

MALAYSIA REEFS AND ISLANDS CONSERVATION PROJECT 2003

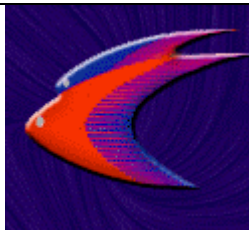
REPORT OF THE MARINE PILOT PHASE

**A COLLABORATIVE PROJECT BETWEEN THE MARINE PARKS SECTION,
DEPARTMENT OF FISHERIES, GOVERNMENT OF MALAYSIA
AND CORAL CAY CONSERVATION.**



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EXECUTIVE SUMMARY

- Development in Malaysia is concentrated to the coastal zone that in turn places direct threat on the coral reef and shallow tropical marine ecosystems that the country relies on for much of its revenue generation.
- These threats have been acknowledged by the Malaysia Government who established a number of Marine Parks under the Department of Fisheries to facilitate the sustainable use of the resources. In 2003 Coral Cay Conservation were invited to conduct a series of surveys around on such Marine Park; Pulau Perhentian in the east coast state of Terengganu on Peninsular Malaysia
- Two hundred and fifty baseline survey dives along 130 transects have been conducted to collect a data set on the coral reef resources of the Perhentian Archipelago in 2003. In addition, twelve Reef Check dives were also performed to facilitate quantitative analysis of three key areas representing a range of environments on the study area.
- The data collected has been used to identify thirteen discrete habitat types that are key to the ecological functioning of the coral reef systems.
- Data on fish and invertebrate populations overlaid on biodiversity and reef health indicators has identified areas of reef that are of key management and conservation importance.
- Signs of impacts are presented in the data; fishing activities are still present within the Marine Park and rapid development on the islands is taking place.
- Key areas where specific management objectives need to be met are geographically identified.
- All development is concentrated into the narrow maritime areas close to the fringing reef systems that exacerbate the issues presented.
- Threats identified include an increase in suspended sediment concentrations, increased solid waste pollution and possible signs of nutrient elevation around the developments as well as direct damage to the marine resources in areas used intensively for recreational activities.
- Management recommendations made by this study include the role that can be played by education and environmental awareness, jurisdictional control of development as well as the effective mitigation of some of the impacts of development.
- Of the management recommendations made, whilst all are relevant to the Perhentian Archipelago, most also have relevance to the other Marine Parks throughout Malaysia and areas of the nation's coastal zone that support coral reef communities.

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1. INTRODUCTION

1.1 Project Background

Malaysia is one of the most affluent countries in the South-East Asia region. Its growth has been assisted to an extent by its abundant and rich coral reef and shallow tropical marine resources. Malaysia enjoys benefits from the world's most rapidly growing industry; tourism. Tourism currently generates 11% of the Global Gross Domestic Product and is forecast to continue to grow with a predicted 1400 million international travellers globally by 2020 (Christ *et al.*, 2003).

Much of the development that is occurring in Malaysia is concentrated into the narrow coastal zone, making this a key area in the issues affecting the sustainability of this development. The coastal zone environments, including coral reefs, are exposed to a suite of anthropogenic impacts and threats. These include, though are not limited to, overfishing, sedimentation, eutrophication and pollution which all result habitat degradation or loss. This coastal zone is however not limited to the maritime areas of the mainland, but instead extends to cover the multitude of islands and islets that are dotted around both East and West Malaysia.

The Fisheries Act of 1985 in Malaysia enabled the establishment of Marine Parks and Reserves to help limit some of these aforementioned impacts on the fragile and unique coastal zone environments of Malaysia and to promote the objectives of conservation, education and recreation.

Although excellent summaries are available for the status of the reefs throughout Malaysia (see Ridzwan, 1994), quantitative data for the marine parks of the east coast of Peninsula Malaysia are limited. Previous studies that have been conducted in this area include the DoFM and WWF-Malaysia collaborative surveys in 1994 (Aikanathan and Wong, 1994) and the surveys undertaken by Lim and Spring (1997). In 2000, WWF-Malaysia undertook a series of surveys to update WWF-Malaysia's Biodiversity Report for the Tioman archipelago (Hendry, 2000). Later in the same year CCC undertook a rapid assessment of reef health, status and biodiversity at 17 sites along the east coast between Pulau Redang and P. Tinggi (Harborne *et al.*, 2000).

Founded in 1986, CCC is dedicated to '*providing resources to protect livelihoods and alleviate poverty through the protection, restoration and sustainable use of coral reefs and tropical forests*' in collaboration with government and non-governmental organisations within a host country. CCC does not charge the host country for the services it provides and is primarily self-financed through a pioneering volunteer participatory scheme whereby international volunteers are given the opportunity to join a phase of each project in return for a financial contribution towards the project costs. Upon arrival at a project site, volunteers undergo a training programme in marine life identification and underwater survey techniques, under the guidance of qualified project scientists, prior to assisting in the acquisition of data. Finances generated from the volunteer programme allow CCC to

provide a range of services, including data acquisition, assimilation and synthesis, conservation education, technical skills training and other capacity building programmes. CCC is associated with the Coral Cay Conservation Trust (the only British-based charity dedicated to protecting coral reefs) and the USA-based Coral Cay Conservation Foundation.

Effective coastal zone management, including the conservation of coral reefs, requires a holistic and multi-sectorial approach, which is often a highly technical and costly process and one that many developing countries cannot adequately afford. With appropriate training, non-scientifically trained, self-financing volunteer divers have been able to provide useful data for coastal zone management at little or no cost to the host country (Hunter and Maragos, 1992; Mumby *et al.*, 1995; Wells, 1995; Darwall and Dulvy, 1996; Erdmann *et al.*, 1997; Harding *et al.*, 2003; Harborne *et al.*, In press). This approach has been pioneered and successfully applied by Coral Cay Conservation (CCC) since 1986.

Following a preparatory mission in May 2001 and project launch in March 2002, Coral Cay Conservation (CCC) and the Marine Parks Section of the Malaysian Department of Fisheries implemented a six-month pilot project in the Perhentian Islands in 2003. The pilot phase of the Malaysia Reefs and Islands Conservation Project (MRICP), between March and August 2003, aimed to provide basic data on the marine resources of the Perhentian Islands and their status. Subject to evaluation of the outputs from this pilot project by Government and other stakeholders, the objective is for CCC to establish a more long-term presence on the east coast of peninsula Malaysia in order to provide detailed biological assessment and monitoring data, along with training, capacity building and environmental education work.

1.2 The Perhentian Archipelago

The Perhentian archipelago is situated offshore of Terengganu state on the east coast of Peninsular Malaysia (Figure 1.1). The nearest towns on the mainland are Kuala Besut, where boats ferry passengers to the islands and Jerteh (Figure 1.2). In addition to these local towns, Kuala Terengganu the state capital is approximately 90 kilometres to the south and the town of Kota Bharu in the next state of Kelantan is approximately 50 kilometres to the north.

The waters around the Perhentian Islands were gazetted as a Marine Park under the Establishment of Marine Park Malaysia Order of 1994, part of the Fisheries Act of 1995. Since this date the Marine Park Centre on Pulau Perhentian Besar was opened in March of 2003.

The Perhentian Archipelago consists of two the main islands of Pulau Perhentian Besar and Kecil as well as five smaller islets namely Pulau Serenggeh, P. Susu Dara Besar and Kecil, P. Rawa and Tokong Burung (Figure 1.3). The islands themselves are of granitic rock origin with high relief. The island system sits atop the continental shelf with the

continental slope beginning some thirty kilometres further offshore to the east of the Islands. The bathymetry of the area is therefore a shallow continental platform extending from the mainland with an average maximum depth of thirty metres between the islands and mainland coastline. The offshore islands support coral reef areas mainly composed of the fringing reef system.

Situated approximately 5°55' north of the equator, the Perhentian Islands have a tropical climate with generally calmer conditions from March until October when the annual south east monsoon season heralds high winds and periods of prolonged heavy rainfall. Blowing across the large fetch of the South China Sea, these winds create rough seas with large waves that break on the exposed eastern coasts of the Perhentian archipelago.

The Perhentians support coral reef areas mainly composed of shallow fringing reefs or coral growth on bedrock and boulder slopes. In common with the reef systems of the other Marine Park Islands on the east coast of Peninsular Malaysia, the coral reefs around the Perhentians are presumed to contain high biodiversity despite their limited topographic complexity. A study by Coral Cay Conservation in 2000 around the adjacent Marine Park Islands along this eastern coastline recorded 221 hard coral species and 298 fish species in what was by no means an exhaustive taxonomic study (Harborne *et al.*, 2000). Both these figures represent approximately 80% of the total species number of both taxonomic groups (Scleractinia and Osteichthyes) found in the global centre of coral reef diversity within the 'coral triangle' or Wallacea bioregion.

However, the shallow coral reef communities around the Perhentians are subject to a number of anthropogenic impacts and threats. Most of these impacts come from the development of the coastal zone on the mainland and on the islands themselves, where development is concentrated very tightly into the narrow nearshore and maritime environments.

One chronic influence is the condition of the riverine input from the two main river systems that are geographically close enough to the Perhentian Islands, the Besut and Keluang rivers. River water discharging into the coastal zone greatly affected by land-based development and agriculture on the peninsula and also mariculture activities within their water sheds. The effect of these activities on the Perhentian Islands is still poorly understood.

Development on the Perhentian islands themselves is proceeding at a rapid rate, with forty-five resort operations now in place. Such development brings threats from both solid and liquid waste pollution, local erosion and sedimentation, and recreational use impacts to name just a few examples.

1.3 Project Aims

Of the studies mentioned earlier, the most recent one conducted by Coral Cay Conservation in 2000 did not survey the coral reefs around the Perhentian Islands. Consequently very little recent information exists on the status, health and biodiversity of the coral reefs in the island group

The aims and objectives of MRICP are to provide a baseline information set on the condition and status of the coral reefs around the Perhentians in 2003 (see Table 1 below). The information collected can then be used to facilitate local planning activities by being a source of data on the spatial distribution and ecological value of discrete areas within the Marine Park. The data presented needs to be in a readily accessible format for use in the support of further studies and documents such as Environmental Impact Assessments. It should also enable future temporal comparison by forming a baseline data set of the condition and status of reef resources in the Perhentians in 2003. In addition, the management recommendations made will provide a framework around which more general management initiatives can be constructed. Finally, throughout the course of the Pilot Phase of the Malaysia Reef and Islands Conservation Project, in-country capacity building will be a key facet of the work conducted.

Table 1. Main aims, objectives and anticipated outputs of the pilot phase of the MRICP.

AIM	OBJECTIVE	ANTICIPATED OUTPUTS
➡ Resource assessment.	➊ Undertake an initial scientific survey of target coral reefs. ➋ Conduct preliminary human impact assessment studies. ➌ Establish a baseline database. ➍ Provide preliminary management tools and recommendations.	➊ Initial baseline database. ➋ Description of reef habitat types. ➌ Documentation of gross anthropogenic impacts. ➍ Preliminary habitat map using satellite imagery. ➎ Preliminary management recommendations.
➡ Reef health assessment.	➊ Undertake 'Reef Check' surveys within the project area to quantitatively assess benthic and fish communities and anthropogenic impacts. ➋ Establish a Reef Check database for the Perhentian Islands. ➌ Provide data for the national and global Reef Check databases. ➍ Provide preliminary management tools and recommendations.	➊ Quantitative assessment of reef health. ➋ Data set for comparison with future surveys. ➌ Preliminary management recommendations.
➡ Training and conservation education.	➊ Provide scientific and SCUBA training for CCC volunteers and local counterparts. ➋ Heighten awareness of marine resources, their use and protection. ➌ Begin to develop a sense of community stewardship in managing the coastal zone.	➊ Trained project members. ➋ Increased awareness amongst local communities.



Figure 1.1. The Perhentian Islands in relation to Peninsular Malaysia, Kuala Lumpur and Singapore. Map taken from Reef Base online at www.reefbase.org

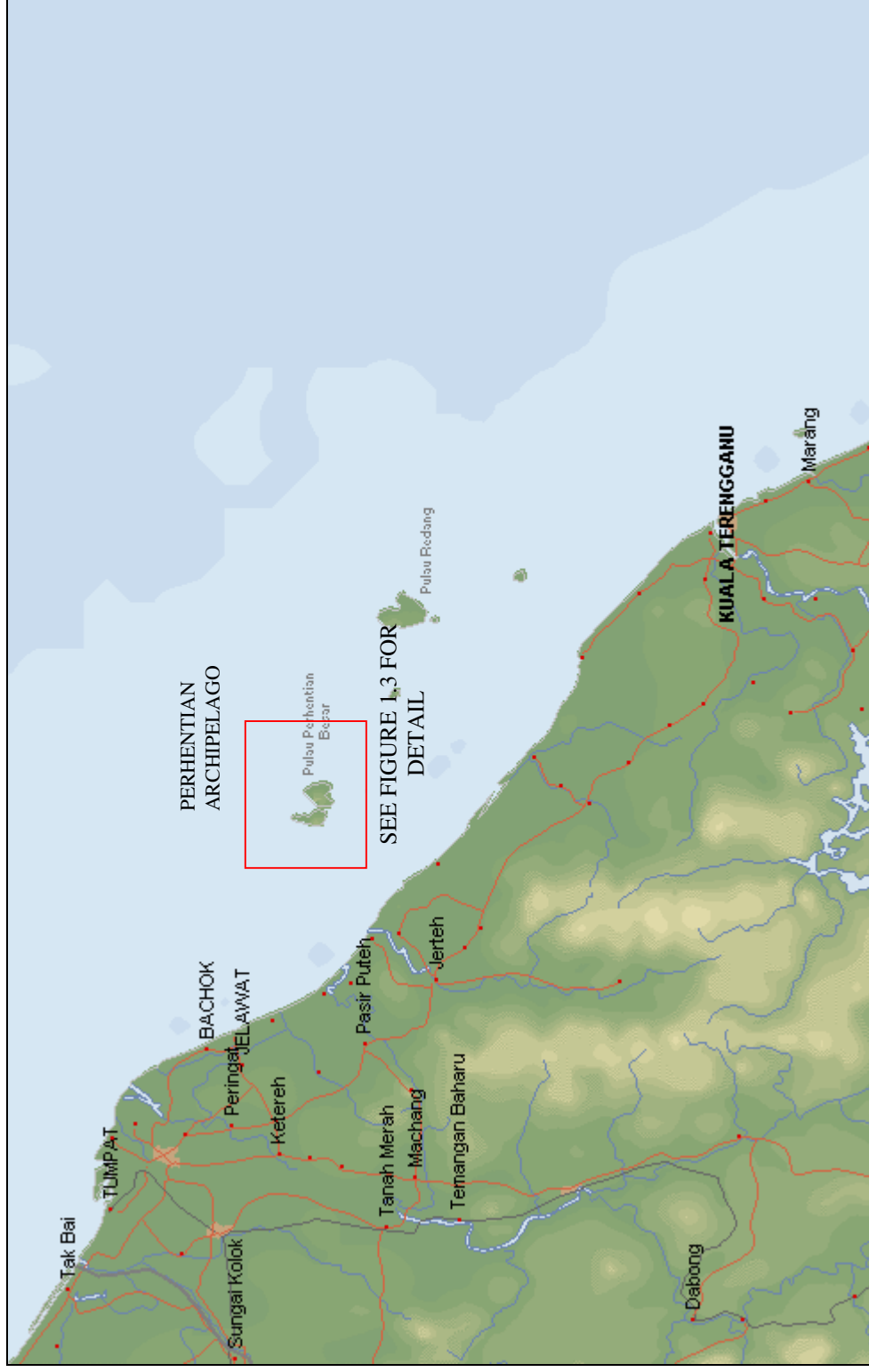


Figure 1.2. The Perhentian Islands in relation to major settlement centres on mainland Peninsular Malaysia. Map taken from Reef Base online at www.reefbase.org

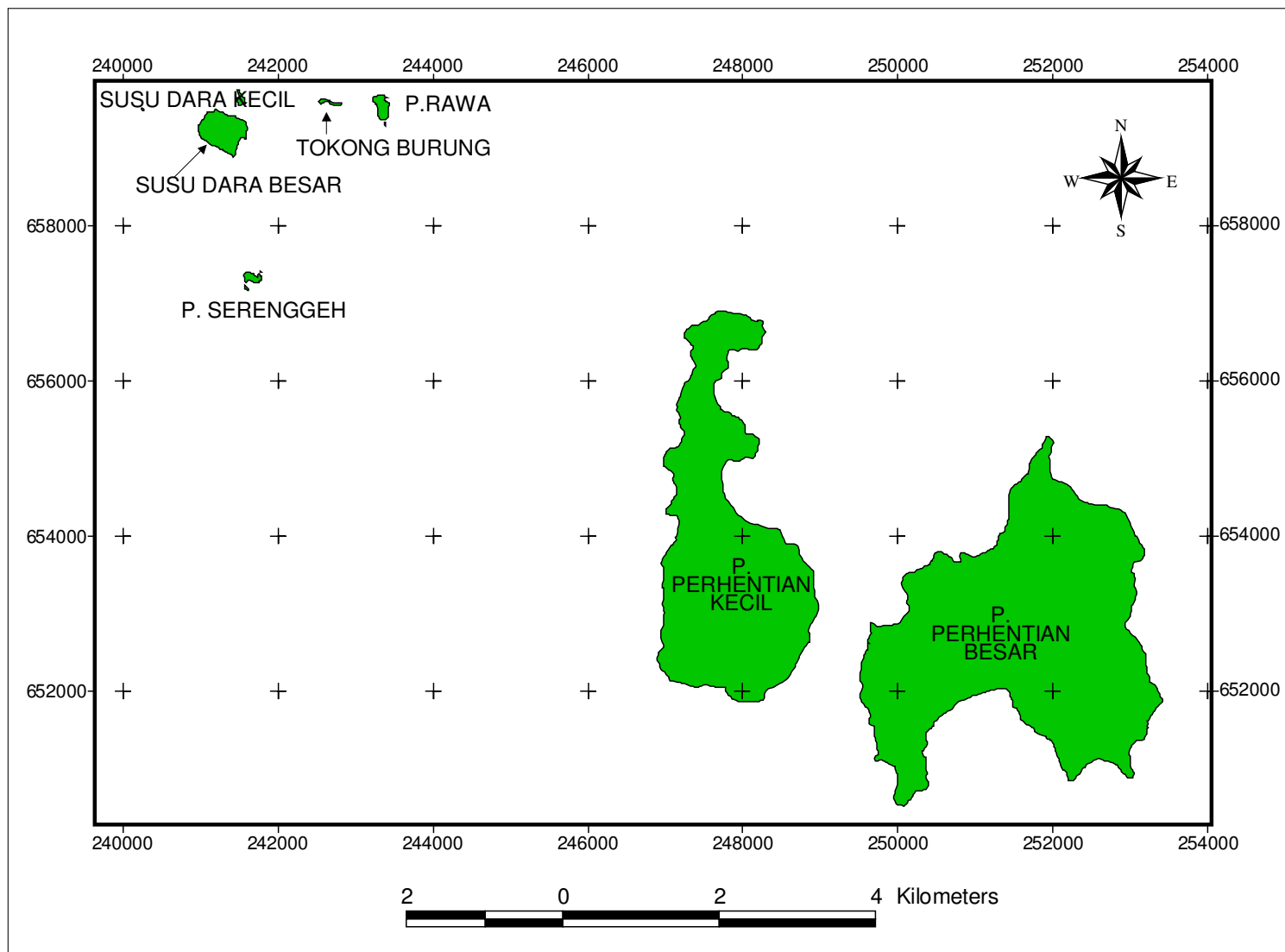


Figure 1.3. Islands in the Perhentian Archipelago.

2. METHODS

2.1 Volunteer training

Efficient and effective training is a vital component of any volunteer programme in order that participants quickly gain the required identification and survey skills that allow them to collect accurate and useful data. During the MRICP, CCC used an intensive 12-day training programme, plus one day of validation, which is outlined in Table 2.1. The programme was designed to provide volunteers, who may have no biological knowledge, with the skills necessary to collect useful and reliable data. The primary aim of the lecture programme was to give volunteers the ability to discern the specific identification characteristics and relevant biological attributes of the target organisms they would encounter during diving surveys. The training programme was co-ordinated by the Project Scientist (PS) and Science Officer (SO) and involved two lectures and two dives or snorkels each day along with de-briefings and evening audio-visual presentations. Volunteers were also encouraged to snorkel and utilise identification guides to ensure a thorough understanding of the information provided in the lectures.

An important component of the training schedule was a series of testing procedures to ensure that each volunteer had reached a minimum acceptable standard. Hence the training programme concluded with a series of tests, which ensured that the volunteers had reached an acceptable standard of knowledge. These tests used both ‘flash-cards’ and in-water identification exercises for corals and fish. Furthermore, to assess the quality of data collected by CCC volunteers during actual survey work, two validation exercises were undertaken. The benthic validation exercise used a test transect survey set up and thoroughly surveyed by the PS and SO to collate a reference data set. During Phase 1, test transects were conducted in buddy pairs with one person recording coral and the other soft corals, invertebrates and algae (as performed by Divers 3 and 4 during surveys; Section 3.3). During Phase 2, each person surveyed the transect line as during an actual Reef Check transect. Data were then transferred to recording forms and entered into a spreadsheet where the results from each pair were compared to the reference using the Bray-Curtis similarity coefficient (Equation 1; Bray and Curtis, 1957).

Equation 1:

$$\text{Bray - Curtis Similarity, } S_{jk} = \left[1 - \frac{\sum_{i=1}^p |X_{ij} - X_{ik}|}{\sum_{i=1}^p (X_{ij} + X_{jk})} \right]$$

Where X_{ij} is the abundance of the i th species in the j th sample and where there are p species overall.

Since it is impossible to compare volunteer fish data to a reference, validation of fish surveys were conducted by measuring the consistency between pairs of surveyors. It is then assumed that if surveyors are consistent they are also accurate. Therefore, both divers within a buddy pair independently survey the whole fish list and each surveyor fills out their own survey form and enters it onto a spreadsheet. As with the benthic validation, the pairs of results were compared using the Bray-Curtis similarity coefficient. These assessments were similar to the critical assessment conducted by

CCC in Belize in 1993 to test the accuracy of volunteer divers conducting baseline transect surveys (Mumby *et al.*, 1995).

