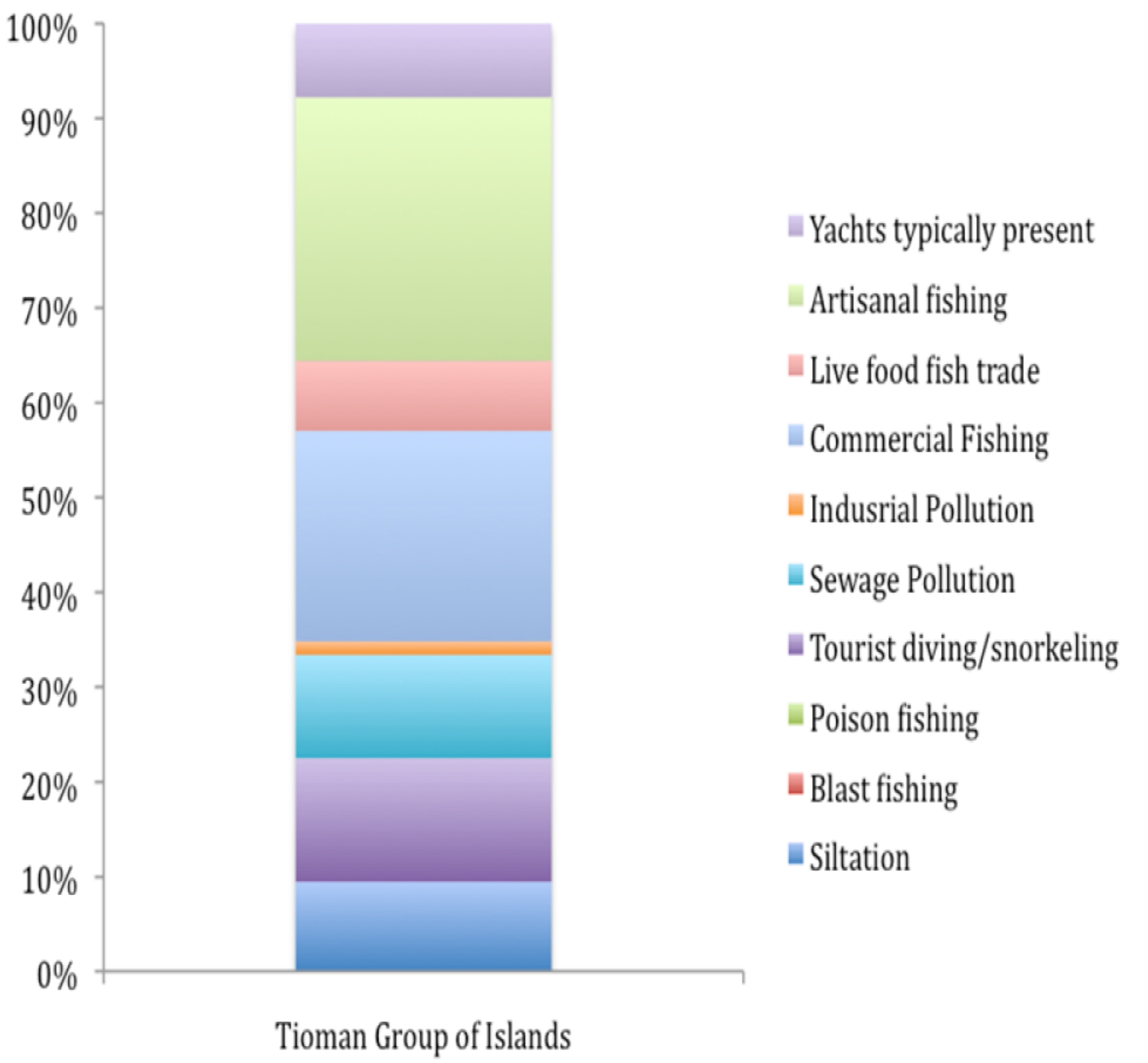

Figure 2.3r. Percentage share of mean rankings of impacts observed across the region. Impacts were ranked from none (0), low (1), medium (3) and high (5).

Comparing geographic locations

It was noted that impacts acting upon the sites vary in the different geographic locations. Group 1 sites are along the east and south coast of Tioman Island in areas where villages are small and few tourists visit. Individual sites in group 1 have medium to high ranking impacts of commercial and artisanal fishing and low ranking impacts of tourist diving/snorkelling, pollution and siltation (Figure 2.3s).