	Day +1 (Tue)	Day +2 (Wed) No diving	Day +3 (Thu)	Day +4 (Fri) No diving	Day +5 (Sat)	Day +6 (Sun)	Day +7 (Mon)	Day +8 (Tue)	Day +9 (Wed)	Day +10 (Thu)	Day +11 (Fri) No Diving
←AM	<u>Transfer</u> New vols (i.e. trained scuba divers) to Castaway <u>Survey dive</u> (Trained Volunteers only - see note 2) <u>Orientation</u> ► Welcome & tour of facilities ► Expedition life & duties ► General health & safety ► CCC rules & regulations <u>Practical</u> ► Scuba kit allocation ► PADI AOW Elective Dive: PPB (6m) with new diver volunteers	<u>Lecture 2</u> ► Dangerous animals! <u>Safety briefs</u> ► PADI MFA: Ac mods 1+2 ► O₂ therapy ► PADI tables & quiz (OW mods 4+5) ► CCC dive standards ► Radio use ► Emergency procedures ► Boat safety ► Boat marshalling ► Use of boat safety kit	<u>Lecture 3</u> ► Intro to coral reef ecology <u>Practical</u> ► Reef orientation (scuba-18m) ► <u>PADI AOWD Training</u> Elective Dive 3 (18m)	<u>Review</u> ► ID – coral, fish, inverts & algae <u>ID skills evaluation</u> ► Inverts & algae (slides & samples) ► Inverts & algae (snorkel)	<u>Lecture 6i</u> ► Hard coral ID – target grps <u>Practical</u> ► Hard coral ID (scuba-18m) ► Hard coral ID	<u>Lecture 11i</u> ► Fish families and species ID <u>Practical</u> ► Fish ID – Families (18m) <u>Review</u> ► Fish ID – Families	<u>Lecture 11iii</u> ► Fish ID – target species <u>Practical</u> ► Fish ID – target species (scuba-18m) <u>Review</u> ► Fish ID – target species	<u>Lecture 13</u> ► Invert. ID <u>Practical</u> ► Invert. ID (scuba-18m) <u>Review</u> ► Invert. ID	<u>Lecture 15</u> ► Intro to CCC Reef Survey Technique <u>Practical</u> ► CCC Reef Survey methods (dry run) ► CCC Reef Survey methods practice (scuba-18m) <u>Review</u> ► CCC Reef Survey technique	<u>Lecture 17</u> ► CCC data validation <u>Skills refresher</u> ► Benthic validation (scuba-18m)	<u>Review</u> ► ID – hard & soft corals <u>(a) Skills validation</u> ► Coral trail (Snorkel)
←PM	<u>Safety briefs</u> ► PADI RD: Ac mods 1+2 <u>Practical</u> ► PADI RD: OW exc. 1 (surface only) ► OW exc. 2 (3m)	<u>Lecture 10</u> ► Marine plants & algae <u>Practical</u> ► Marine plants & algae ID (snorkel) ► Specimen ID – reference collections	<u>Lecture 4</u> ► Intro to hard coral biology <u>Practical</u> ► ID - coral life forms (scuba-16m) <u>Review</u> ► Coral life forms	<u>Practical revision</u> ► ID – all fauna and flora (snorkel)	<u>Lecture 7</u> ► Soft coral and sponge ID <u>Practical</u> ► Hard/soft coral ID (scuba – 16m) <u>Review</u> ► Hard/soft coral ID	<u>Lecture 11ii</u> ► Fish ID – target species <u>Practical</u> ► Fish ID – target species (16m) <u>Review</u> ► Fish ID – target species	<u>Practical</u> ► Fish ID – target species (scuba-18m) <u>Review</u> ► Fish ID – target species	<u>Review</u> ► ID – coral, fish, inverts & algae <u>Practical</u> ► ID – coral, fish, inverts & algae (scuba-16m) <u>Self-revision</u> ► ID – coral, fish, inverts & algae	<u>Lecture 16</u> ► Intro to CCC Reef Survey forms, habitat classifications and use of Abundance Scales <u>Practical</u> ► Practice survey (scuba-16m) ► Data entry onto CCC forms	<u>Skills validation</u> ► Coral trail (scuba-16m)	<u>Review</u> ► ID – fish <u>Skills validation</u> ► Fish (Snorkel) <u>Review</u> ► Validation assessment

Table 2.1. CCC Skills Development Programme timetable for CCC volunteers and local counter-parts during the MRICP Marine Pilot Phase.

EVE	Lecture 1 ▶ Malaysia Review ▶ Expedition Skills Training schedule	Review quiz ▶ CCC health & safety regulations ▶ CCC dive standards ▶ Emergency procedures ▶ Local culture & customs	Lecture 5 ▶ Coral biology and taxonomy		Lecture 8 ▶ Intro to fish ecology & behaviour Lecture 9 ▶ Intro to GPS	Review ▶ Coral & fish ID (pictionary) Lecture 12 ▶ Ropes & knots	Review ▶ Coral, fish and algae ID (pictionary) Review ▶ GPS & knots	ID skills evaluation ▶ Corals Lecture 14 ▶ CCC data: analysis & use	Safety brief ▶ Night-diving procedures Practical ▶ Optional night-dive (12m)	ID skills evaluation ▶ Fish (slides)	ID skills evaluation ▶ Re-takes (if required) Lecture 18 ▶ Other survey methods

Table 2.1. (Continued). CCC Skills Development Programme timetable for CCC volunteers and local counter-parts during the MRICP Marine Pilot Phase

	Day +12 (Sat)	Day +13 (Sun)	Day +14 (Mon)
⇐ AM	Skills validation Retakes if required (fish or coral) review Coral and soft coral ID	practice CCC Reef Survey dive shore dive/boat dive Followed by Data entry	Data collation – practice CCC Reef Survey dive Validation retake if required ID skills evaluation if required
⇐ PM	Practice CCC Reef Survey dive from boat Lecture 19 ▶ Data entry to CCC computer database – (groups of 4)	Practice CCC Reef Survey – shore/boat dive Followed by Data entry PADI MFA* ▶ Mods 3+4	Practice CCC Reef Survey dive Validation retake if required Graduation! Congratulations on completing the CCC Skills Development Programme PADI MFA* ▶ Mods 5+6
EVE		Lecture 20 ▶ Marine reserves retakes of ID skills if required	Lecture 21 ▶ mangrove ecology retakes of ID skills if required

2.2 Survey strategy

Since the area encompassed by the Perhentian Archipelago is extensive the survey strategy focused on gathering detailed data from a wide range of geographical locations. The main aim was to generate data from a broad range of habitat types that represent most reef types of the area and hence provide a thorough overview of all of the marine resources that are found around the Perhentians.

2.2.1 *The Concept Of ‘Survey Sites’*

During the pilot phase of the MRICP, CCC volunteers collected data from a series of ‘survey sites’, which correspond to a particular island’s reef or part of a reef depending on reefal area. Surveys at each site generate a standardised data set that will facilitate characterisation of each area and also powerful comparisons at a range of spatial scales. Sites were chosen to represent: (1) popular diving areas; (2) the ‘best’ reefs of the project area; (3) the ‘worst’ reefs of the project area; (4) a range of reef (and hence habitat) types. Site selection was based on a combination of existing data, local information (e.g. dive resorts), local biologists and initial assessments (e.g. snorkelling). A total of 15 Survey Sectors were designated for potential surveying during the Pilot Phase of the project; six around the outlying islands of the Perhentian Archipelago, plus four and five around the main islands of Perhentian Kecil and Besar respectively (Figure 2.1).

Two survey techniques were used during the Pilot Phase of the MRICP: CCC baseline transects for habitat mapping; and Reef Check surveys to assess reef health.

Firstly, standard *CCC Baseline Survey Technique* transects were surveyed to provide general data on each habitat type present. The exact number of transects at each site varied, depending on the topography of the reef (e.g. fewer transects at those sites with a wide or deep reef profile), but usually numbered between 3 and 20, depending on the scale and size of each survey site.

Secondly, modified ‘Reef Check’ surveys were used to collect quantitative data on the health of survey sites. Reef Check¹ is an established method for rapidly assessing reef health and was designed specifically for non-specialist researchers. CCC has adapted the standard Reef Check technique to record a further level of detail in terms of benthic habitats, hard coral and reef fish targets. In addition to these key techniques, further data such as compiling species lists and assessing water quality will be undertaken concurrently.

Baseline transects were completed throughout all months of the pilot project. Reef Check surveys were undertaken at the three discrete sites to provide a good geographical distribution of survey effort. These sites were close to the paths of the baseline transects so that the data sets would be complimentary and could be analysed in conjunction with benthic habitat data.

¹ <http://www.ReefCheck.org/>

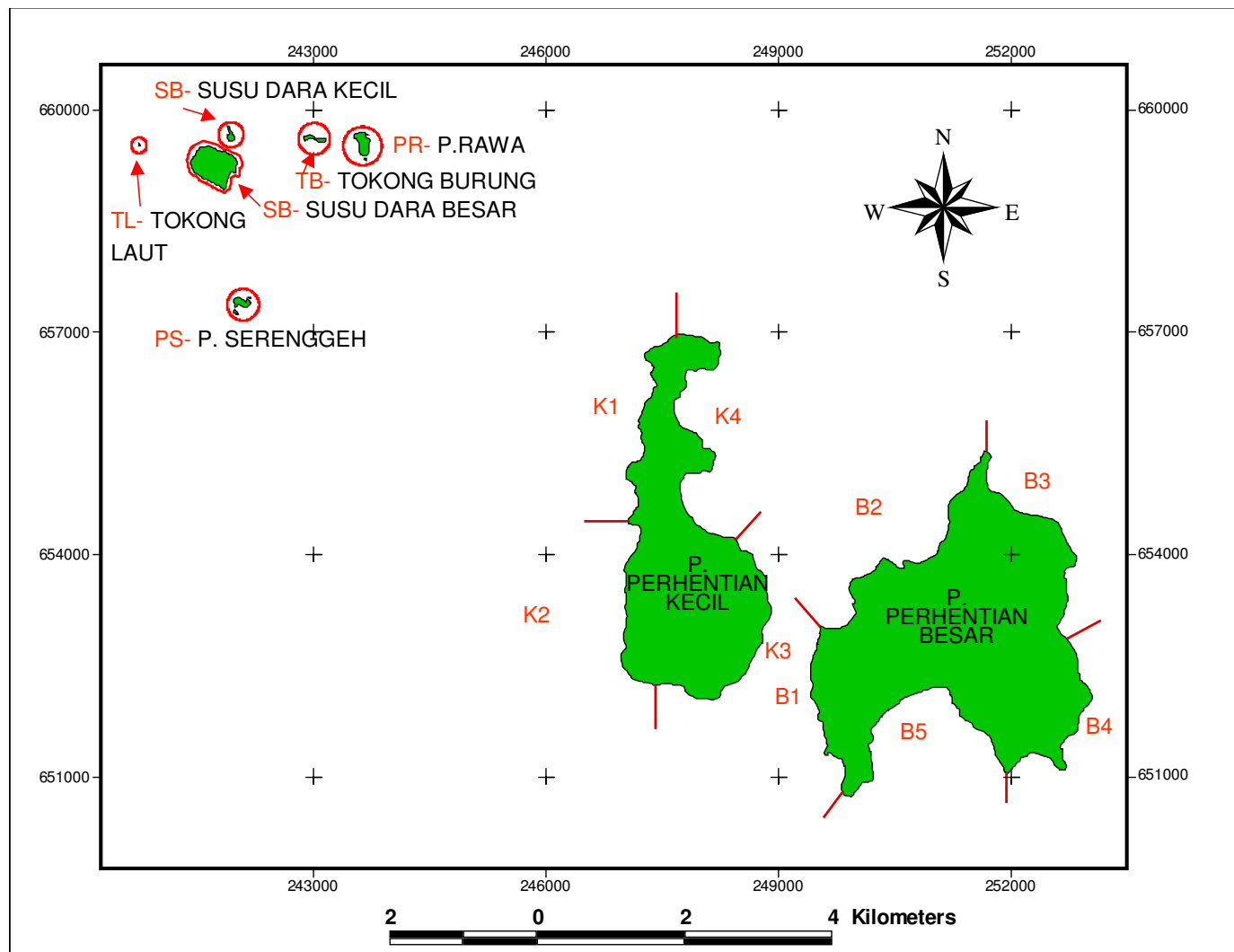


Figure 2.1. Location of the different survey sectors within the Perhentian Archipelago. Site codes are highlighted in red.

2.3 Baseline transect technique

The Pilot Phase of the MRICP utilised the standard baseline survey techniques developed by CCC for the rapid assessment of biological and physical characteristics of reef communities by trained volunteer divers. Following an intensive training programme, CCC's techniques have been shown to generate precise and consistent data appropriate for baseline mapping (Mumby *et al.*, 1995). All surveys were co-ordinated by the PS and SO to ensure accurate and efficient data collection.

CCC's standard baseline transect survey technique utilises a series of plot-less transects, perpendicular to the reef, starting from the 28 metre depth contour or four meters below the bottom of reefal development, whichever is deeper. Surveys terminate at the reef crest or in very shallow water. Benthic and fish surveys were focused on life forms or families along with a pre-selected number of target species that were abundant, easily identifiable or ecologically or commercially important. Stony corals were recorded as life forms as described by English *et al.* (1997) and selected corals were identified to species level. Fish were generally identified to family level but in addition, important target species were identified. Sponges and octocorals were recorded in various life form categories. Seaweeds were classified into three groups (green, red and brown algae) and identified to a range of taxonomic levels such as life form, genera or species.

Since most transects require two or more dives to complete, transect surveys were usually divided up into sections (or 'sub-transects') with surveys of each sub-transect carried out by a team of four trained divers divided into two buddy pairs (A and B) as shown in Figure 2.2. At the start point of each sub-transect, Buddy Pair B remained stationary with Diver 3 holding one end of a 10 m length of rope, whilst Buddy Pair A swam away from them, navigating up or along the reef slope in a pre-determined direction until the 10 m line connecting Diver 1 and 3 became taught. Buddy Pair A then remained stationary whilst Buddy Pair B swam towards them. This process was repeated until the end of the planned dive profile, when a surface marker buoy (SMB) carried by Diver 2 was deployed to mark the end of that sub-transect. The SMB acted as the start point for the next survey team and this process was repeated until the entire transect was completed. The positions of the SMB at the start and end of each dive were fixed using a Global Positioning System (GPS).

Diver 1 was responsible for leading the dive, taking a depth reading at the end of each 10m interval, and documenting signs of anthropogenic impact such as broken coral or fishing nets. Diver 1 also described the substratum along the sub-transect by recording the presence of six substrate categories (dead coral, recently killed coral, bedrock, rubble, sand and mud). Divers 2, 3 and 4 surveyed fish, hard corals and algae, soft corals, sponges and invertebrates respectively. Diver 3 surveyed an area of approximately 1 metre to each side of the transect line whilst Divers 1, 2 and 4 survey an area of approximately 2.5 metres to either side of the line.

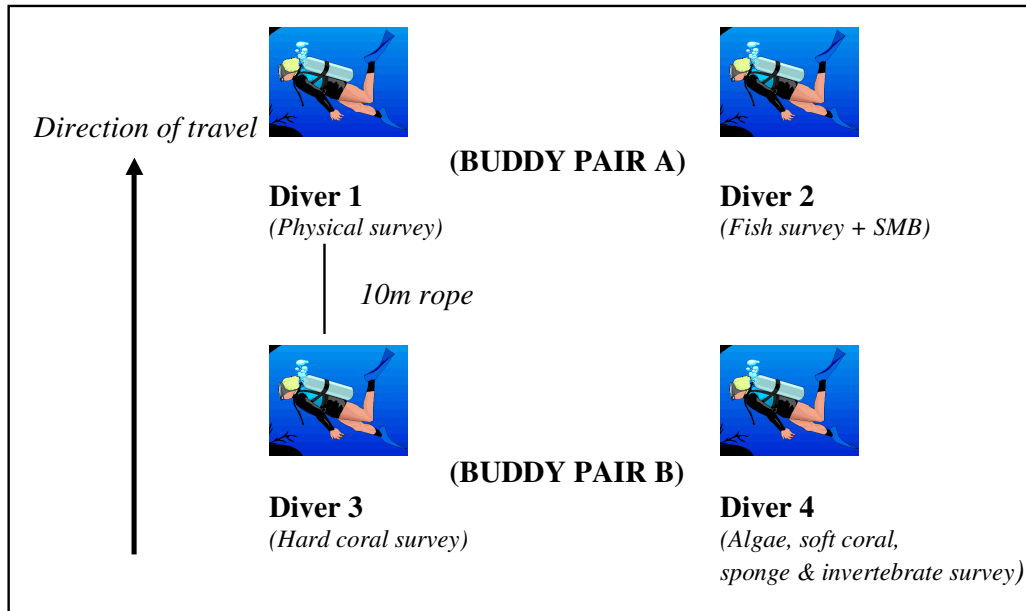


Figure 2.2. Schematic diagram of a baseline survey dive team showing the positions and data gathering responsibilities of all four divers. Details of the role of each diver are given in the text.

During the course of each sub-transect survey, divers may have traversed two or more apparently discrete habitat types, based upon obvious gross geomorphological (e.g. forereef, escarpment or lagoon) or biological differences (e.g. dense coral reef, sand or rubble; Figure 2.3). Data gathered from each habitat type were recorded separately for subsequent analysis.

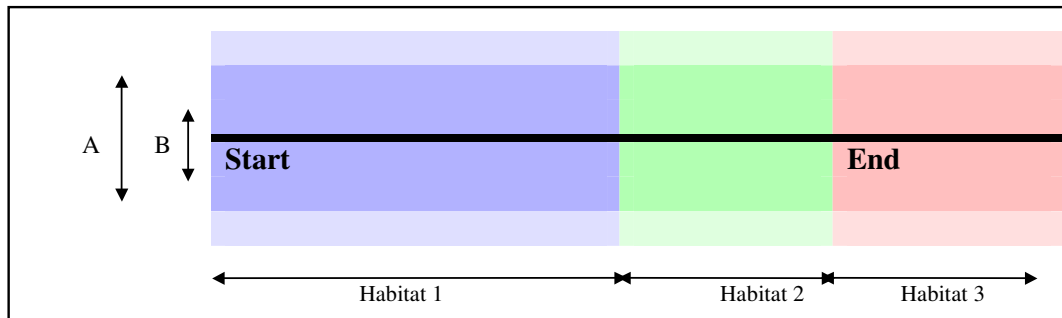


Figure 2.3. Schematic diagram (aerial aspect) of an example of a reef area mapped by divers during a sub-transect survey. Solid line represents imaginary sub-transect line. Dashed lines and shaded areas represent areas surveyed (A = 5m wide swathe surveyed by Divers 1, 2 and 4; B = 2 m wide swathe surveyed by Diver 3). Benthic data from habitats 1, 2 and 3 (e.g. reef, sand and rubble) are recorded separately.

Each species, life form or substratum category within each habitat type encountered was assigned an abundance rating from the ordinal scale shown in Table 2.2.

Abundance rating	Coral and algae	Fish and invertebrates (number of individuals)
0	None	0
1	Rare	1-5
2	Occasional	6-20
3	Frequent	21-50
4	Abundant	51-250
5	Dominant	250+

Table 2.2. Ordinal scale assigned to life forms and target species during baseline surveys.

During the course of each survey, certain oceanographic data and observations on obvious anthropogenic impacts and activities were recorded at depth by the divers and from the surface support vessel. Water temperature readings ($\pm 0.5^{\circ}\text{C}$) were taken from the survey boat using a bulb thermometer at the sea surface. The survey team also took the temperature at the maximum survey depth (i.e. at the start of the survey). Similarly, the salinity was recorded using a hydrometer and a water sample taken from both the surface and the maximum survey depth. Water visibility, a surrogate of turbidity (sediment load), was measured both vertically and horizontally. A secchi disc was used on the survey boat to measure vertical visibility through the water column (Figure 2.4). Secchi disc readings were not taken where the water was too shallow to obtain a true reading. Horizontal visibility through the water column was measured by divers' estimates while underwater. Survey divers qualitatively assessed the strength and direction of the current at each survey site. Direction was recorded as one of eight compass points (direction current was flowing towards) and strength was assessed as being 'None', 'Weak', 'Medium' or 'Strong'. Similarly, volunteers on the survey boat qualitatively assessed the strength and direction of the wind at each survey site. Direction was recorded as one of eight compass points (direction wind was blowing from) and strength was assessed using the Beaufort Scale.

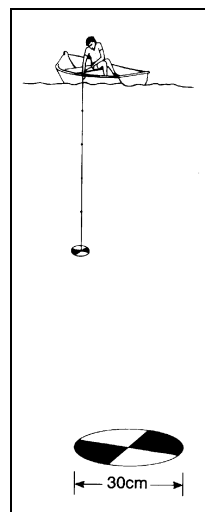


Figure 2.4. The use of a secchi disc to assesses vertical water clarity. The secchi disc is lowered into the water until the black and white quarters are no longer distinguishable. The length of rope from the surveyor to the disc is then recorded. *Source: English et al. (1997).*

Natural and anthropogenic impacts were assessed both at the surface from the survey boat and by divers during each survey. Surface impacts were classified as 'litter', 'sewage', 'driftwood', 'algae', 'fishing nets' and 'other'. Sub-surface impacts were categorised as 'litter', 'sewage', 'coral damage', 'lines and nets', 'sedimentation', 'coral disease', 'coral bleaching', 'fish traps', 'dynamite fishing', 'cyanide fishing' and 'other'. All information was assessed as presence / absence and then converted to binary data for analysis. Any boats seen during a survey were recorded, along with information on the number of occupants and its activity. The activity of each boat was categorised as 'diving', 'fishing', 'pleasure' or 'commercial'. Finally the divers recorded a general impression of the site during each survey. These ratings were completed for biological (e.g. benthic and fish community diversity and abundance) and aesthetic (e.g. topography) parameters. Both parameters were ranked from a scale of 5 (excellent), 4 (very good), 3 (good), 2 (average) or 1 (poor).

Data collected from each sub-transect survey were transferred to recording forms prior to incorporation into CCC's database. The recording forms are shown in Appendix I and consist of a 'Boat Form', 'Physical Form' and 'Biological Form'. Each form is completed for each individual dive, although there may be more than one biological form depending on the number of habitats observed. The Boat Form holds data on the GPS co-ordinates of the dive along with oceanographic and climate data such as winds, currents, temperatures and salinities. The Physical Form holds data on the maximum and minimum depths of the dive, the aesthetic and biological ratings and also a reef profile drawn from the depths collected every 10 m. Finally the Biological Form(s) contain data on the reef zone, the major biotic and substratum features of the habitat and the ordinal ratings of each life form and target species.

2.4 Reef Check

Reef Check was designed to be used by non-professional divers to assess reef health and hence generates relatively simple, but quantitative, information. During the MRICP the standard Reef Check protocol was modified to collect more detailed data (e.g. via greater taxonomic resolution) and hence provide a better assessment of reef health. Such modifications were possible because all CCC volunteers received more intensive training than regular sport divers. Each Reef Check site was located close to a baseline transect in order that the data sets could be spatially linked together and hence analysed in conjunction.

The standard Reef Check survey protocol utilises two transects at depths of approximately 3 and 10 m. Along each depth contour a 100 m transect was deployed and along it four 20 m long replicate transects were surveyed. The replicate transects followed the designated depth contour in sequence but the start and end points are separated by a 5 m space (Figure 2.5) i.e. the distance between the start of the first transect and end of the last transect was $20 + 5 + 20 + 5 + 20 + 5 + 20 = 95$ m. By collecting data from each of the four 20 m sections, four replicates were collected per survey allowing the calculation of a mean per replicate and hence more powerful statistical analysis.

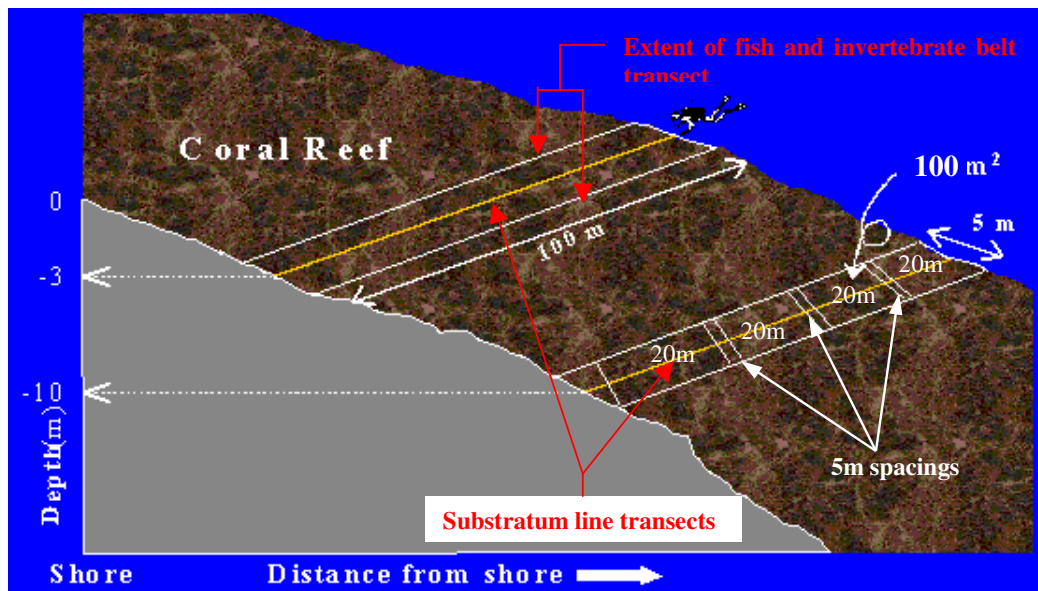


Figure 2.5. Schematic diagram showing the position of the transect lines during a Reef Check survey. 100 m transect is divided into four 20 m replicates so area of each belt transect is $20 \times 5 \text{ m} = 100 \text{ m}^2$. In addition to the standard 3 and / or 10 m transects, CCC used one or more deeper transects when appropriate. Source: modified from figures on <http://www.reefcheck.org>.

Five types of data were recorded via three surveys along each transect line at each depth. Firstly, a site description sheet was completed which included anecdotal, observational, historical, locational and other data. Secondly, four 5 m wide by 20 m long transects (centred on the transect line) were sampled for commercially important fish, for example those typically targeted by fishers and aquarium collectors. Fish were only counted if they were less than 5 m above the transect line, giving a survey area for each transect replicate of $20 \times 5 \times 5 \text{ m} = 500 \text{ m}^3$. CCC volunteers in Malaysia recorded data on more fish species than specified by the standard Reef Check protocol. The divers assigned to count fish swam slowly along the transect and then stopped to count target fish every 5 m and then waited three minutes for target fish to come out of hiding before proceeding to the next stop point. Thirdly, four 5 m wide by 20 m long transects (centred on the transect line) were sampled for invertebrate taxa typically targeted as food species or collected as curios. Quantitative counts were made of each species. In addition, the invertebrate surveyors noted the presence of coral bleaching or unusual conditions (e.g. diseases) along the transects.

Finally, four 20 m long transects were point sampled at 0.5 m intervals to determine the substratum types and benthic community of the reef. The diver looked at each point and noted down what lay under each of those points. The standard Reef Check protocol specifies that the categories recorded under each 50 cm point are: hard coral, soft coral, recently killed coral, dead coral, fleshy seaweed, sponge, rock, rubble, sand, silt / clay and 'other'. However, CCC volunteers recorded hard corals to life form level (along with target species), soft corals to life form level and five categories of algal cover (mixed assemblage, coralline, *Halimeda*, 'macro' and 'turf'). Finally, the substratum surveyors recorded coral damage from anchors, dynamite, or 'other' factors and trash from fishing nets or 'other'. Divers rated the damage caused by each

factor using a 0-3 scale (0 = none, 1 = low, 2 = medium, 3 = high). All data were transferred to specially designed recording forms (Appendix II).

Data from the Reef Check surveys will be made available to the global and national databases, hence increasing the impact of the project.

2.5 Data analysis

2.5.1 Baseline data

Oceanographic, climate and anthropogenic impact data

Data on water temperature, salinity, visibility, the strength and direction of currents and wind, natural and anthropogenic impacts, the presence of boats and the biological and aesthetic ratings were summarised graphically and via univariate statistics, along with more detailed examination of the data using Analysis of Variance (ANOVA) and subsequent least significant difference multiple range tests. Data were either summarised for the whole project area or for each of the five reef complexes as appropriate.

Benthic data

In order to describe the reefal habitats within the project area, benthic and substratum data were analysed using multivariate techniques within PRIMER (Plymouth Routines in Multivariate Ecological Research) software (Clarke and Warwick, 1994). Data from each Biological Form (which represents a 'snap-shot' of the benthic community from either part or all of a habitat type distinguished by the survey team) are referred to as a Site Record. Multivariate analysis can be used to cluster the Site Records into several groups, which represent distinct benthic classes.

The quantity of data collected in the Pilot Phase was greater than that which could be analysed using the PRIMER program. Accordingly, a subset of Site Records was taken to include 999 data sets; with the remaining 64 data sets having been randomly selected out of the data set returned to the analysis after the formation of the dendrogram. To ensure that none of these 64 Survey Records which had been removed contained an additional Benthic Class (which would not be identified by hierarchical cluster analysis), once the remaining 999 data sets had been assigned to an individual habitat, discriminant analysis was used to assess how well the remaining 64 Site Records fitted into one of the pre-defined Benthic Classes. Discriminant Analysis was performed in the Minitab statistical package where the prediction of group membership function was used. Each of the Site Records was assigned to the most probable Benthic Class to which they belonged. The output of Probability indicated the statistical likelihood of belonging to this Benthic Class. Site Records that had a probability less than or equal to 0.05% could not be said to have been placed in that Benthic Class by anything other than random statistical probability and were not therefore said to belong to that Benthic Class. These Site Records were then placed back into the PRIMER analysis at the exclusion of another randomly chosen Site

Record. This ensured that all Benthic Classes represented in all 1063 Site Records were identified during the analysis.

During PRIMER analysis, firstly, the similarity between benthic assemblages at each Site Record was measured quantitatively using the Bray-Curtis Similarity coefficient without data transformation (Equation 1; Bray and Curtis, 1957). This coefficient has been shown to be a particularly robust measure of ecological distance (Faith *et al.*, 1987).

Agglomerative hierarchical cluster analysis with group-average sorting was then used to classify field data. Cluster analysis produces a dendrogram grouping Site Records together based on biological and substratum similarities. Site Records that group together are assumed to constitute a distinct benthic class. Characteristic species or substrata of each class were determined using Similarity Percentage (SIMPER) analysis (Clarke 1993).

To identify characteristic features, SIMPER calculates the average Bray-Curtis similarity between all pairs of intra-group samples (e.g. between all Site Records of the first cluster). Since the Bray-Curtis similarity is the algebraic sum of contributions from each species, the average similarity between Site Records of the first cluster can be expressed in terms of the average contribution from each species. The standard deviation provides a measure of how consistently a given species contributes to the similarity between Site Records. A good characteristic species contributes heavily to intra-habitat similarity and has a small standard deviation. The univariate summary statistics of median abundance of each species, life form and substratum category were also used to aid labelling and description of each benthic class.

Finally, the benthic class of each Site Record was combined with the geomorphological class assigned during the survey to complete the habitat label. The combination of a geomorphological class and benthic class to produce a habitat label follows the format described by Mumby and Harborne (1999).

Fish and invertebrate data

Fish and invertebrate data were summarised graphically and via univariate statistics, along with more detailed examination of the data using ANalysis Of SIMilarity (ANOSIM, a routine within PRIMER). ANOSIM tests for differences between groups of community samples, defined *a priori*, using randomisation methods on a similarity matrix produced by cluster analysis.

2.5.2 Management Rating

The concept of the establishment of a Marine Protected Area or Areas is based on the need for environmental stability as well as the influence of socio-economic demands placed on the natural resources of an area. This trade off often results in the areas that are declared as MPA's are as geographically small as is possible whilst protecting the marine resources of the entire region- a concept of representation. Ideally, MPA sites should represent the best and most ecologically important areas. This idea is related to the theory that certain reef areas are source reefs that have a net export of larvae

whilst other areas are sink reefs that have a net import of larvae. The concept behind this source and sink reef management is that if the source reefs are protected, they will repopulate the denuded sink reef areas.

Source reefs are reefal areas of good health. The concept of a healthy coral reef community is a complex one and one that relies on a number of variables. In this study, the relative health and therefore the relative management potential of each surveyed area of reef is defined using a range of univariate health indicators. Each of these indicators is calculated for each habitat or benthic class, which is in itself, a geographically defined data set. The factors used were; mean hard coral cover, Shannon-Weiner Diversity Index of benthic species associated with the habitat, the number of benthic species recorded, Shannon-Weiner Diversity Index of fish associated with the habitat in question, and the number of fish species recorded in the habitat.

Mean values of each of these reef health indicators were calculated across all benthic classes. Each class in turn was then assessed to determine how many of its calculated reef health variables were above average. Finally, each survey record that had been assigned to a Benthic Class was given a rating using the number of univariate reef health indicators on which it scored above average. A score of zero on this rating scale equates to the Survey Record belonging to a habitat or benthic class where none of the five univariate reef health indicator variables were above average across all the Survey Records analysed. By contrast, a Survey Record with a score of five belongs to a benthic class where all five variables were above the average value calculated.

Each transect surveyed during the CCC Baseline technique is comprised of a composite of more than one Survey Record, each of which may belong to different benthic classes and therefore have differing degrees of reef health. By splitting each transect into its constituent parts, and weighting the composition of each transect according to the length surveyed, it was possible to construct an overall reef health statistic for that survey transect ranging from 0-5.

To facilitate easy interpretation of these values, the following scale was used; where transects scored an overall rating >4.5 they were classified as of high management potential, from 3.5-4.5 as moderate management potential and finally below 3.5 of low management potential. With each of these transects being spatially locatable data sets, a map to show the relative management potential of each transect surveyed thus far has been constructed.

2.5.3 Reef Check

Reef Check data were summarised graphically and via univariate statistics, along with more detailed examination of the data using Analysis of Variance (ANOVA) and regression analysis to test for correlations. Percentage data were Arcsin transformed to ensure normality where appropriate. Note that coral cover is generally divided into ‘*Acropora*’ and ‘non-*Acropora*’. Such a division is often used in coral reef ecology since *Acropora* is the largest genus of coral within the Indo-Pacific region, with over 160 species (Veron, 2000), and may have distinct ecological properties. For example,

it is known to be particularly susceptible to coral bleaching (e.g. Marshall and Baird, 2000). Total coral cover is a sum of these two parameters.

2.6 Observations of Megafauna

Throughout the surveys undertaken during the pilot phase of the MRICP qualitative observations of megafauna were recorded. The abundance of megafauna is important because, for example, they are attractive to tourists and are often the first species to be reduced or extirpated by over-fishing.

2.7 Species Records

As part of the standard survey protocols employed by CCC during the Pilot Phase of MCRCP, species identified were noted. The resulting species inventory can be found in Appendices III and IV for hard coral and fish species respectively.

3. RESULTS

3.1 Coral Reef Surveys

A total of two hundred and fifty CCC Baseline survey dives on one hundred and thirty four transects were conducted in the period from 20th April to the 26th August 2003. During these dives, a total of 11.55 kilometres of reef were surveyed, collecting 38,489 records of species and substratum abundance. This equates to a total of 716 hours, 40 minutes of underwater survey time. In addition, twelve Reef Check survey dives were completed at three sites, each surveyed at two depth bands. A chronological presentation of survey progress is shown by Table 3.1. The location of CCC baseline and Reef Check surveys completed in the Perhentian island group is depicted by Figure 3.1

All maps reproduced in this report have been digitised from a SPOT Panchromatic satellite image acquired on 18th May 2003. The coordinate system used is the Universal Transverse Mercator system of which the project site is within Zone 48 North. Maps are projected on the World Geodetic System- 84 geographic spheroid (WGS84).

Month (2003)	Sector Number	Sector Name	Transects Completed	Transect Codes
April- May	B3	P. Perhentian Besar	28	B301-B328
April-May	SB	Pulau Susu Dara Besar	24	SB01-SB24
May	SK	Pulau Susu Dara Kecil	9	SK01-SK09
May	TL	Tokong Laut	4	TL01-TL04
May-June, August	B4	P. Perhentian Besar	7	B401-B407
May, July-August	B2	P. Perhentian Besar	12	B201-B212
May, July, August	K4	P. Perhentian Kecil	5	K401-K405
June	PR	Pulau Rawa	3	PR01-PR03
June	PS	Pulau Serenggeh	4	PS01-PS04
June	TB	Tokong Burung	3	TB01-TB03
June, August	B5	P. Perhentian Besar	9	B501-B509
June, August	K1	P. Perhentian Kecil	6	K101-K106
June, August	K3	P. Perhentian Kecil	6	K301-K306
June- August	B1	P. Perhentian Besar	5	B101-B105
August	K2	P. Perhentian Kecil	11	K201-K211
TOTAL	16		134	

Table 3.1. Baseline survey progress by survey sector during the Pilot Phase of the MRICP.

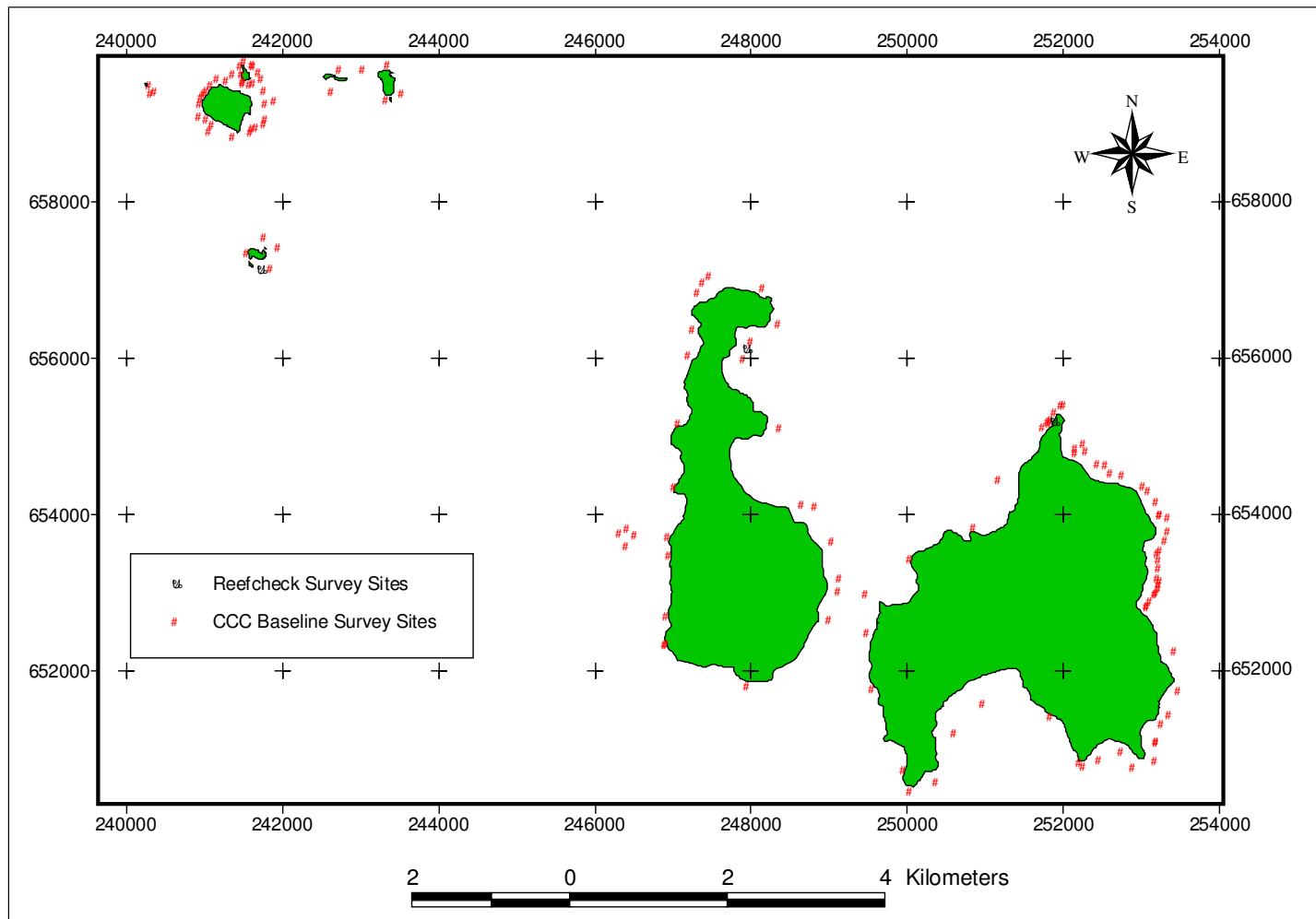


Figure 3.1. Survey site location during the Pilot Phase of the MRICP. Symbols indicate start positions of both CCC Baseline and Reef Check surveys

3.2 Capacity Building and Counterpart Training

3.2.1 Local Environmental Awareness

During the pilot phase of the MRICP, a number of community education initiatives were undertaken. These initiatives were aimed at the two main stakeholder groups on the island; tourists and tour operators and the local community.

Evening seminars conducted at the Marine Parks Centre were attended by both guests and staff from local recreational operations. Subjects covered in these seminars included:

- basic coral reef biology and ecology;
- relationships occurring on coral reefs including symbiotic relationships;
- complex food chain interactions;
- anthropogenic threats to coral reefs

Particular emphasis was placed on the actions both tourists and operators can take to minimise their impact on the marine resources of the Perhentians.

On the 5th of July 2003 a presentation was given to a delegation of secondary school principles from the west coast of Peninsular Malaysia on the importance of coral reefs to the continued development of Malaysia as a nation. The aim of the workshop organised by the teaching staff was to examine and devise a curriculum for an environmental studies module to be taught to children at the secondary level of education. Coral reef protection was identified as one of the most important issues in relation to sustainable development and needs to be included in this curriculum.

Local community education activities concentrated on the children of the Perhentian Islands. The education of this group is essential because ultimately they will become the stewards of the marine resources of the area. The curriculum for these workshops was intended to be educational in terms of environmental awareness yet at the same time, engaging for the children. Activities and topics were chosen to have an educational as well as enjoyable aspect. Topics covered included the food chain principle of coral reefs, the link between tropical forests and coral reefs, the impact of solid waste pollution on the environmental and aesthetic quality of the Perhentian Islands as well as introducing some of the main groups of organisms that can be found associated with coral reefs and tropical forests. A range of activities designed to bring the subject to life dealt with each topic. They included painting and drawing, a litter clean up on the main beach in front of the Marine Park Centre and an introduction to SCUBA diving equipment. Photographs of some of the activities can be seen on the following two pages (Figures 3.2 – 3.4).

A CCC representative attended the PADI Project AWARE weekend held on Perhentian Kecil on the weekend of the 13th-15th September (Figure 3.5). CCC contributed by giving an educational evening presentation on the work that has been conducted in the Perhentian Islands and the importance of the continued protection of coral reef resources in Malaysia. Outside of this formal presentation, a dialogue on coral reef biology was given to many of the guests attending the event.