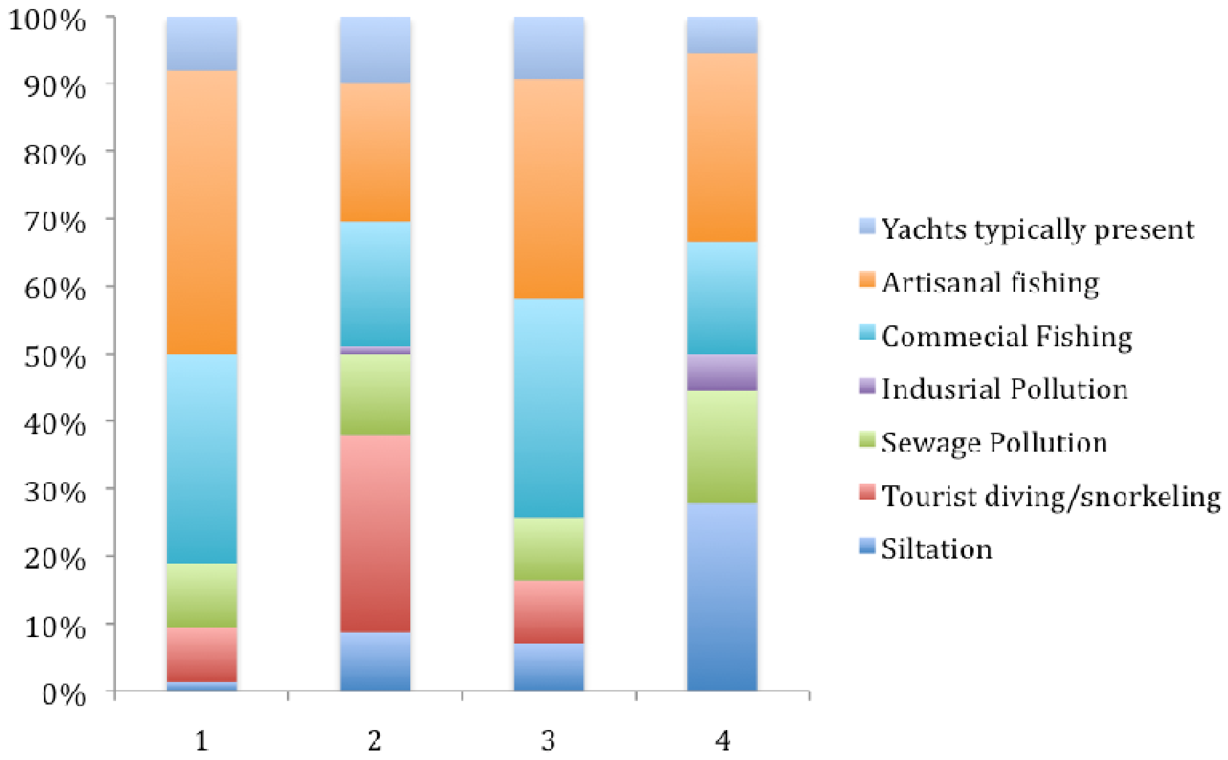

Figure 2.3s. Percentage share of mean rankings of impacts observed at each site within the four geographical locations. Impacts were ranked from none (0), low (1), medium (3) and high (5). The blast fishing and poison fishing rankings were removed as no sites had any effects of these impacts and the live food trade ranking was removed as the ranking was the same for all at 1 (low)).

Group 2 sites are located along the north west coast of Tioman Island, with the highest local and visitor populations, and are more varied in impacts. But individual sites show a general trend of medium to high ranking impacts of tourist diving and snorkelling, low to medium ranking impacts of pollution and siltation and low to medium rankings of fishing activities, except for Sepoi, which ranks artisanal fishing as high.

Group 3 are sites at Pulau Permangil, which has a small local population and few tourists. Sites show low rankings of tourist diving and snorkelling and pollution impacts, but medium to high rankings of fishing activity impacts.

Group 4 are sites at Pulau Seri Buat, an island with no tourist visitors and no local population, but located much closer to the mainland than the others. Sites show high impacts of siltation and fishing activity and low to medium impacts of pollution. Tourist and diving impacts are ranked as none at this site.