Figure 3.2. Local children taking part in community day activities at the Marine Park Centre, Perhentian Besar

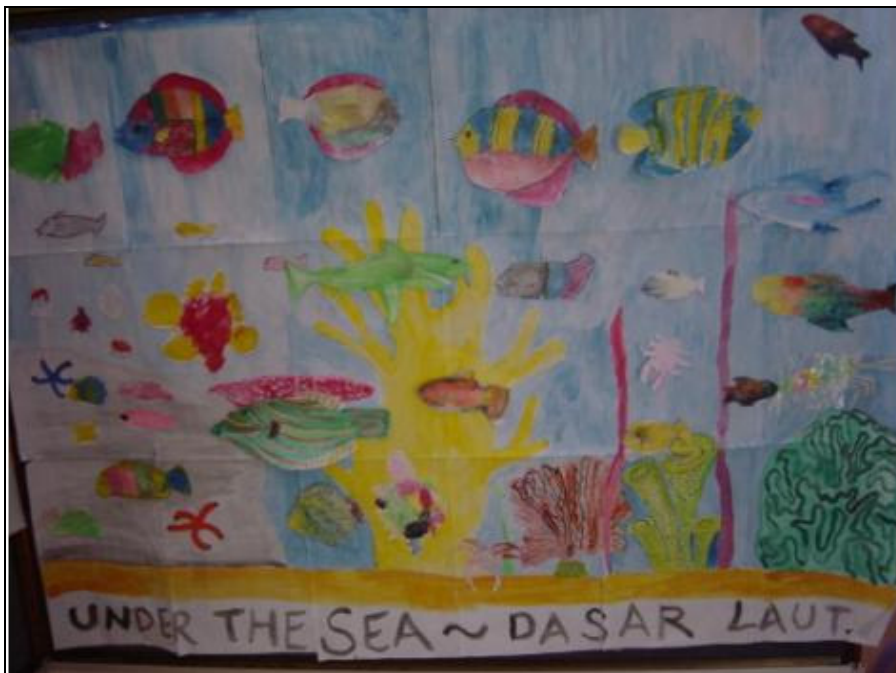


Figure 3.3. Example of an output from the activities on community day- the poster illustrates some of the organisms that live on a coral reef. Such posters are accompanied by a poster outlining some of the anthropogenic threats to coral reefs



Figure 3.4. Example of an output from the activities on community day- the poster illustrates some of the organisms that live in a tropical forest. Such posters are accompanied by a poster outlining some of the anthropogenic threats to tropical forest ecosystems.



Figure 3.5. CCC representatives attending the PADI Project AWARE diver awareness event on Pulau Perhentian Kecil on 13th-15th September 2003

3.2.2 *National Environmental Awareness*

The presence of Coral Cay Conservation in the Perhentian Islands has brought about a number of national media exposures on coral reef related issues. Articles have been published in the Virtual Malaysia Magazine and the national STAR and New Straits Times newspapers. These articles have concentrated on the activities of CCC though they have also contained educational content on the management of coral reef resources. Current plans for extending this educational output through national media include the writing of articles on coral reef ecology and formation for future special editions of the Virtual Malaysia magazine as well as providing scientific input and guidance into a planned documentary series on coral reefs throughout Malaysia.

CCC has also attended a series of seminars on advances in coral reef science and management organised by both the academic and non-governmental community in Malaysia. A poster presentation (Comley *et al.*, 2003) was submitted to the ‘Seminar on Islands and Reefs- Towards Sustainable Management’. This event was jointly organised by the National Oceanographic Directorate, DoFM, University of Malaya Maritime Research Centre (UMMReC), Malaysian Society of Marine Sciences (MSMS) and M. Dot. Sports Sdn Bhd.

CCC Representatives also attended a seminar held at the World Fish Centre (formerly the International Centre for Living Aquatic Resources; ICLARM) in Penang on recent advances in Coral Reef Science.

A formal presentation of this report has been given to the Department of Fisheries and future events are planned to present the work contained to the members of UMMReC and MSMS.

3.2.3 *Capacity Building*

Eight Malaysian citizens have taken part in the MRICP to date. Two main audiences were targetted during this period. The first were Malay students who are engaged in full-time education in a relevant field whilst the second were Malaysian citizens who have an interest and concern in the conservation of Malaysia’s coral reef resources.

Four scholarship places have been offered for each phase of the MRICP pilot programme for students engaged in full time education in a relevant field. These scholarship places are provided by the Coral Cay Conservation Trust and cover all expenses for the students joining the project. In addition, dialogue has been entered into with many of the Malaysian Institutes of Higher Education so that students who complete the training and surveying as part of their scholarships can receive due accreditation. Appendix VI includes a working paper on this accreditation scheme that has been distributed to Universities in Malaysia. Six of the eight Malaysian citizens to take part in the MRICP have been included in the scholarship program.

Reduced cost places on the MRICP have been offered for all Malaysian citizens. Though thus far only one person has attended the MRICP under this scheme, there are plans to increase this number in further programmes in Malaysia next year when the

MRICP resumes. Corporate sponsorship is actively being sought to further reduce the cost of these places to the candidates.

One employee of the DoFM took part in the marine research activities of the MRICP. Trained in marine life identification skills and coral reef survey techniques the individual is now an asset to the DoFM.

All three of these activities mentioned above have been direct initiatives to build capacity within Malaysia with regard to the protection of coral reef resources. It is the ultimate goal of CCC within Malaysia to build a base of skilled surveyors that have been trained in marine life identification and underwater survey techniques so that Malaysia can call upon this resource as and when necessary.

In addition to these direct capacity building links CCC has collaborated closely with other interested NGOs and Institutes of Higher Education. Links have been forged with the Kuala Lumpur based NGO TREES (Treat Every Environment Special) whilst the link with the Coral Reef Alliance (CORAL) is likely to result in a more formal partnership as our programmes in Malaysia progress. CCC is also currently working towards the integration of CCC survey data into the Reef Base website (a global interactive on-line database) from all international project sites, not just within Malaysia. This development will make readily available data for management decision makers and planning authorities as well as other NGO's and interested academic bodies.

Finally, links with Higher Education Institutes including, though not limited to, the University of Malaya, University Sains Malaysia, University Kabangsaa Malaysia and Kolege University Sains dan Technology Malaysia. These links have provided seven of the eight Malaysian volunteers thus far on our programme during the pilot phase, and form an important part of CCC's commitment to capacity building, skills and data exchange.

3.3 Oceanographic data

3.3.1 Wind speed and Direction

The mean wind speed recorded during the survey period at Pulau Perhentian was 1.92 measured on the Beaufort scale. The highest recordings made corresponded to four on the Beaufort scale and occurred fifteen times out of the 339 observations made. The prevailing wind direction was from the south-east, with 47 of the 339 observations originating from this quarter (Figure 3.6). Winds blowing from the mainland were by comparison much rarer, with NW, W and SW winds blowing on only 16, 25 and 22 occasions respectively. In addition, the winds from the mainland were by comparison much lighter, with an average wind speed from these directions of 1.12.

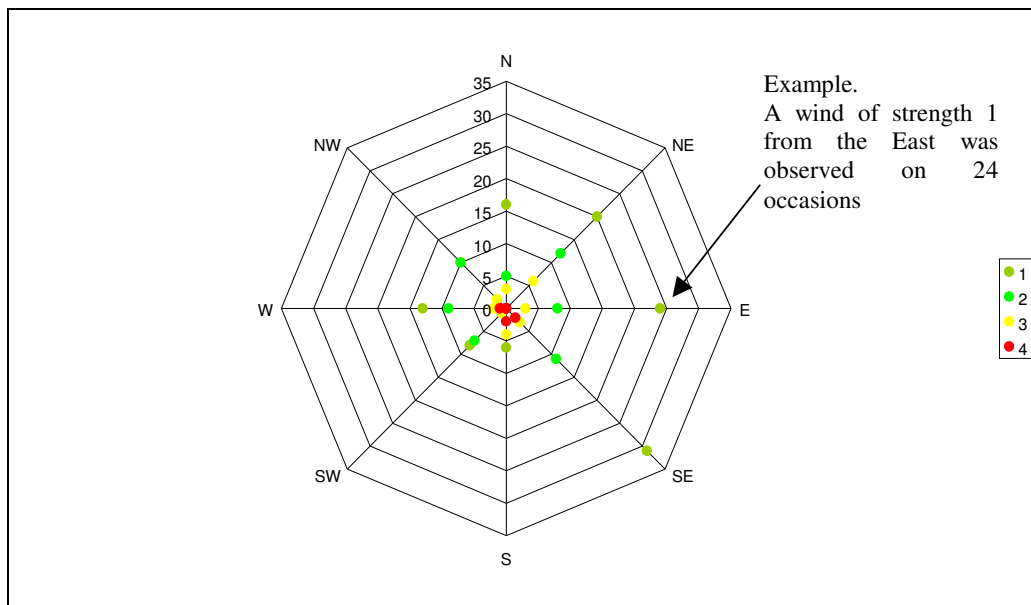


Figure 3.6. Radar diagram showing the prevailing winds recorded during the Pilot Phase of the MRICP. Points represent the frequency of occurrence of combinations of wind direction and strength.

3.3.2 Sea Temperature and Salinity

A total of 507 temperature readings both at the surface and at the depth at which surveying was conducted were recorded. Mean temperature regardless of depth was 30.41°C. Figure 3.7 indicates that the first seven metres of the water column was the most stable with the highest mean temperatures and least range (smallest S.D.). Below five metres there is a trend of decreasing average temperature and increased variance (larger S.D.) with increasing depth. For extended periods during the surveys conducted on P. Perhentian, a visible and obvious thermocline was apparent in dispersed geographic areas, which may be associated with a halocline. In some instances, this thermocline resulted in a decrease of measured temperature of over 1.5°C in less than one metre. In addition to its geographic occurrence, the depth for

thermocline development also varied. The shallowest recorded thermocline was at eight metres, with the deepest at 17 m.

Within the layer of reduced temperature below the thermocline, the temperature again became more stable, as indicated by the reduced variance in the 18.1-20 and >20 meter depth classes (Figure 3.7)

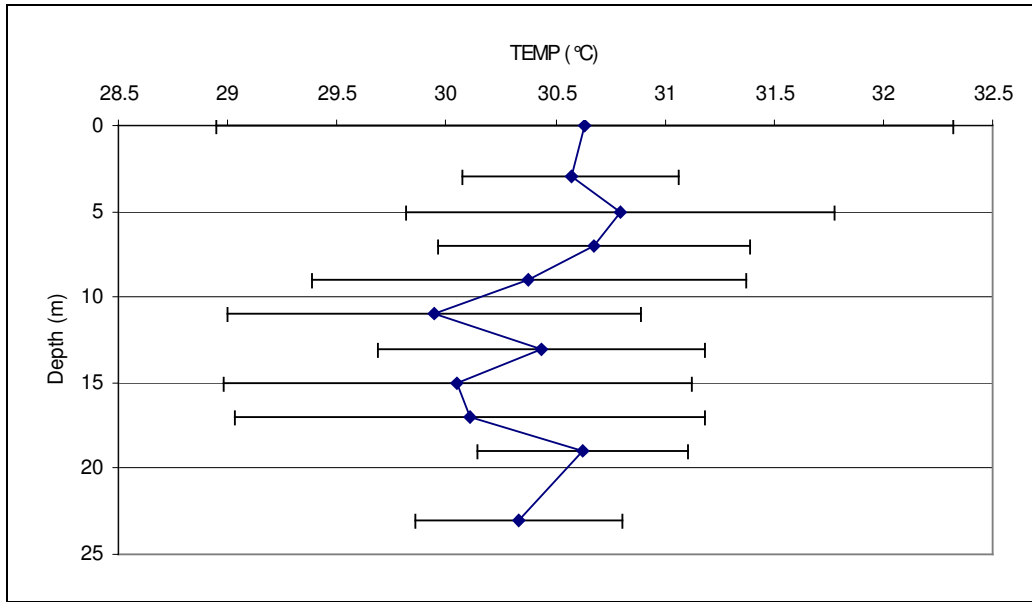


Figure 3.7. Mean water temperatures for all surveys in the project area in 5 metre depth classes throughout the water column. Horizontal bars represent standard deviations around the calculated means. Sample sizes: 0m = 251; 0.1-3m = 7; 3.1-6m = 10; 6.1-8m = 34; 8.1-10m = 37; 10.1-12m = 38; 12.1-14m = 32; 14.1-16m = 40; 16.1-18m = 36; 18.1-20m = 8; >20.1m = 3.

The mean salinity value for all depths recorded during the CCC baseline surveys was 31.36 ‰ (n = 483, S.D.= 1.75‰). Overall there is a trend of increasing salinity with increasing depth in the water column, with the exception of surface salinity (Figure 3.8). Lowest mean salinity values were recorded in shallow waters (<5 m). However, the large range in S.D. values around the calculated means for all depths suggests that there is spatial and possibly temporal heterogeneity. Below 20.1 metres mean salinity does not follow the aforementioned trend of increasing salinity with depth, with a decrease from 31.7‰ at 18.1 - 20 metres to 31.4‰ at depths greater than 20.1 metres.

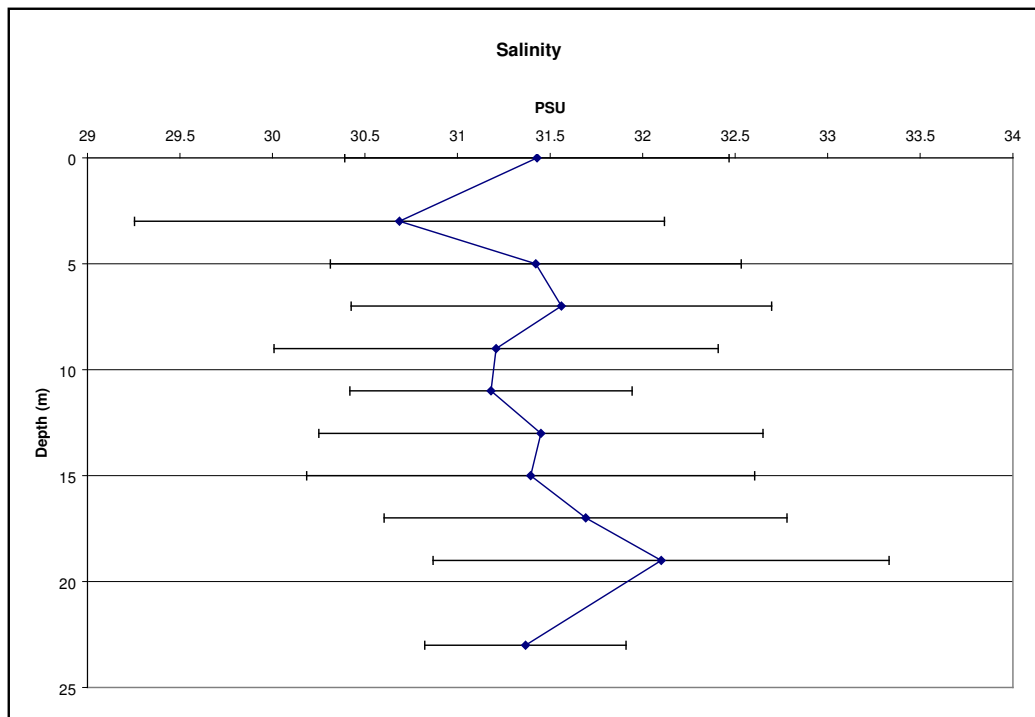


Figure 3.8. Mean salinity recordings for all surveys in the project area in 5m depth classes throughout the water column. Horizontal bars represent standard deviations around the calculated means. Sample sizes: 0m = 251; 0.1-3m = 7; 3.1-6m = 10; 6.1-8m = 34; 8.1-10m = 37; 10.1-12m = 38; 12.1-14m = 32; 14.1-16m = 40; 16.1-18m = 36; 18.1-20m = 8; >20.1m = 3.

3.3.3 Current Strength and Direction

The most frequently observed currents during the MRICP were classed as weak by the survey divers, with 74% of the current observations in this category. From the data collected there appears to be little or no overall pattern in terms of the prevailing current direction in the survey area (Figure 3.9). The Perhentians, being situated on a shallow continental platform are exposed primarily to tidal currents. It is believed that there is a net long shore current from south to north along the Terengganu coastline that passes through the Perhentian Islands. However, this current is likely to be weak in comparison to the local tidally induced currents around the shallow areas of the island.

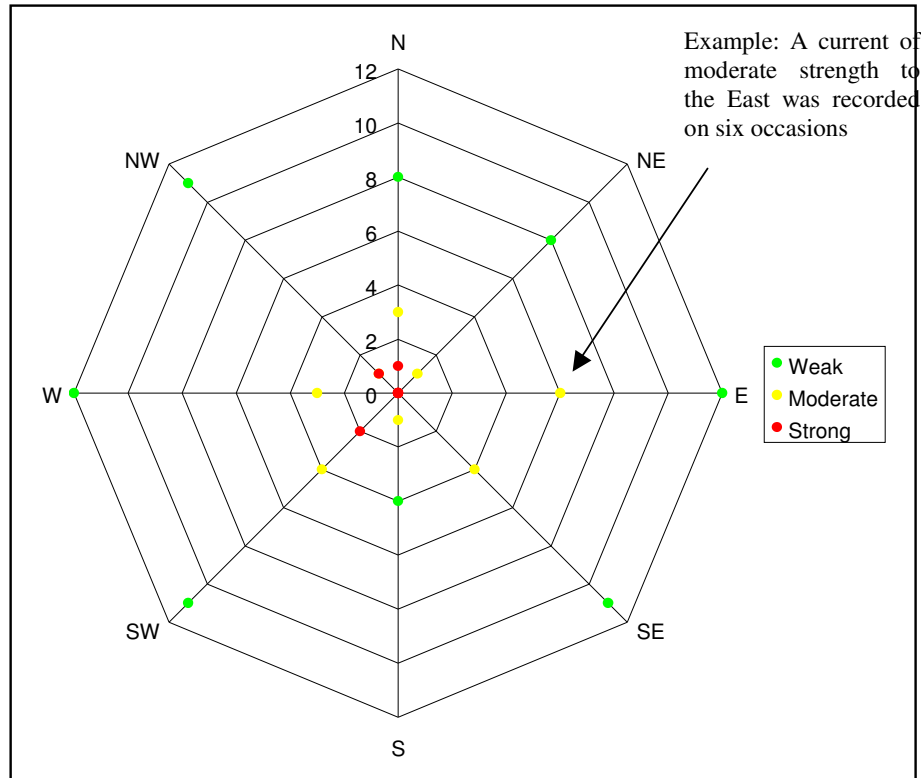


Figure 3.9. Mean underwater current strength and direction recorded in the Perhentian Islands during surveys. Points represent the frequency of occurrence of combinations of current direction and strength. Symbols represent current strength from weak to strong.

3.3.4 Underwater Visibility

Underwater visibility was observed in two ways during the MRICP. Firstly the vertical visibility through the water column was measured with the use of a Secchi disc as described in the methods section. Dive teams at the deepest points of the survey also estimated horizontal visibility. Whilst the recordings made from these two measures are often closely correlated, fluctuations in the visibility at different depth ranges in the water column such as those produced within an area of a thermocline may cause a significant difference in the readings. Both sets of data are presented spatially in Figure 3.10 and graphically in Figures 3.11 and 3.12.

Around the two main islands of Perhentian Besar and Kecil, the areas of greatest visibility are found in the more exposed locations, notably to the South West of P. Perhentian Besar in survey sector B4 and the North East of Kecil in sector K1. Around these two islands, the worse visibility was observed within Flora Bay, around the village and along the stretch of beach adjacent to the Marine Park Centre.

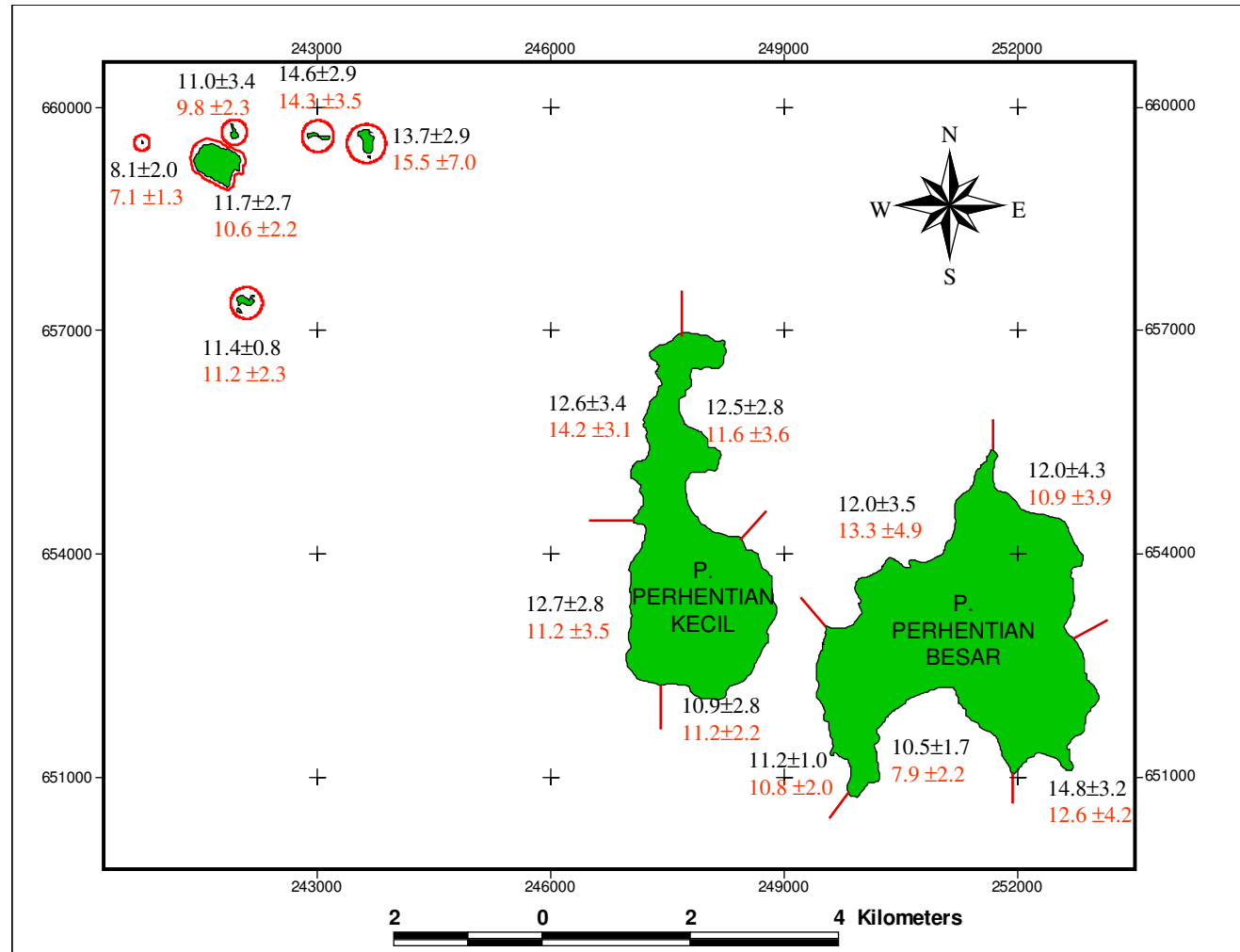


Figure 3.10. Maps showing vertical (black text) and horizontal (red text) underwater visibility ($\pm$ Standard Deviation around the calculated mean values) for each survey sector in the Perhentian Islands.

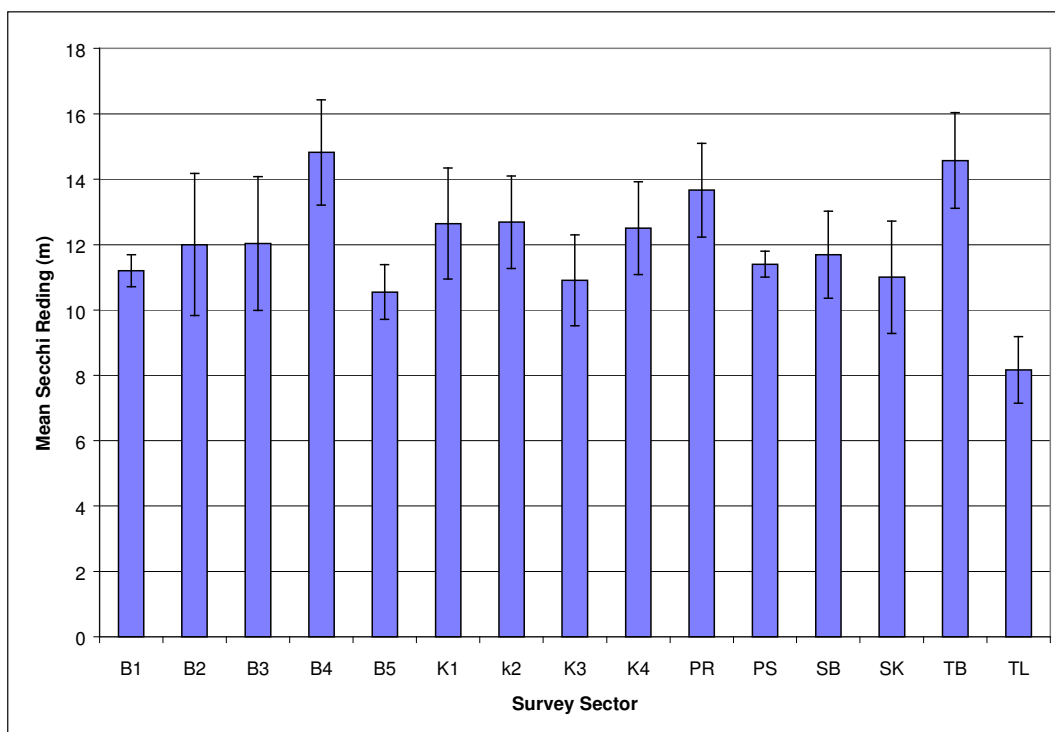


Figure 3.11. Mean Secchi Disc recordings of vertical visibility in metres ($\pm$ S.D.) for each survey sector.

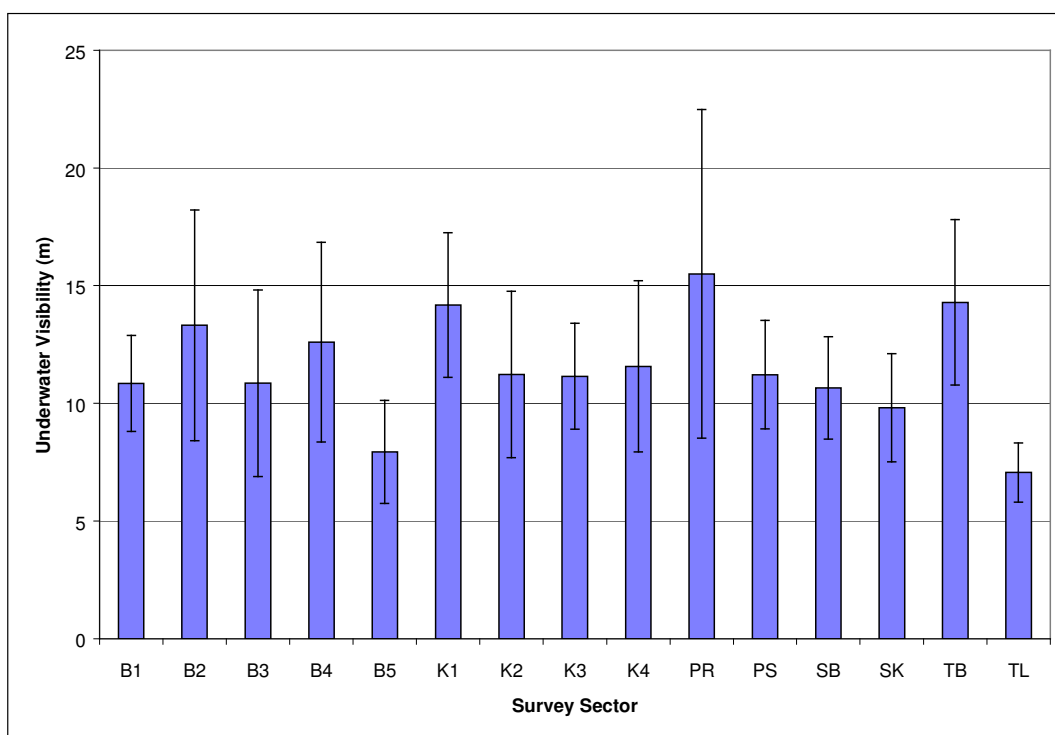


Figure 3.12. Mean horizontal visibility recordings by divers in metres ($\pm$ S.D.) for each survey sector.

Areas where thermoclines were regularly present, such as sector B4, have a high variance (S.D.) in salinity values in terms of horizontal visibility (Figure 3.12). Where these observations were made within the zone of the thermocline, visibility was greatly reduced. Where observations were made outside of this zone then the visibility estimates were much greater. The large range of values recorded around the more exposed North and North West facing coasts of both Pulau Perhentian Besar and Kecil reflect the almost daily fluctuations in visibility in response to the degree of vertical mixing and sediment re-suspension as a result of the prevailing weather conditions.

Amongst the outlying islands of the Perhentian Archipelago there is a clear pattern of increasing turbidity in the water column towards the mainland to the east. Tokong Laut has the lowest readings of both horizontal and vertical visibility of all survey sectors; only 8.1 and 7.1 metres respectively (Figures 3.10–3.12). Orientated almost directly North to South, Pulau Susu Dara Kecil, Pulau Perhentian Besar and Pulau Serenggeh all have approximately equal visibilities both vertically and horizontally through the water column; 11.0, 11.7 and 11.4 metres vertical visibility and 9.8, 10.6 and 11.2 m horizontal visibility in the respective survey sectors. Finally, Tokong Burung and Pulau Rawa, sighted the furthest west of all these islands have the greatest underwater visibility of 14.6 and 14.3; and 13.7 and 15.5 metres for vertical and horizontal visibility in these two survey sectors respectively.

3.4 Anthropogenic data

3.4.1 Boat Activity

Both the number and type of boat observed in a surveyed area gives an indication of the origin of impacts that may be affecting a coral reef environment. A summary of observations recorded for boat activity during the pilot phase of the MRICP is presented in Figures 3.13 and 3.14. The survey sector with greatest number of recorded boats was southwest P. Perhentian Kecil (K3). This is not surprising considering that within this sector the major population center on Perhentian Kecil is situated. The adjacent sector B1 also has similarly heavy boat traffic. Fifty-five and 72 % respectively of the boats seen in these sectors have been classified as being engaged in commercial activity, fishing boats arriving and departing the village and boats used to supply both personnel and provisions sold locally to the tourist resorts through the study area.

The majority of the boats observed in sector B2, north west of P. Perhentian Besar were engaged in diving activities. It is not unusual for five or more dive boats to be observed at one of the more popular dive spots at Tanjung Basi at the northern most point of this island.

Perhaps what is surprising is the number of fishing boats that were observed within the study area. To be defined as engaged in fishing for the purposes of this investigation, personnel on the boat have to be actively fishing; a fishing vessel in transit is not considered to be fishing. Although the frequency of boat sightings in the

survey sectors around both Tokong Laut and Pulau Serenggeh were lower than average (0.7 and 0.4 sightings per survey period of up to one hour), over 50% of the boats observed were actively fishing (51% and 59% for the respective sectors). It was not just these outlying islands where fishing was observed. Twenty four percent of the boat sightings in sector B3 of P. Perhentian Besar were actively engaged in fishing. In most cases the fishing method being used was of the traditional hook and line, although the use of commercial scale nets and the setting and recovery of fish traps was observed in sectors K1, B3, B4 and B5.

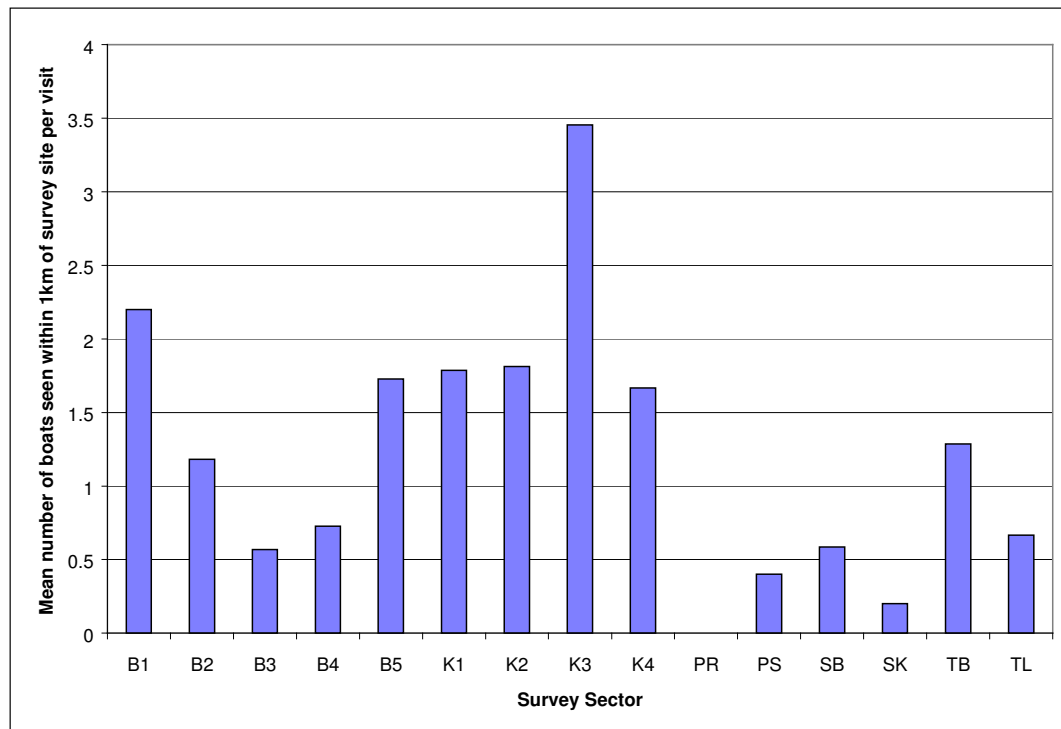


Figure 3.13. Mean frequency of boat sightings within 1 km of survey sites for each survey sector.

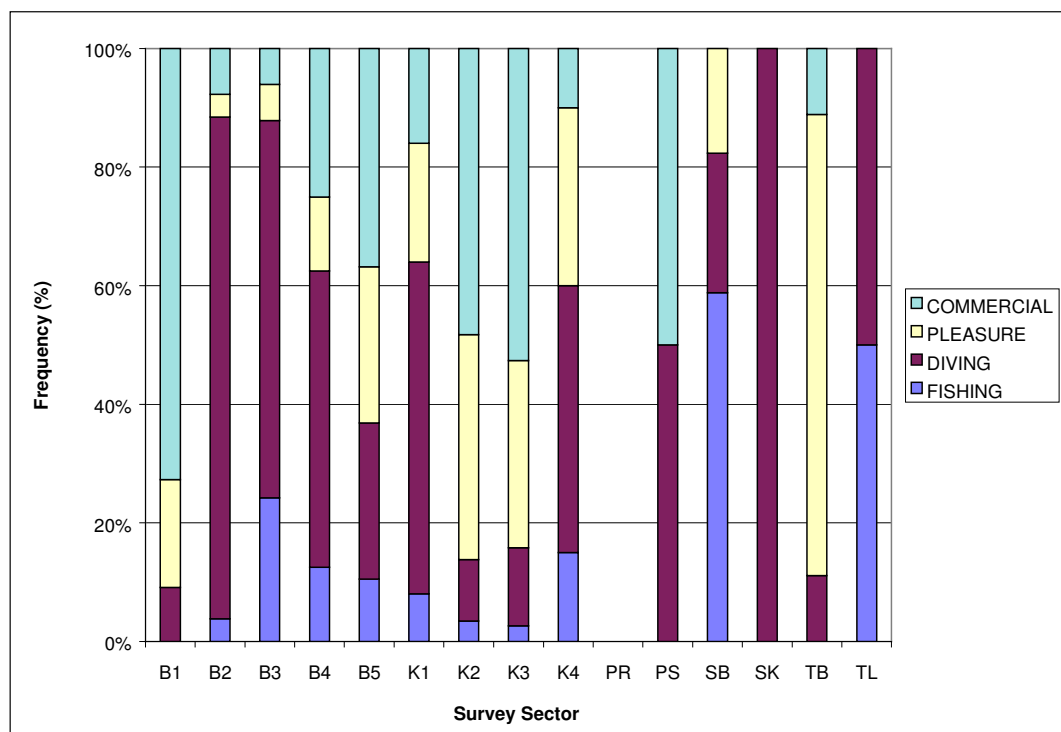


Figure 3.14. Percentage boat activity recorded within each survey sector.
Sample sizes; B1=11, B2=26, B3=33, B4=8, B5=19, K1=25, K2=29, K3=38, K4=20, PR=0, PS=2, SB=34, SK=2, TB=9, TL=4.

3.4.2 Surface and Sub-surface Impacts

The most commonly observed surface impact recorded by CCC divers during the MRICP was the presence of litter (Figure 3.15). Litter was recorded in all but one of the survey sectors that surround the main islands of P. Perhentian Besar and Kecil. By contrast, litter was only observed in two of the six survey sectors around the outer islands; namely around Susu Dara Besar and Tokong Laut. The greatest frequency of litter observations was found away from population centers in sectors B3 and K2. Other observed surface impacts were sewage, driftwood, macroalgae and nets. When found, a combination of surface impacts was usually recorded around the two main islands of P. Perhentian Besar and Kecil.

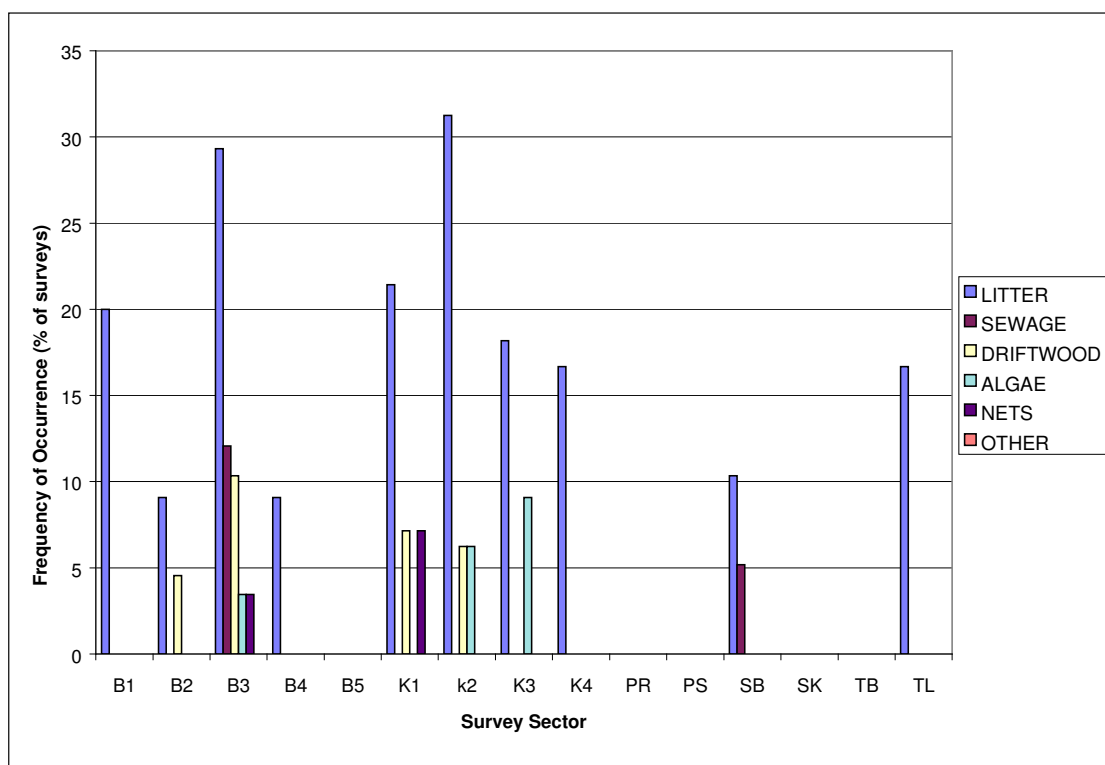


Figure 3.15. Percent frequency of the occurrence of surface impacts within each survey sector.

Underwater the occurrence of anthropogenic impacts was greater still, though the spatial pattern of distribution of these impacts is notably different. The area surrounding Flora Bay notably had a high quantity of discarded lines and nets. This discarded fishing gear was observed in over 45% of all dives conducted within this survey sector (B5). In addition to discarded gear, fish traps were also observed on 18% of all surveys conducted in this sector.

The most striking bar on Figure 3.16 is the presence of coral bleaching in over 65% of all survey dives conducted around Pulau Rawa. Bleaching was also prominent in sectors K3 and PR (>20% of survey dives). Coral damage was more common and

observed in 11 of the 16 survey sectors. Of these, seven sectors had the highest incidence of coral damage, recorded on more than 30% of survey dives. The sectors were B2, B5, K3, PR, PS, SB and TB.

Litter on the seabed was most commonly seen within K3 around the population center of the village on P. Perhentian Kecil. This litter is likely to be a small fraction of which originated from the village; only that which has settled close to the source of origin. It is likely, as suggested previously that much of the litter floats and is eventually carried by current and wave patterns to areas remote from the village.

Evidence of sedimentation (hard coral colonies unable to remove sediment at a faster rate than the current siltation rate) was observed in the vast majority of the survey

sectors. The occurrence was particularly marked around Tokong Laut, Pulau Serenggeh and in the sectors around the settlement on Perhentian Kecil, where it was observed on 17, 20 and 26% of the time respectively.

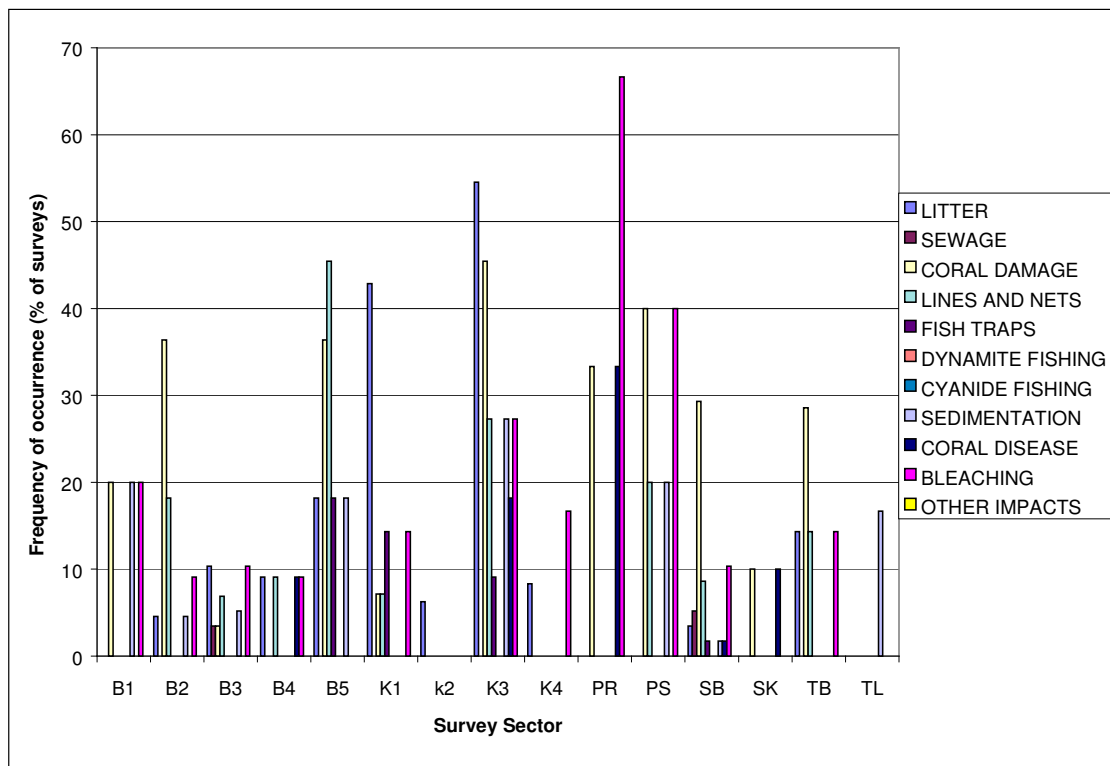


Figure 3.16. Percent frequency of occurrence of sub-surface impacts within each survey sector.