Statistical analyses show that impacts differ between the groups (see Figure 2.3t). Siltation has a highly significantly different ranking between grouped locations (p < 0.01) with group four sites being much more affected. Tourist activity is also highly significantly different between grouped locations (p < 0.01), as is sewage pollution (p < 0.01) and industrial pollution (p < 0.01). These tourism and land development impacts mainly affected sites in group 2 and 4 with diving and snorkelling impacts being higher for group 2 and sewage impacts being higher for group 4. The rankings of impacts from artisanal fishing are also significantly different, but less so (p = 0.03) with sites in groups 4 and 1 being most affected.

Commercial fishing has an equal impact on all locations (p = 0.18) and so does yacht activity (p = 0.41).

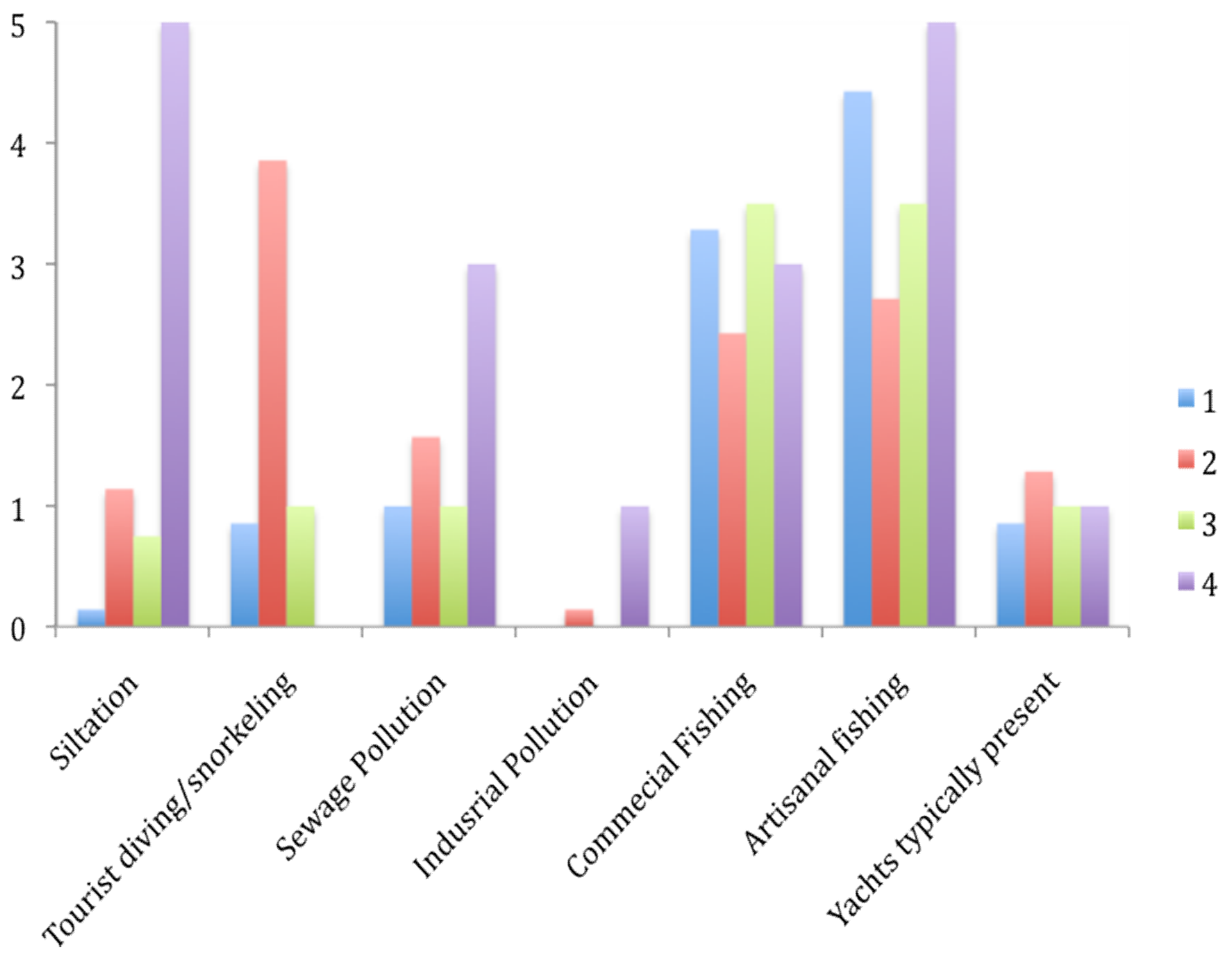

Figure 2.3t. Average rankings given to each impact by location. The blast fishing and poison fishing rankings were removed as no sites had any effects of these impacts and the live food trade ranking was removed as the ranking was the same for all at 1 (low).