3.4.3 Aesthetic and Biological Impressions

Whilst the overall impressions of divers following diving a site are, by their very nature, subjective, this information does provide a gross indicator of the condition of sites. The results of such a study are shown in Figures 3.17 and 3.18. Survey dives conducted in Survey Sectors B4 and K4- the SE corner of Perhentian Besar and the NW side of Perhentian Kecil stand out as having the best overall ratings for both aesthetic and biological value. It is interesting to note that what is perceived locally to be the best recreational dive site- Tokong Laut was rated 50% good and 50% average in terms of the aesthetic value of the site whilst it was only rated as poor in terms of its biological value in 17% of the times it was assessed. The area around Flora Bay within Sector B5 was consistently rated as poor, with over 50% of the observations in terms of aesthetic properties and failing to gain a rating of above average on any occasion.

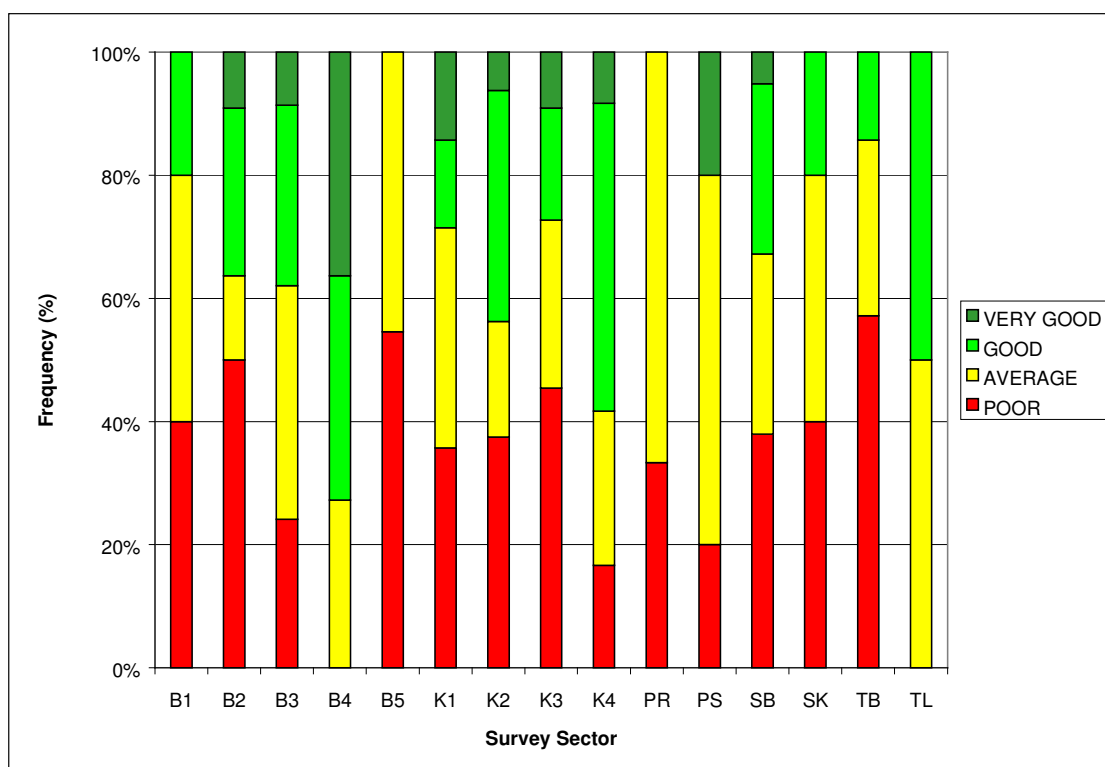


Figure 3.17. Survey diver impressions of aesthetic value of sites surveyed within each sector.

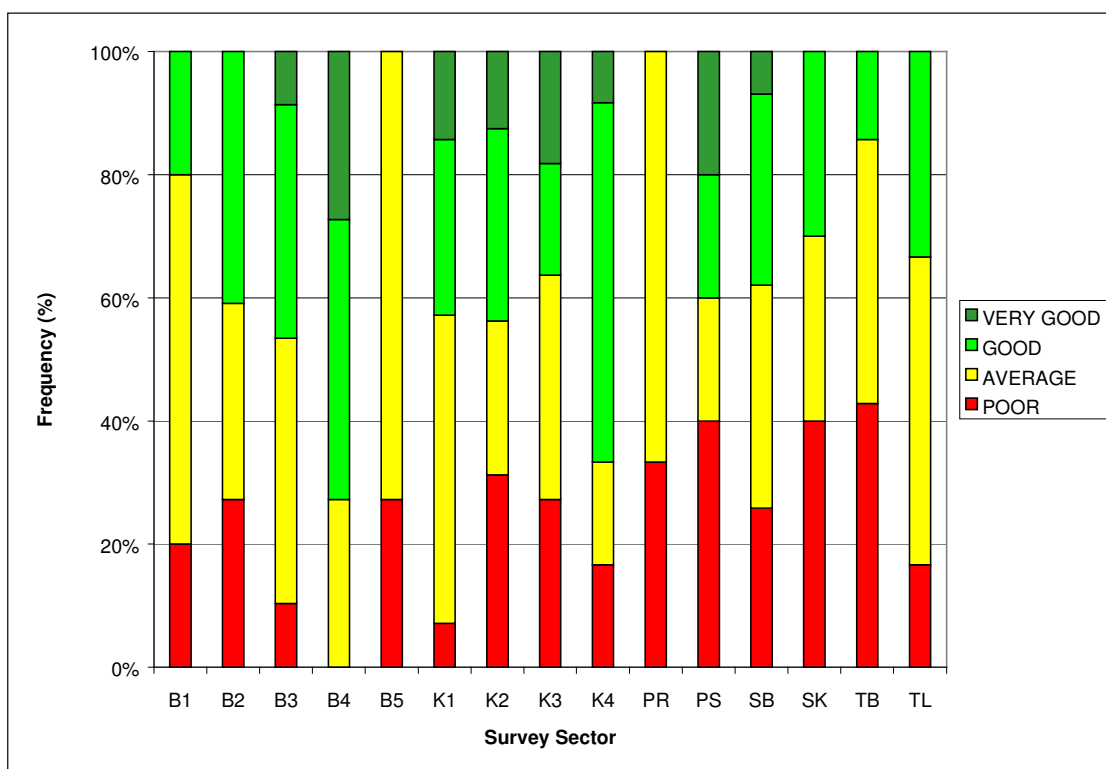


Figure 3.18 Diver impressions of biological value of sites surveyed within each sector

3.5 Hard Coral Diversity

A total of one hundred and five species of hard corals have been positively identified during the Pilot Phase of the MRICP at Pulau Perhentian. These species include representatives from 41 genera and 16 families. By far the most diverse and commonly observed genera present was *Acropora* which had twenty individual species recorded. Amongst the genera, thirty-eight were of the order Scleractinian and three were non-Scleractinian. The full species list is given in Appendix III.

3.6 Multivariate Analysis and Habitat Definitions

The following section presents the dendrogram produced by agglomerative hierarchical cluster analysis as outlined in the methods section (Figure 3.19). Secondly, using the characteristics of the benthic classes as defined by SIMPER and univariate analysis; a full and quantitative description of each habitat identified is presented in Table 3.2. Lastly, the location and habitat composition of individual transects in each of the sixteen survey sectors are also depicted (Figures 3.20 – 3.32).

3.6.1 Habitat Descriptions

A total of thirteen statistically discrete habitat groups or Benthic Classes (BC) were defined from the data set collected during the Pilot Phase of the MRICP. Table 3.2 summarises the main biological and substratum characteristics of each habitat type and provides a semi-quantitative description of each benthic group. The values in the table represent mean relative abundance using the DAFOR scale.

The highest abundance ratings for total cover of hard corals were found in Benthic Classes 3, 8, 12 and 13. Of these maximum hard coral abundance was recorded in BC 5 on the upper reef slope and reef crest where branching Acroporids were dominant. Two of the previously mentioned habitats (BC 5 and BC 13) also revealed relatively high levels of dead coral or dead coral covered with algae. However BC 7 contained the highest abundance of these two substrata that exceeded the living hard coral cover present in this habitat. Soft corals and sponges were generally recorded at low levels (<1.0) although sponge cover exceeded this average rating in Benthic Classes 10-12 on the lower reef slope. Blue-green or filamentous algae were recorded at low levels in almost all habitat types with the exception of the shallow reef crest and back reef areas (BC 1)

3.6.2 Habitat Distributions

Figures 3.20-3.32 depict the spatial distributions of the thirteen habitats defined from the data set collected during the Pilot Phase of the MRICP. The distribution of the habitats is shown by survey sector following the locations depicted in Figure 3.1. The base maps onto which the transects have been overlaid are to scale and have the correct geographic orientation. The transects themselves are a diagrammatic representation of the distribution of each of the habitats found. The size of each block in the scale represents on ten-metre section of the transect that belongs to the habitat. The orientation and geographic positioning of each end of each transect relative to the

shoreline or shallow back reef area is correct, though the scale in terms of the overall length and width of each transect have been exaggerated to allow easier representation of the data they contain.

Notes on Statistics

When used in the presentation of statistical data, P-values denote the probability of an observation occurring by chance alone. A P-value of <0.05 indicates that the observation would have happened by chance alone on only 5 or less times in 100 repetitions. A p-value of <0.05 is therefore an indicator that some factor other than the probability of chance is producing the data. It is therefore considered to be significantly different if the p-value is greater than, or equal to 0.05.

Other statistical conventions used in the report are the χ^2 that refers to the Chi-squared value calculated during this test; the T-value calculated during the Mann-Whitney test on non-parametric and non-normalised data; and the R-value calculated during multivariate analysis comparing two or more populations of data.

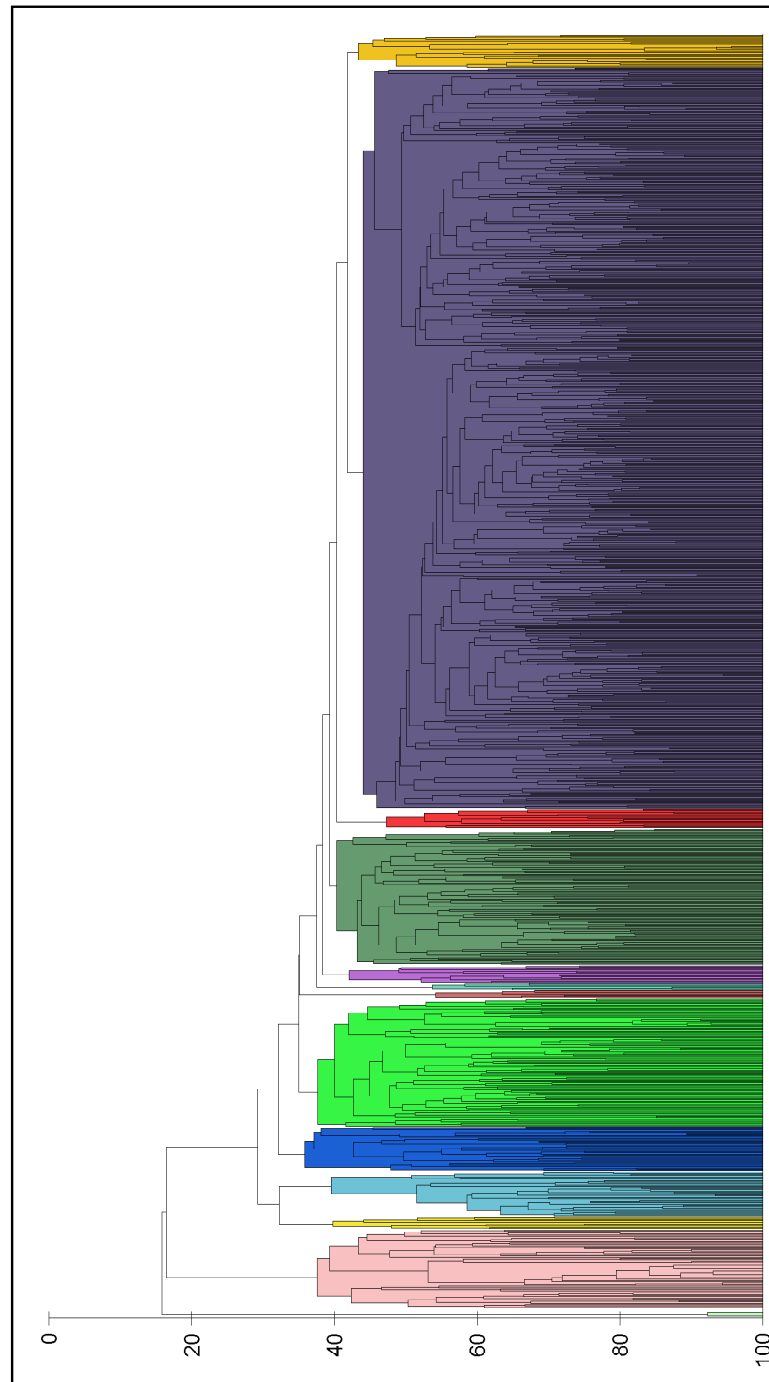


Figure 3.19. Dendrogram derived from cluster analysis of CCC baseline survey data collected during the MRICP Pilot Phase Project. Each line represents benthic and substratum data from each Site Record. The different colours highlight the major clusters representing the benthic classes discriminated. Horizontal axis represents similarity as calculated with the Bray- Curtis coefficient (%). 999 Site Records are included in the dendrogram; with the remaining 64 being reintroduced later via discriminant analysis to subsequent analysis procedures.

Habitat	# surveys	Mean depth	Substratum	Hard Corals	Octocorals	Invertebrates	Sponges	Algae/ Seagrass
1 Rubble dominated upper reef slope and back reef areas	12	0.6	Rubble (4.5), Sand (0.3)	Total cover (0.0)	Total cover (0.0)	-	Total cover (0.0)	Brown macroalgae (1.0), Padina (1.0), Turbinaria (1.0), Red / Brown branching algae (1.0)
2 Lower reef slope and foreereef dominated by sand with low biotic cover	70	9.4	Sand (4.8), Dead coral (0.2), Dead coral with algae (0.2)	Total cover (0.3), Non-Acropora encrusting (0.1), Non-Acropora Massive (0.1), Favia (0.1)	Total cover (0.1), Anemone (0.1)	Non-synaptid sea cucumber (0.2), Synaptid sea cucumber (0.2), Feather duster worm (0.1)	Total cover (0.2), Lumpy (0.1)	Schizothrix (2.0), Brown filamentous (0.3), Red filamentous (0.2), Halophila seagrass (0.2)
3 Upper reef slope/ reef crest regions with mixed sand and hard substrate, supporting sparse hard coral cover	11	6.5	Sand (2.5), Bedrock (2.5)	Total cover (1.2), Non-Acropora encrusting (0.7), Non-Acropora submassive (0.6), Pocillopora damicornis (0.5), Favia (0.5), Porites annae (0.4)	Total cover (0.5), Sinularia (0.2), Sarcophyton (0.2), Anemone (0.2)	Synaptid sea cucumber (0.6), Diadema (0.4), Zoanthid (0.4), Hydroid (0.4), Clam (0.4)	Total cover (0.7), Encrusting (0.4), Lumpy (0.3)	Brown filamentous (0.8), Lobophora (0.7), Green filamentous (0.5), Red coralline algae (0.1)
4 Lower reef slope dominated by bedrock with moderate hard coral cover	38	9.3	Bedrock (2.3), Sand (1.0), Dead coral (0.9)	Total cover (1.8), Non-Acropora massive (1.0), Non-Acropora submassive (0.5), Porites massive (0.8), Pachyseris speciosa (0.2), Platygyra sp (0.3), Plerogyra (0.3)	Total cover (0.3), Sinularia (0.1), Sarcophyton (0.1)	Tunicate (0.3), Zoanthid (0.2), Hydroid (0.2), Clam (0.2)	Total cover (0.2), Encrusting (0.2)	Red coralline algae (0.8), Schizothrix (0.3), Brown filamentous (0.1)
5 Upper reef slope and reef crest dominated by dense hard coral cover, which in turn is dominated by branching species of the genus Acropora	39	3.2	Dead coral (1.4), Rubble (1.0), Bedrock (0.5)	Total cover (2.8), Acropora branching (2.2), Non-Acropora branching (0.7), Acropora tabulate (0.6), Pocillopora damicornis (0.5), Porites nigrescens (0.5)	Total cover (0.0)	Feather duster worm (0.2), Clam (0.2), Non-synaptid sea cucumber (0.2)	Total cover (0.4), Lumpy (0.3)	Brown filamentous (1.6), Padina (1.1), Schizothrix (0.7), Red coralline algae (0.6)
6 Sand dominated lower reef slope with a moderate hard coral cover of shade tolerant species	105	10.2	Sand (3.7), Rubble (1.5)	Total cover (1.0), Non-Acropora encrusting (0.6), Non-Acropora massive (0.6), Acropora branching (0.3), Favia (0.3), Favites (0.3), Porites massive (0.2)	Total cover (0.6), Anemone (0.4), Sinularia (0.2), Sarcophyton (0.2)	Non-synaptid sea cucumber (0.8), Chiton (0.3), Cnidaria medusae (0.2), Feather duster worm (0.2)	Total cover (0.8), Lumpy (0.6), Encrusting (0.2)	Schizothrix (1.5), Brown filamentous (1.0), Red filamentous (0.5)

Table 3.2. Quantitative description of the thirteen benthic classes defined from the data collected in the Perhentian Islands. Figures in parenthesis indicate mean observational abundances from the DAFOR (0-5) semi-quantitative scale as used during CCC Baseline surveys

Habitat	# surveys	Mean depth	Substratum	Hard Corals	Octocorals	Invertebrates	Sponges	Algae/ Seagrass
7 Lower/ mid-reef slope dominated equally with dead and live hard coral cover.	7	8.8	Dead coral with algae (1.7), Rubble (1.6), Dead coral (1.4), Sand (1.3)	Total cover (1.7), Non-Acropora foliose (1.3), Non-Acropora mushroom (1.1), Acropora tabulate (0.7), Non-Acropora encrusting (0.9), Echinopora lamelllose (1.0), Euphyllia (0.9), Favia (0.9), Favites (0.9), Porites nigrescens (0.9), Sandalolitha (0.7)	Total cover (0.0)	Non-synaptid sea cucumber (0.7), Ophiurix (0.4)	Total cover (0.9), Lumpy (0.5)	Schizothrix (1.0), Brown filamentous (0.6), Green filamentous (0.4), Padina (0.4), Red filamentous (0.5)
8 High energy, calcium carbonate shallow reef crest and back reef areas dominated by rubble and a moderate cover of high energy adapted corals	6	2.9	Rubble (1.8), Sand (1.5), Dead coral with algae (0.8)	Total cover (2.0), Non-Acropora massive (1.5), Acropora branching (1.2), Non-Acropora branching (1.2), Porites annae (1.5), Pavona cactus (0.8)	Total cover (0.0)	Christmas tree worm (2.0), Diadema (2.0), Feather duster worm (1.2)	Total cover (0.7), Lumpy (0.7)	Brown filamentous (1.3), Schizothrix (1.2), Dictyota (1.2), Ventricaria ventricosa (0.9), Amphiroa (0.5)
9 Bare, exposed shallow bedrock of terrigenous origin supporting a high energy adapted hard coral community	14	2.1	Bedrock (3.1), Sand (0.7), Rubble (0.6)	Total cover (1.7), Non-Acropora encrusting (0.9), Non-Acropora massive (0.9), Acropora branching (0.9), Acropora tabulate (0.9), Pocillopora verrucosa (0.6), Favia (0.4), Favites (0.4), Porites massive (0.4)	Total cover (0.3), Sinularia (0.2), Anemone (0.3)	Zoanthid (1.1), Clam (0.6)	Total cover (0.7), Lumpy (0.7)	Brown filamentous (1.1), Red coralline algae (1.1), Schizothrix (1.0), Turbinaria (0.7)
10 Mid/ lower reef slope of mixed sand and rubble supporting a moderate hard coral cover of branching Acropora, Non-Acropora massive and encrusting	115	6.9	Sand (1.9), Rubble (1.6), Dead coral with algae (1.2)	Total cover (1.8), Acropora branching (1.2), Non-Acropora encrusting (0.8), Non-Acropora Massive (0.7), Non-Acropora mushroom (0.6), Porites annae (0.8), Pocillopora damicornis (0.5), Favia (0.7)	Total cover (0.4), Anemone (0.3), Sea Whip (0.2), Sinularia (0.1)	Synaptid sea cucumber (0.9), Christmas tree worm (0.7), Diadema (0.7), Crinoid feather star (0.5)	Total cover (1.3), Encrusting (0.3), Lumpy (0.1)	Brown filamentous (1.1), Red coralline algae (0.9), Green filamentous (0.6), Red filamentous (0.5)

Table 3.2 (Continued). Quantitative description of the thirteen benthic classes defined from the data collected in the Perhentian Islands. Figures in parenthesis indicate mean observational abundances from the DAFOR (0-5) semi-quantitative scale as used during CCC Baseline surveys