Correlation analysis

Some data were subject to further analysis where potential relationships could be seen. A linear correlation analysis was carried out on these data sets.

Grazing activity versus algal growth

During analysis, it was noted that *Diadema* abundance, parrotfish abundance and nutrient indicator algae presence was significantly varied between the different location. *Diadema* sea urchins and parrotfish are herbivores and their presence can help to keep algal growth under control. A linear regression analysis was run on these sets of data to determine a relationship between data points.

First, one site at Chebeh (group 2) was a clear outlier and so was removed from this analysis. A significant negative correlation ($p = 0.03$) was found between the two, showing less algae as *Diadema* urchins numbers increase. However, no correlation was found between parrotfish abundance and nutrient indicator algae ($p > 0.5$).

Fishing activity versus food fish abundance

Intensive fishing activity can lead to overfishing, that is, the removal of target fish faster than the fish can replenish their own stocks through reproduction. Overfishing can be assessed by looking at the abundance of larger, higher trophic level fish, such as snappers, groupers and sweetlips. The abundance of these fish was combined for each transect, and barramundi cod were included as this is a popular food fish in this area to make up the ‘food fish’ count and this count was compared to the rating for the impact of artisanal fishing for that site. There was no correlation found between the rating of the impact and the abundance of food fish ($p > 0.5$). In addition, there was no significant correlation found when the rating of artisanal fishing was compared to abundance of groupers only ($p = 0.3$).

Fishing activity versus rock

Rock is a measurement of the substrate cover that was found to be significantly different between the sites. Artisanal fishing was also significantly different between the sites. So a linear regression analysis was run to see if these two variables are related. A significant correlation was found between the two ($p = 0.01$), where rock cover increased as fishing activity increased. No significant relationship was found between fishing activity and rubble cover ($p = 0.9$)

Tourist activity versus hard coral cover and food fish abundance

Tourism and development activities (diving intensity, sewage and siltation) rankings were analysed against hard coral cover and food fish abundance. No significant correlations were found.

COTs and recently killed coral

The incidence of recently killed coral on each survey is recorded, however, the cause of the death of the coral is not and it is not always obvious. COTs are known to be voracious predators of coral and so the abundance of COTs was compared with the incidence of recently killed coral (RKC). A significant correlation between the number of COTs seen and the occurrence of RKC ($p < 0.001$) was found.

2.4. Discussion and conclusions

Fish community

A lack of food fish such as groupers, sweetlips and barramundi cod indicates an overfishing of these fish families. Few bumphead parrotfish and humphead wrasse also indicate intensive harvesting of these species. The low number of species that are predatory, such as snapper, groupers, sweetlips and moray eels is concerning as this indicates that reefs are not balanced, healthy and diverse enough to support the top levels of the reef food chain.

As the area is a marine park, it could be assumed that the lack of these indicator fish is a hangover from intensive fishing that occurred before the marine park was established and that numbers will increase given time. However, fourteen years have now passed since the marine park was established and numbers are still low. This coupled with the regular observations of fishing activity as well as the fishing impact ratings given to sites surveyed suggests that fishing is still occurring at a level, although probably lower than before, that is preventing the reefs from recovering. There is also the possibility that other impacts are adding to the slow recovery of the reefs.

It is worth noting that commercial fishing was seen to be occurring across the whole region and no variation of intensity was noticed at the four locations. Commercial fishing is likely to be the cause of the overfishing here and any effects would also be seen across the whole region. Commercial fishing in this case was understood to be fishing with the intent to sell the catch. Having said this, the ‘commercial’ fishing boats seen were relatively small compared to industrial fleets that may be seen in other parts of the world.

Artisanal fishing intensity varies across the sites with sites in location 4 and 1 being worst affected. Fish net trash was also seen to vary between the locations with group 4 again being the most affected. However, surprisingly, no correlation was found between artisanal fishing and abundance of food fish. This could be because artisanal fishing is at a level low enough to have no effects on the abundance of food fish stock.

However, the results also indicate that grouper numbers are low and vary across the locations and, more specifically, that sites in groups 4 and 1 have significantly fewer groupers, a fish most often caught by the artisan fishing method of rod and line. In addition, the much higher number of smaller groupers compared to larger ones is another indication of overfishing. A region with no or little fishing would have a more equal number of adults and juveniles.

It is worth bearing in mind that the measurement of all the impacts is a simple observational rating and not a quantifiable measurement. In addition, the difficulty of defining artisanal versus commercial fishing has probably led to inaccuracies.

Other fish data tells us that locations 2 and 3 have the most butterflyfish, which indicates a more diverse reef. Zones 2 and 3 also have the most groupers, indicating slightly healthier reefs. As group 2 sites experience the most diving and snorkelling pressure, these results would suggest that tourism levels are low enough not to be having a detrimental effect on the reefs. In addition, no correlation was found between tourist activity and food fish abundance.

Parrotfish numbers vary across the locations, with location 1 having the most and 4 having the least. But there does not seem to be any trend in regards to impacts or nutrient indicator algae level. It would be expected that where there is more algae, or impacts that would cause the growth of algae, there would be more parrotfish to feed on it. Alternatively, more parrotfish mean more grazing of algae leading to fewer algae in those areas, which could be the reason for the contrasting results.

After looking at the data from a number of aspects, it can be said that the current, not past, level of fishing activity is having a detrimental effect on the recovery of fish numbers the entire region with zones 1 and 4 being a little more affected.

Invertebrate community

Lobsters are present in the area, but none were seen during any of the surveys. The fact that the environment does support them, but that their numbers are low reveals a heavy fishing pressure on these animals. In addition, triton shells were absent proving that they have been fished out in this part of the ocean (as well as much of the rest of the world). A lack of pencil urchins, collector urchin and banded coral shrimp is also noted and may be attributed to fishing pressure, but no sightings of this kind of collection have been reported.

The abundance of giant clams was found to be significantly different across the locations but the size was not. If fishing for these animals was occurring, it is likely that there would be a great number more smaller ones than larger. Possibly, this result is unrelated to anthropogenic impacts and more related to environmental conditions.

Sea cucumber numbers were normal, suggesting that they are not targets for collectors.

COTs numbers are variable with some site having vey high numbers per survey. For example Renggis and Chebeh (both group 2) both had just under an average of 3 per 20 m belt transect. The four sites have slightly different abundances, with group 2 and 3 having the most. The effects of their presence is discussed below in regards to the impacts survey, but it should be noted that there does not seem to be an impact that is linked to the COT numbers. This is also true for global presence of COTs. Scientists cannot agree on what causes COT population explosions and the long-term effects of them. Arguments range from booms being a natural occurrence that is needed to maintain coral diversity, to being the anthropogenic effects of predator removal and pollution.

Underwater impacts

Impacts are generally low across the region. However, other coral damage (representing damage caused by impacts such as predation by COTs and *Drupella* sp. snails) was the biggest impact noted. This impact was most obvious at sites in group 2, with some effects noticed in group 3. In addition, recently killed coral (RKC) was very low across the region, with just under 1% on average. However, where it is found, there is a highly significant relationship with COTs. It is safe to say that predation by COTs seems to be the biggest cause of recent death of the corals.

Other damage of significance was boat and anchor damage, which was noted most in groups 2 and 3. Groups 2 and 3 are sites with the most diving and snorkelling and are closest to the biggest populations. It is unsurprising, therefore, that this result has been found, but could be attributed to local fishing boats as well as tourist boats.

There was little bleaching. However, there was a significant amount of white band disease noted only at sites in group 4. As siltation was also significantly high at these sites and they are the closest to mainland industrial pollution, it can be assumed that these are the causes of the disease. This disease puts extra pressure on coral that is already struggling with siltation and further reduces the area's chance for recovery.

Substrate cover

Hard coral

At 33.2% across the whole region, although just above average global hard coral cover, the hard coral cover does not represent a healthy reef system. The range of hard coral cover is wide (from 5% to 84%), so there are clearly areas of very healthy reef close to areas that have been badly damaged. The overall percentage in this case is not a good representation of the area as a whole, but it does raise serious concerns for the region's coral health and stresses the importance of identifying and removing threats and impacts.

Reef Check Malaysia found the Tioman group of islands to have 56.3% hard coral cover in 2008 and 44% in 2011. Recent results would therefore seem to suggest a serious decrease in hard coral cover in the area. However, the lower percentage is more likely to be due to using different sample sites from those used by Reef Check Malaysia.