Habitat	# surveys	Mean depth	Substratum	Hard Corals	Octocorals	Invertebrates	Sponges	Algae/ Seagrass
11 Lower reef slope exposed terrigenous bedrock with high octocoral cover and moderate hard coral cover	16	14.2	Bedrock (3.4), Sand (0.6), Rubble (0.6)	Total cover (1.3), Non-Acropora massive (0.8), Non-Acropora mushroom (0.8), Non-Acropora foliose (0.6), Non-Acropora encrusting (0.5), Seriatopora hystrix (1.0), Pectinia lactuca (1.3), Favia (0.8)	Total cover (1.6), Xenia (1.4), Sarcophyton (1.2), Gorgonacea (0.6)	Short spined urchin (1.9), Diadema (1.8), Bivalvia (0.9), Zoanthid (0.6)	Total cover (1.3), Lumpy (0.9), Vase (0.2)	Red coralline algae (1.2), Blue/ Green algae (1.0), Brown filamentous (0.5)
12 Most commonly found habitat on the lower reef slope supporting high coral cover dominated by low light intensity tolerant coral lifeforms, a moderate cover of macroalgal assemblages and octocorals	602	8.9	Bedrock (1.8), Rubble (1.3), Sand (1.2), Dead coral with algae (1.1)	Total cover (2.1), Non-Acropora encrusting (1.2), Non-Acropora massive (1.2), Acropora branching (0.9), Acropora tabulate (0.7), Non-Acropora branching (0.7), Favites (0.9), Pocillopora damicornis (0.7), Favia (0.7), Diploastrea heliopora (0.5)	Total cover (0.9), Anemone (0.8), Xenia (0.5), Sinularia (0.5)	Feather duster worm (0.7), Chiton (0.7), Non-synaptid sea cucumber (0.6), Zoanthid (0.4), Cnidaria medusae (0.4)	Total cover (1.2), Lumpy (0.9), Encrusting (0.3)	Blue/ Green algae (1.0), Brown filamentous (0.8), Red coralline algae (0.9), Green filamentous algae (0.6), Lobophora (0.7)
13 Low/ mid reef slope of mixed substrate supporting moderate to high hard coral cover with branching Acropora and Non-Acropora species dominating	28	7.1	Dead coral (1.4), Rubble (1.3), Dead coral with algae (1.2), Bedrock (1.1), Sand (1.1)	Total cover (2.0), Acropora branching (1.5), Non-Acropora branching (1.1), Non-Acropora mushroom (1.1), Pocillopora damicornis (1.4), Sandalolitha (0.5), Seriatopora hystrix (0.4)	Total cover (0.4), Xenia (0.3)	Non-synaptid sea cucumber (0.8), Annelid worm (0.4), Ophiurix (0.4), Chiton (0.3)	Total cover (0.7), Lumpy (0.4)	Blue/ Green algae (1.1), Red coralline algae (1.1), Brown filamentous (0.7), Red filamentous (0.7)

Table 3.2 (Continued). Quantitative description of the thirteen benthic classes defined from the data collected in the Perhentian Islands. Figures in parenthesis indicate mean observational abundances from the DAFOR (0-5) semi-quantitative scale as used during CCC Baseline surveys

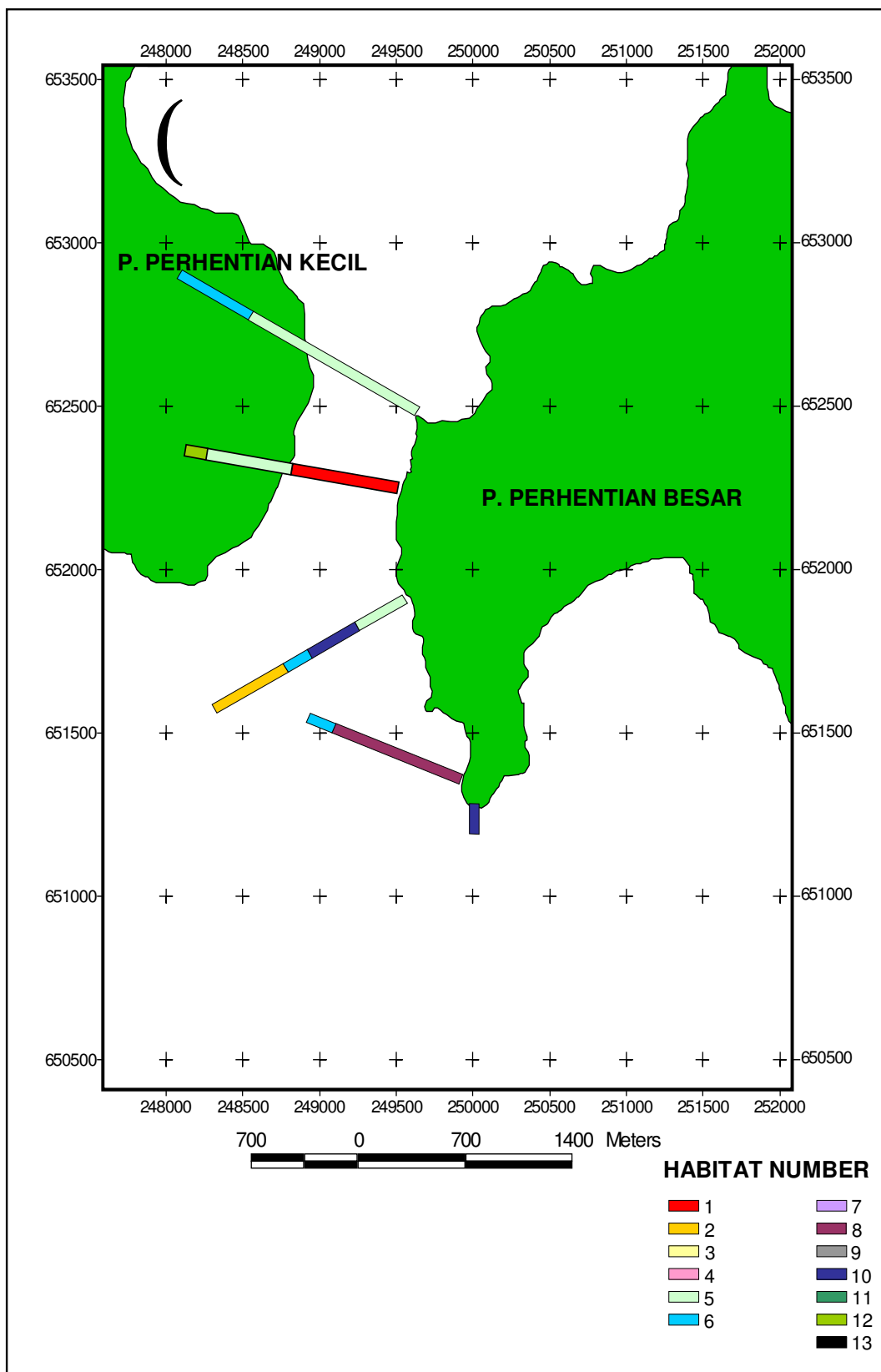


Figure 3.20. Benthic habitat distribution within Survey Sector B01

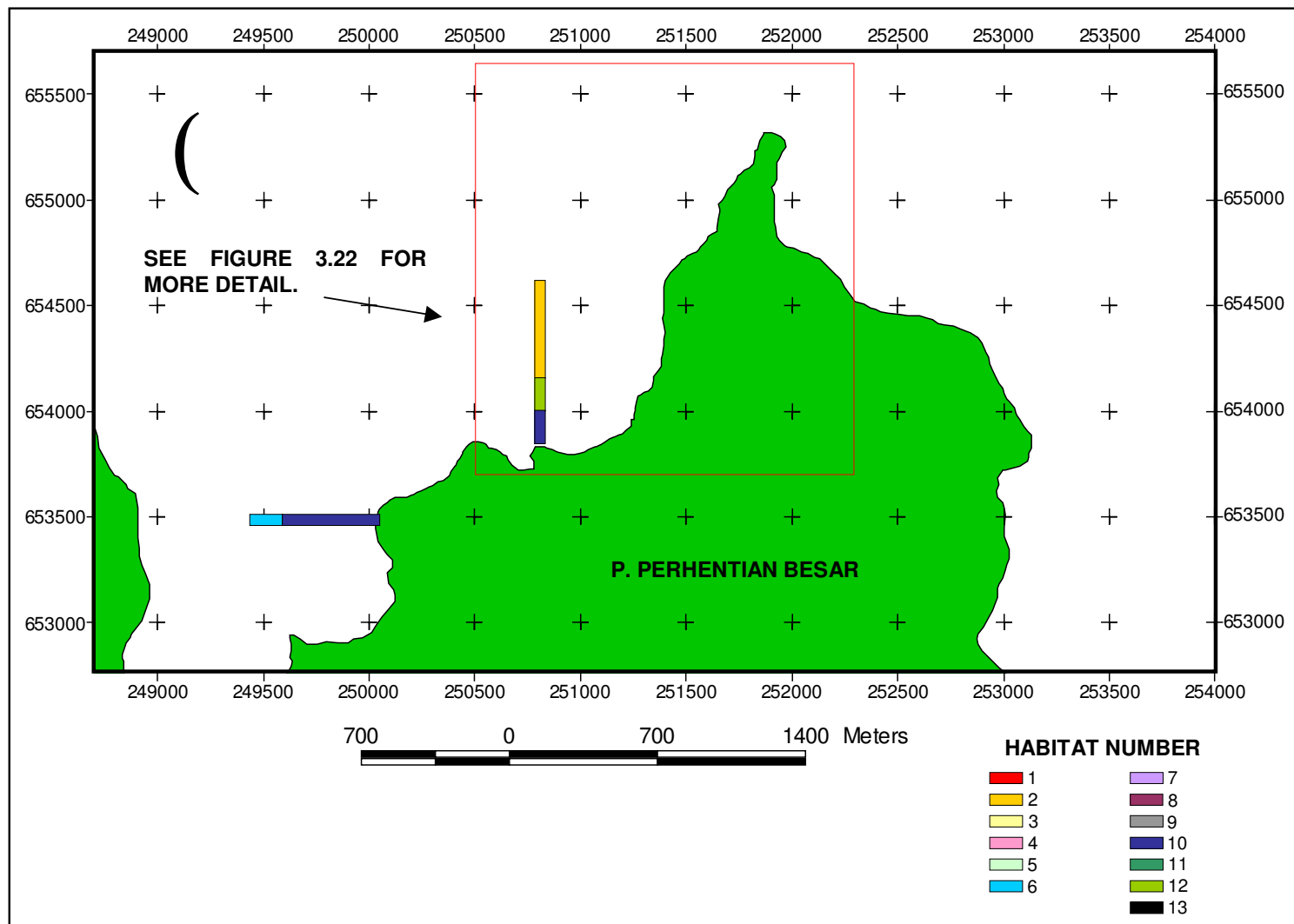


Figure 3.21. Benthic habitat distribution within Survey Sector B02

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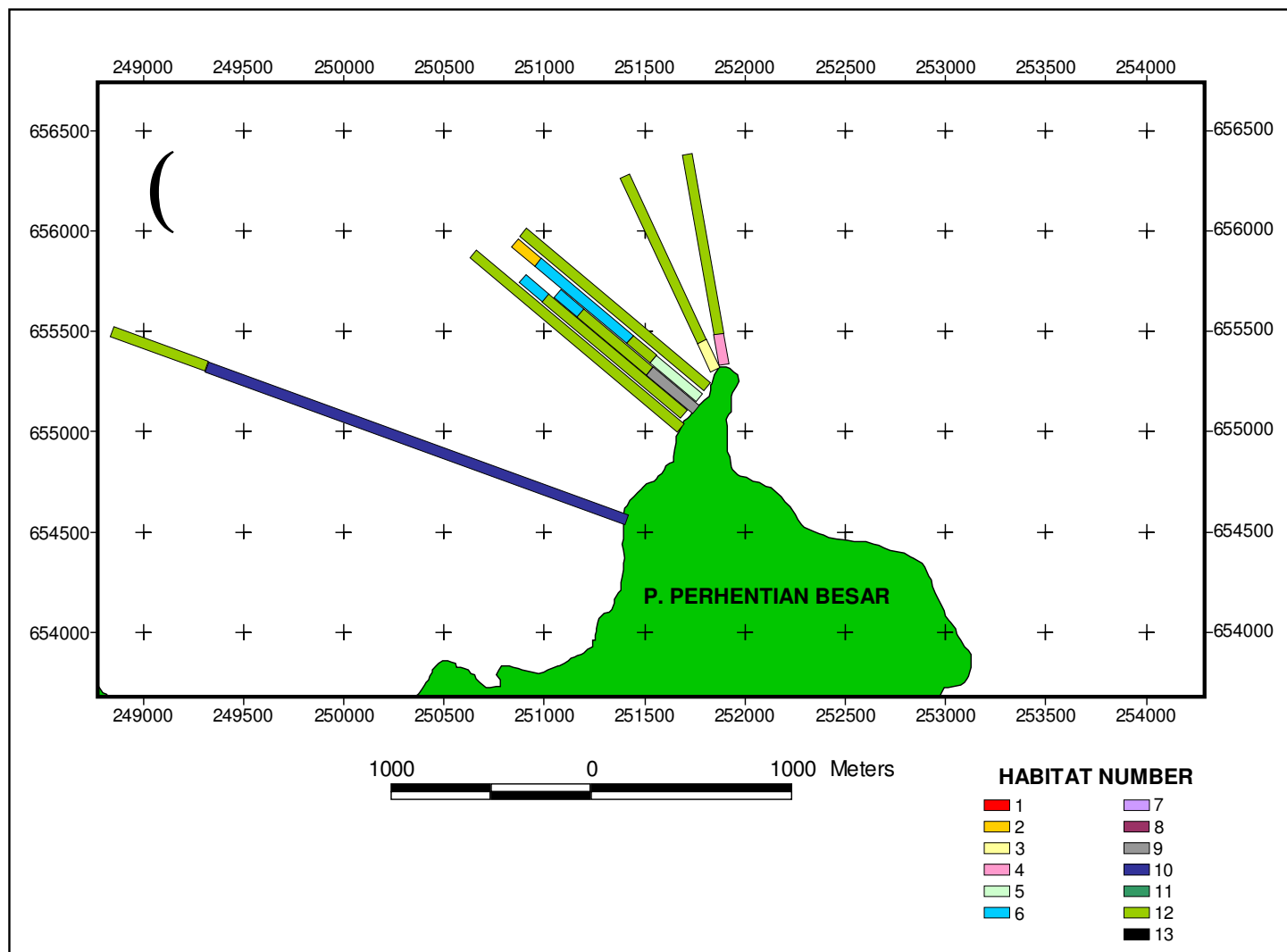