Comparing geographic locations does not yield a conclusive indication of what may be causing the low hard coral cover, as the results within the locations are as varied as the results between locations. Group 3 sites have marginally higher cover with no sites within that location dropping below 24% cover. Group 2 sites have the next best hard coral cover. These two sites are the areas that have the highest diving and snorkelling pressure, suggesting tourist activity is not having the most detrimental effect on the cover.

Sewage pollution and siltation caused by on-land development are other impacts that can affect hard coral cover. However, neither of these impacts show significant corresponding patterns with hard coral cover when comparing all four locations, but interference in the data may be caused by the difference in reef habitats. Location 1 tends to be more exposed with rocky reefs where hard coral cover would be expected to be low naturally. When comparing sites in group 2, 3 and 4, mainly sheltered, coral dominated habitats, a gentle pattern emerges. Hard coral cover is higher in group 3 sites than group 2 and 4 where siltation, sewage and diving activity is lower. This suggests that on-land development may have an impact on the hard coral cover. Results from group 4 sites support this argument particularly well as the low coral cover there is very likely to be due to the very silty conditions caused by deforestation and development on the mainland.

The inverse is true when it comes to comparing hard coral cover with the impacts of fishing. Sites where fishing has a higher impact, such as those in groups 1 and 4, do displays lower hard coral cover.

In summary, hard coral cover is ominously low. A lack of significant difference between the locations infers that all impacts are having a roughly equal effect on the hard coral cover, with siltation, fishing and pollution seeming to be slightly more damaging.

Rock

The category 'rock' includes bare, exposed rock as well as still standing coral that has been dead for more than a year. The presence of bare rock is often due to the exposed nature of a location as coral is unable to grow in poorly sheltered areas. Coral that has been dead for more than a year indicates the potential for coral recruitment. However, long dead coral is also indicative of a chronic or acute disturbance. This disturbance could be a mass bleaching event, a COTs outbreak, heavy siltation or even overfishing and the removal of herbivorous fish. Note that still standing dead coral was categorised as rock, whereas broken dead coral was categorised as rubble, which indicates slightly different disturbances as discussed below.

During the surveys, much of the 'rock' recorded was actual bare, exposed rock present in the more exposed sites around the island. Much of the rest of the 'rock' recorded, however, was long dead coral. Moreover, it was long dead *Acropora* sp. coral.

The close relationship between rock cover and ratings of artisanal fishing activity could indicate that fishing activity is the cause of the dominance of rock as a substrate. If the 'rock' recorded was long dead coral, overfishing, and more specifically, fishing down the food chain, could cause coral die-off of this kind. Rapid removal of top predators means that few of these fish are left to catch, forcing fishers to move on to catching herbivorous fish such as parrotfish, surgeonfish and rabbitfish for subsistence purposes. Overfishing of these species could allow algae to grow unchecked and take over a coral-dominated community, causing a phase shift to an algal-dominated one.

This situation is usually found in areas with a very high fishing pressure, where locals need the fish protein to survive. The small population on these islands coupled with the relative prosperity of the people does not, therefore, support this argument. More understanding of the area's fishing habits are needed before it can be known if fishing intensity is high enough to cause overfishing.

If the 'rock' recorded was bare, exposed rock, the correlating relationship is more likely to be connected with the fact that more fishing occurs on the more exposed areas of the islands, such as location 1, mainly due to the lack of tourism revenue in those areas. The lack of tourism is likely linked to the reduced coral cover that is due to the exposed nature of the sites.

As mentioned, much of the long dead coral was *Acropora* sp. *Acropora* is known to be particularly vulnerable to bleaching and is also a favourite food for COTs. Knowing that there were mass bleaching events in the Indo-Pacific region in 1998 and 2010 and knowing that COTs are prolific in the area, it is more likely that large areas of dead coral in the region here are due to one or both of these disturbances.

The dominance of rock over rubble or nutrient indicator algae is encouraging as rock represents a surface that new coral can grow upon. This suggests that once impacts are removed, the site has a very good chance of natural recovery.

Rubble

Rubble is categorised as loose coral and other materials such as shells, etc. Rubble is usually indicative of a physical disturbance such as an unusually large storm, physically damaging fishing activities such as the dropping and retrieval of fish traps and dropping and retrieval of anchors and chains.

Rubble cover is reasonably low across the area at just over 7%. However, some individual sites showed up to 37% rubble along an average 20 m transect. These sites were in areas where fish traps are regularly seen to be used and some had discarded fish traps still in situ. Although no correlation between artisanal fishing or fishing trash and rubble was found, it is highly likely that fish traps and the dropping of anchors were responsible for this damage. One reason for the lack of correlation could be that neither of these impacts are measured quantitatively. Another reason could be that discarded nets and discarded traps were counted together. Where nets were found, often the net had become assimilated into the reef and not caused rubble, whereas the traps were surrounded by badly broken up reef. It is likely that if fishing activity was monitored more closely, a direct linear relationship would be found.

Nutrient indicator algae

Nutrient indicator algae (NIA) were fairly low across the region, however, significantly more were found in group 3 and group 1 sites. High NIA levels usually indicate nutrient pollution. However, both locations 3 and 1 have low population densities and are farthest from mainland pollution. Low *Diadema* urchin numbers correlates with sites with high NIA, which provides the explanation for this pattern. This begs the question why *Diadema* numbers vary so much between locations. Many more *Diadema* were found at sites in group 2, close to the highest island population and most tourist activity. It could be that nutrient levels are actually higher at locations in group 2, but *Diadema* urchin numbers are disguising this fact by grazing most of the algae. This does not, however, answer the question as to why *Diadema* urchins have not migrated to the other areas where there are clearly enough algae to support their numbers. In addition, herbivorous fish numbers are not elevated in the areas of higher NIA. The lack of herbivores in these sites is concerning as grazing would prevent algae from taking over these areas, should they become more damaged in the future.

Siltation

Siltation is fairly low on average at just under 3%. However, it is very high at all sites in group 4. These sites are on Pulau Seri Buat, an island just 14 km from the mainland, versus Pulau Tioman's 40 km (at the closest point). Deforestation and land development on the mainland has caused significant river run-off. The resulting siltation has coated the previously coral-dominated reefs fringing the island and hard coral cover is at an average of 27%. Unlike sites in location 1, these reefs are not exposed and would be expected to have a healthy coral cover. Also unlike the other locations, recovery of silt-dominated sites such as this is highly unlikely, even if the cause of the siltation was removed. Development plans currently underway on the mainland make recovery of this vulnerable island extremely unlikely and pose a threat to other islands further away, such as Tioman and Permanggil.

Living substrate versus non-living substrate

There is significantly less living substrate at sites in group 1 and group 4, whereas living and non-living substrate percentage cover is similar in sites in groups 2 and 3. This significant difference supports arguments already made for damaging effects of siltation and fishing, but is also subject to artefacts of including the bare rock unsuitable for coral growth.

2.5. Summary and recommendations

To summarise, it is important to look back to the aims of this study. The study has certainly allowed a fuller, wider understanding of the reefs in the area, especially by investigating sites that had not been studied before, such as those in groups 1, 3 and 4. It is hoped that by highlighting impacts on the reef and making suggestions for its protection, park authorities will update management methods in line with suggestions made below. In addition it is hoped that the scientific community gains more ecological knowledge of the area's reefs through this study.

Reef health

The reefs around the Tioman groups of islands are in fair health overall, but alos range dramatically in health, suggesting that there are impacts acting locally upon them. Results do shed some light on which impacts are most damaging, that is, reefs in group 3 seem to be the healthiest with good coral cover, little NIA, few COTs and more groupers. These reefs also have the least land development and fishing impacts. However, results are less conclusive than hoped. This is due the complexity of ecological processes interacting with anthropogenic impacts along with the fact that sites are affected by a variation of combinations of impacts, making it difficult to demonstrate individual cause and effects.

Impacts damaging reef health and suggestions for management

Tourism and coastal development

Coastal development is certainly a threat to the health of the reefs in Tioman and surrounding islands and the effects of planned developments could be devastating. Building out into the oceans will physically crush more of the remaining reefs and sedimentation will be caused by erosion of artificial beaches, clearing of land for space and dredging of mudflats for reclamation material.

As seen by the results of surveys at Seri Buat, siltation is the biggest threat. In addition, siltation has also been linked to white band disease, causing even more devastation to the coral populations. If poorly planned development continues to generate effects such as these, all islands close to the mainland are at risk of becoming choked by silt. It is not known if Pulau Tioman, Permangil, Aur and other islands further away will escape this damage. Planners must stop ignoring the needs of these reefs and consider the effects developments will have on the marine systems that underpin a large majority of the area's economy. Professional environmental impact studies should be required before any development commences and their findings should be adhered to strictly, even if it means that a development does not go ahead.

Diving and snorkelling activity, as well as sewage pollution originating from the islands may be having an effect on reef health. At current levels, they are not a major concern, but effects will increase if levels increase. Tourism expansion on the islands must be done responsibly if local communities are to continue to derive revenue from the marine environment. Local communities and park managers have a part to play in ensuring that their tourists behave in an environmentally responsible manner.

Also, anchor damage was significantly higher in areas with more boat activity and tourist and/or local boats are causing this damage. Park management needs to address this issue by introducing a regular mooring buoy maintenance programme, as well as educating boat drivers about the damage caused.

Illegal fishing activities and destructive fishing practices

Not enough information is available for the levels of fishing that continue on and around Tioman island. It is suspected that levels are much higher than realised. Commercial fishing boats are regularly seen fishing in the marine park area and many tourist fishing boats were also seen during the expedition.

Effects of overfishing are very much present, as evidenced for example by the lack of larger fish, and Marine Park protection should be having a much more positive effect than it currently is, considering the length of time since the island was gazetted. In addition, fish traps are causing great physical damage to the bottom environment. The destabilisation of substrate is not only damaging corals, but also prevents recovery and recruitment. Managers must enforce current fishing regulations, which are widely and obviously flouted throughout the Marine Park at all time. Alternatively, a system that ensures once and for all that only local or artisanal fishers are extracting from the Marine Park area and that they are doing so in a non-physically destructive way, must be developed.

In addition, more effort needs to be invested in educating local people about responsible practices in regards to fishing and the introduction of incentives to prevent activities such as shark fining should be considered.

Crown-of-thorn starfish

The effects of COTs predation are also felt by the areas' reefs and COTs appear to be one of the main reason for recent coral death. This was demonstrated by the close relationship with recently killed coral (RKC). COTs have probably been having an effect for a number of years too, due to the that much of the long-dead coral (categorised as 'Rock") can likely be attributed to COTs predation too. Even with the cause of COT population expansion and the long-term effects of their predation unknown, die-off of corals due to COTs is an issue that needs consideration and assessment. Further research and observation is needed, not just in Tioman, but also around the world, before a definitive answer can be given to the question of how to respond to these plagues of starfish.

Warm water bleaching

The reefs around Tioman were heavily affected by the mass bleaching event of 2010 with some sites showing bleaching of 90% of the coral population (own research, unpublished). Anecdotal evidence from long-residing divers also indicates a massive loss in 1998.

The effects of these bleaching events were observed at many of the sites surveyed and it has been discussed that much of the ‘rock’ recorded was actually long-dead coral that was killed by bleaching. However, very little current bleaching was observed. There is little that management authorities can do to prevent bleaching events, but limiting damage by other impacts will greatly increase the areas’ ability to recover afterwards.

Potential for recovery

If fishing activity, tourist activity, land development and COTs impacts are reduced, much of the area has a very good chance of recovery. Low levels of rubble and nutrient indicator algae and a high dominance of rock mean that there is a very encouraging chance of coral recruitment and growth. Indeed, even in areas where COTs and bleaching are suspected of causing a decline in health, the substrate is stable and the presence of herbivorous fish and invertebrates promise an even more diverse settlement of coral species.

However, there are some sites that are a cause for concern. Areas where grazer urchins and fish are low, such as Pulau Permangil, have less of a potential for recovery and are more vulnerable to disturbances. Also, silt that chokes the reefs of Seri Buat and other islands is not easily shifted and as such represent a serious, long-term threat.

Future surveys

It is recommended in the future to either focus on fewer sites and collect more randomly placed transects within those sites or to place permanent transects in situ and continue with many sites. The advantages of larger numbers of random transects are that this decreases the bias and gives a good representation of the area as a whole, but any changes over time may be due to different areas of the reef being surveyed and not actual changes in health. An advantage of permanent transects is that changes over time are more accurately represented. However, there is the danger of the change being too local and not representative of the area as a whole.

It is recommended that Juara Rocks as well as Jahat are dropped as survey sites as the environment at these two sites is not well suited to the transect survey method as (very rocky with very uneven reef surfaces).

Gaps in the data include a lack of understanding of the fishing habits in the area and a lack of data documenting the impacts of the bleaching events. Filling these data gaps is desirable. However, this could be difficult because of time and resource constraints.

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Appendix I: Expedition diary and reports

A multimedia expedition diary is available on http://biosphereexpeditions.wordpress.com/category/expedition-blogs/malaysia-2012/.

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