Figure 3.22. Benthic habitat distribution within the Tanjung Basi area

Prepared by Coral Cay Conservation

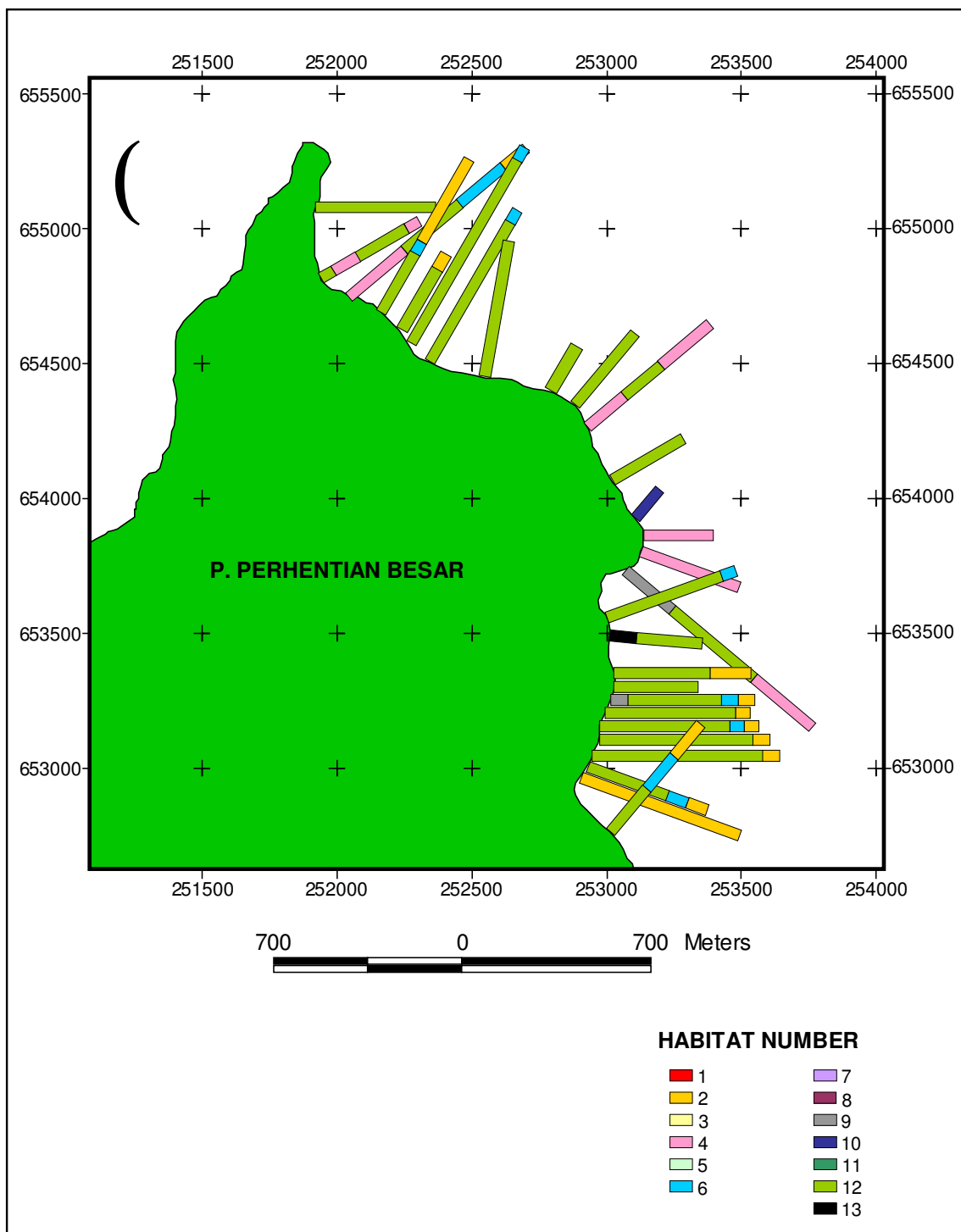


Figure 3.23. Benthic habitat distribution within Survey Sector B03

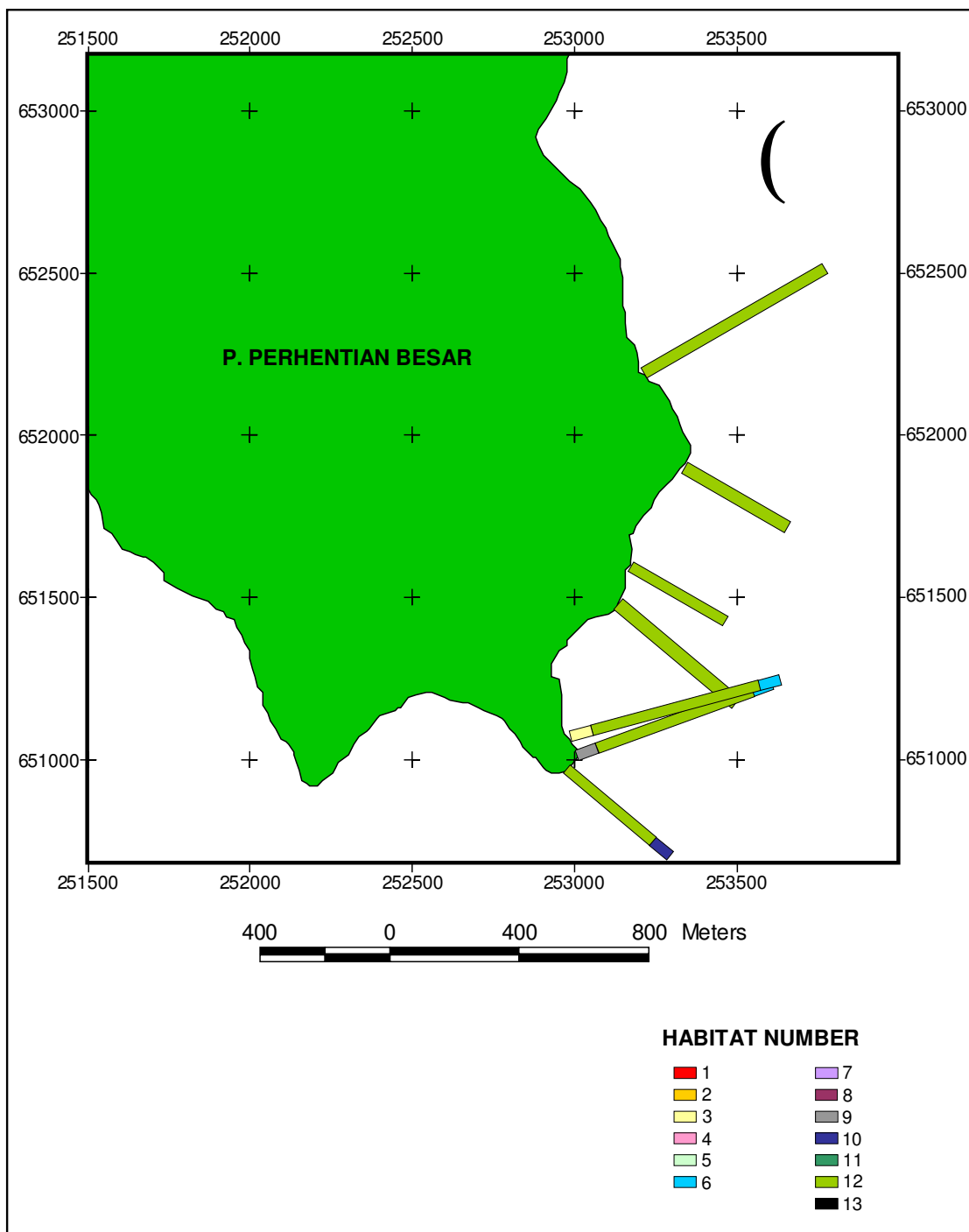


Figure 3.24. Benthic habitat distribution within Survey Sector B04

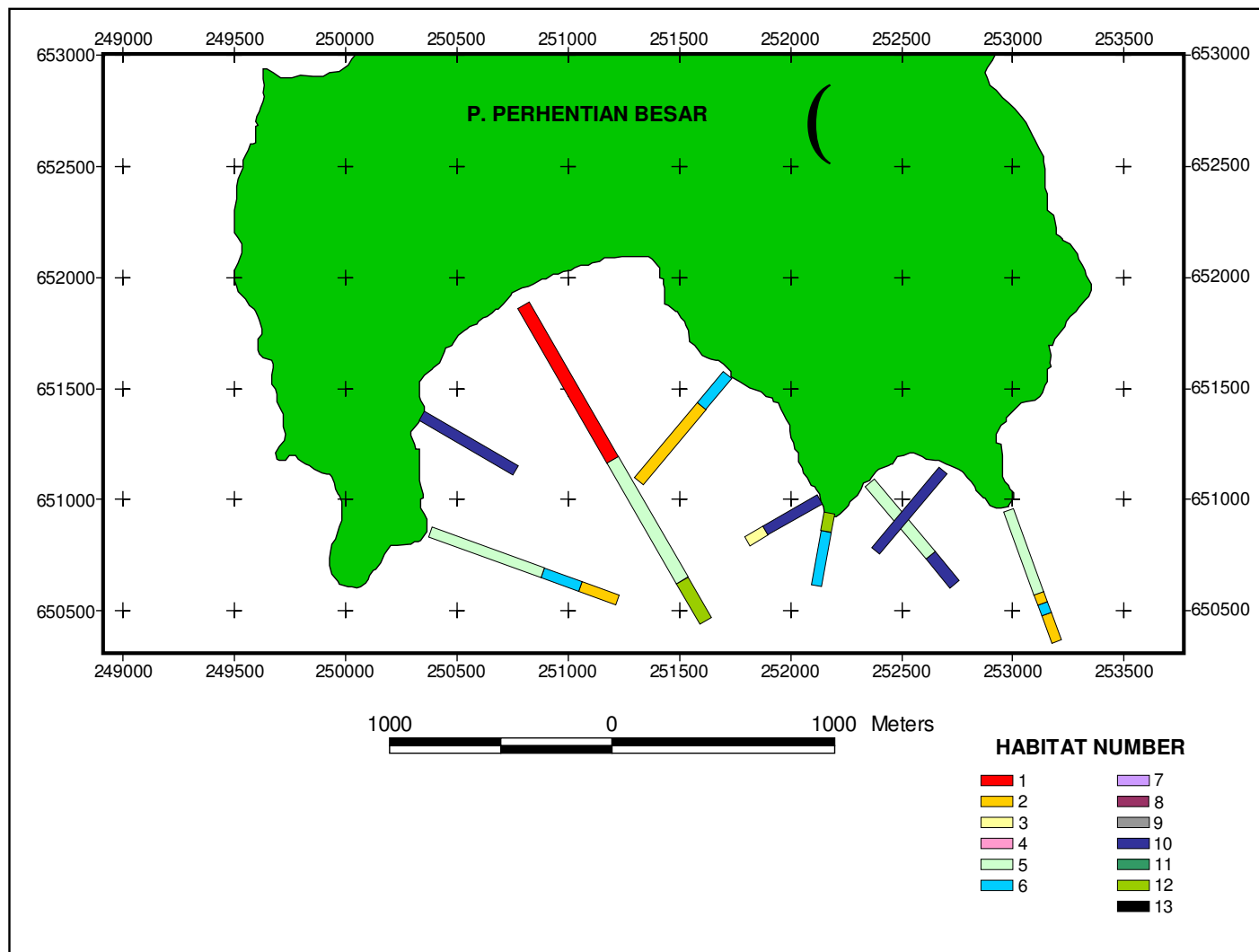


Figure 3.25. Benthic habitat distribution within Survey Sector B05

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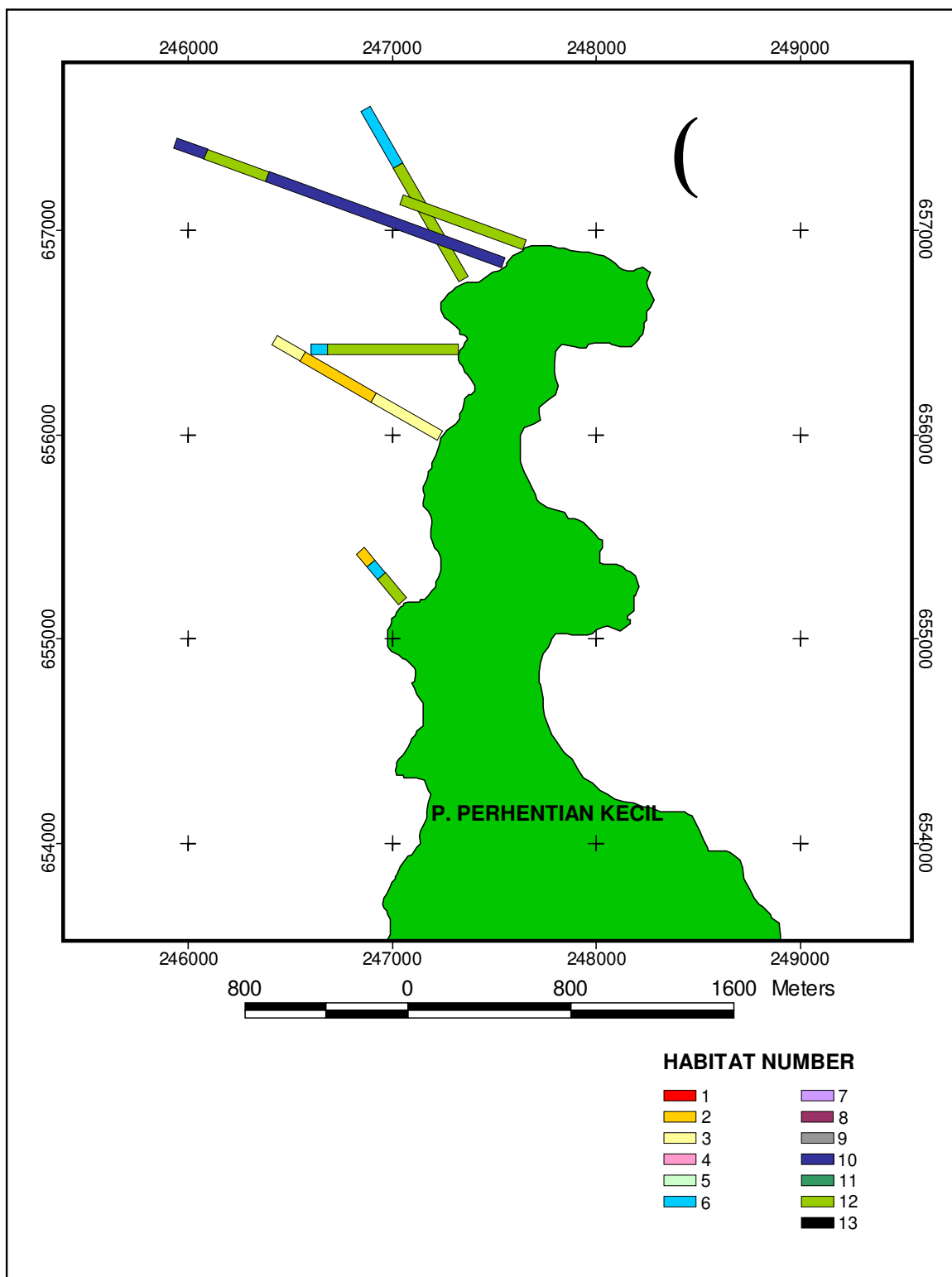


Figure 3.26. Benthic habitat distribution within Survey Sector K01

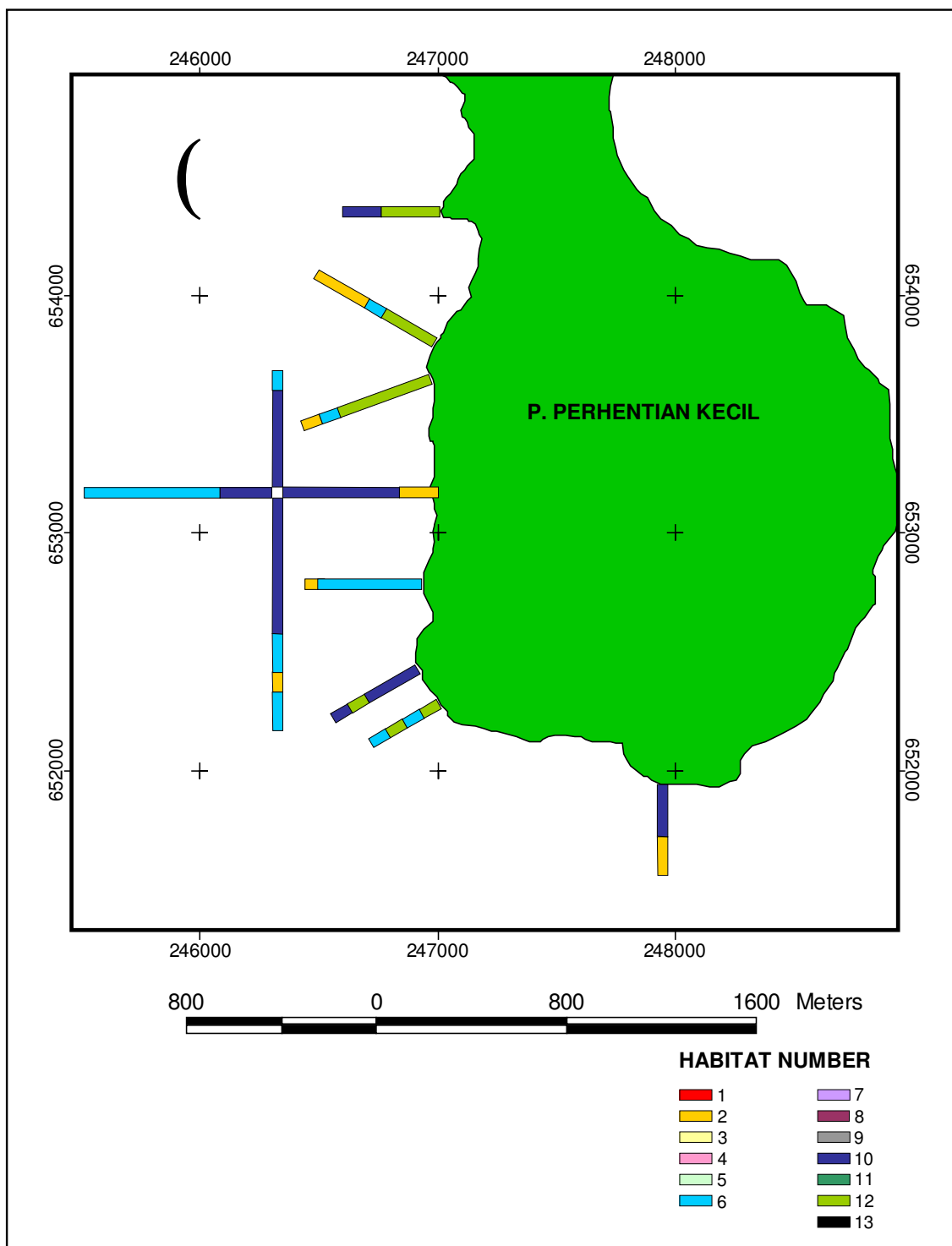


Figure 3.27. Benthic habitat distribution within Survey Sector K02

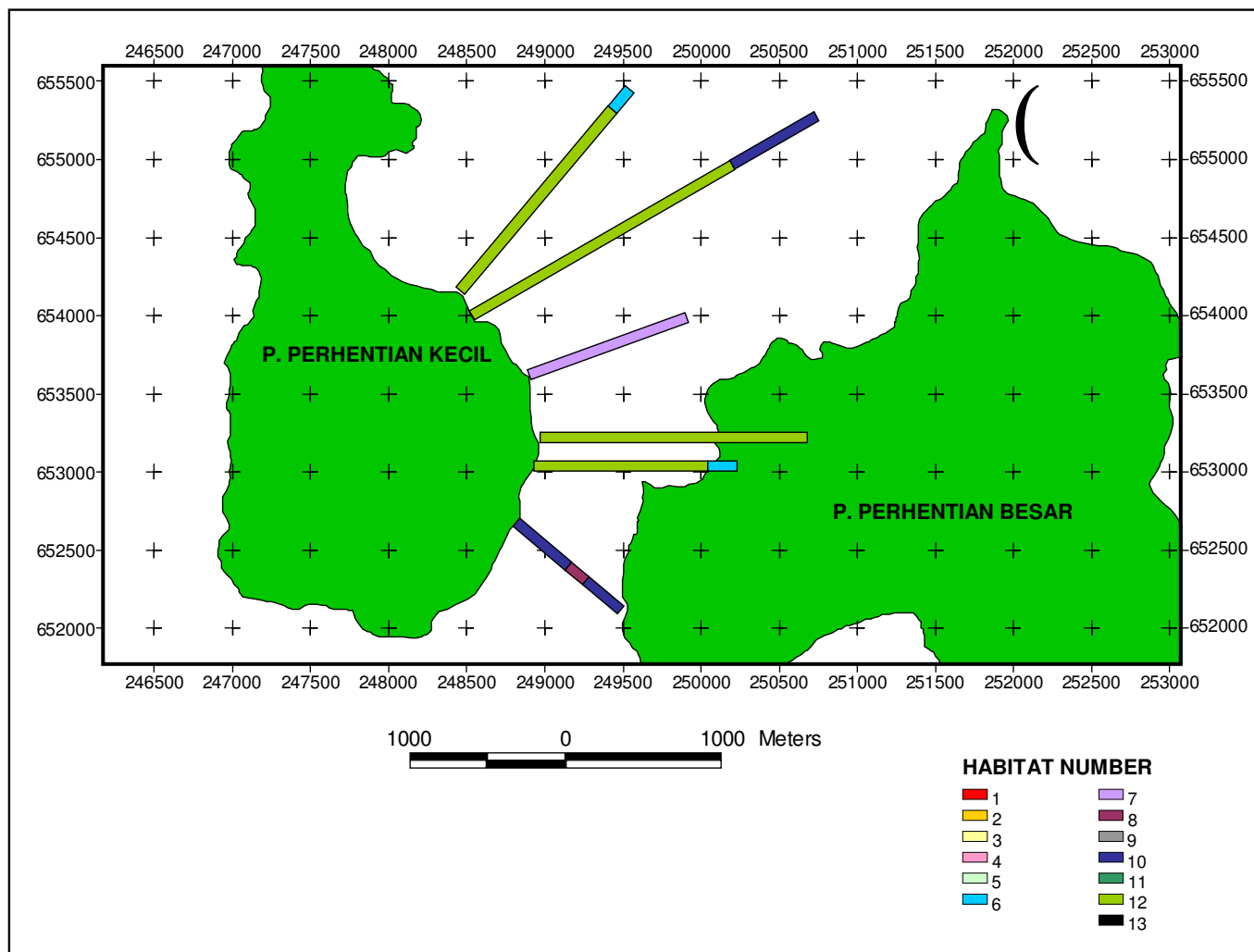


Figure 3.28. Benthic habitat distribution within Survey Sector K03

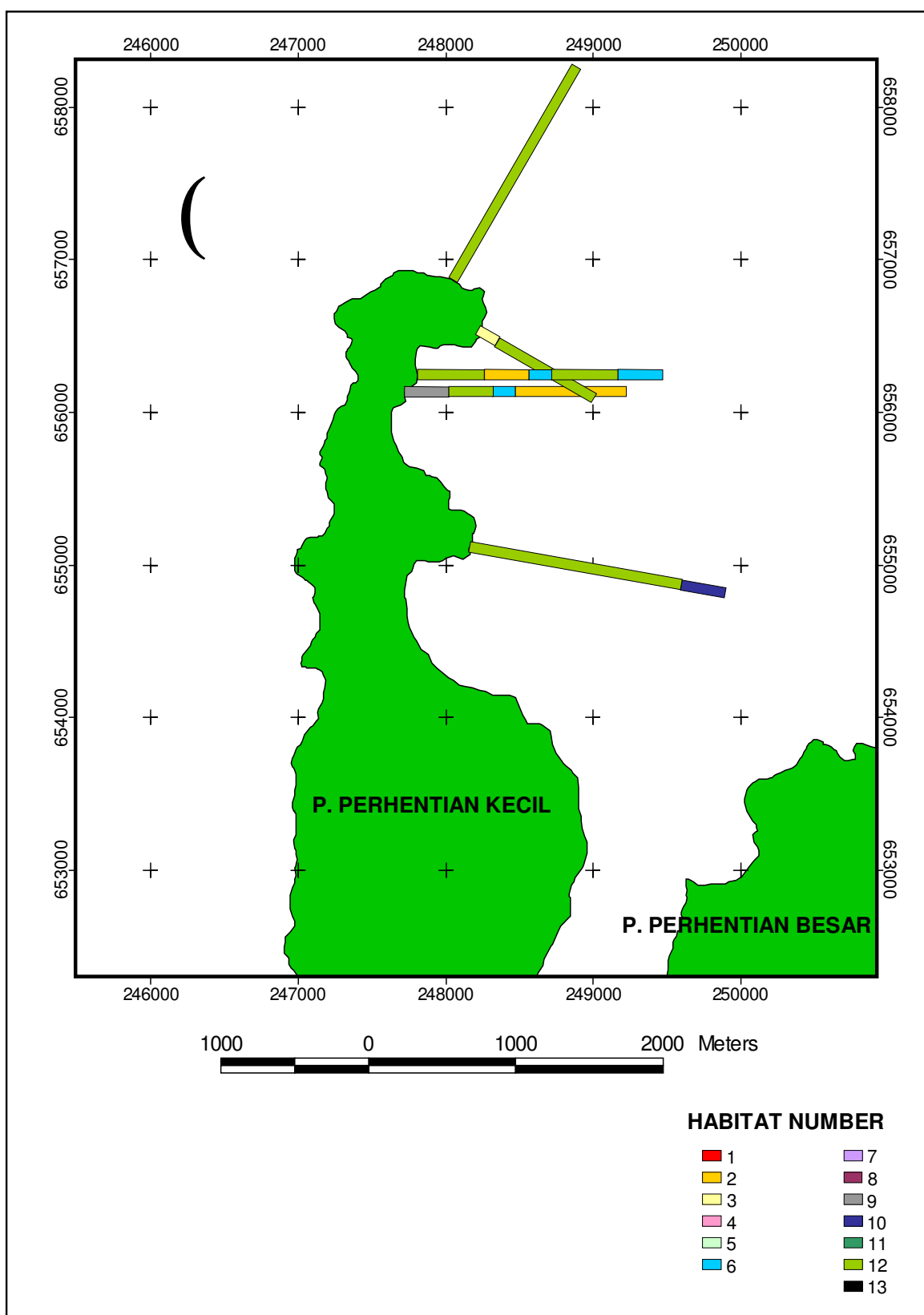


Figure 3.29. Benthic habitat distribution within Survey Sector K04

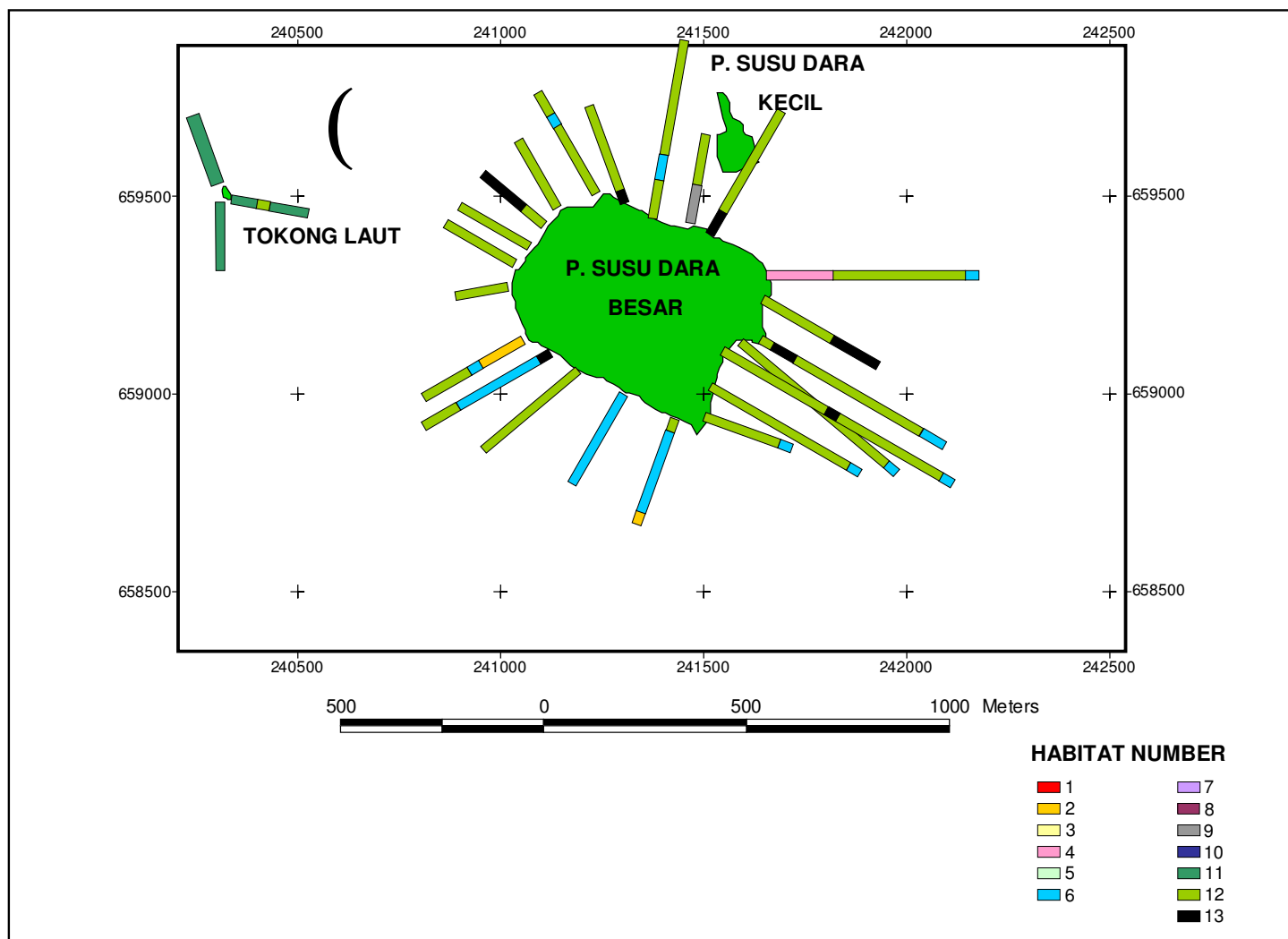


Figure 3.30. Benthic habitat distribution within Survey Sectors TL and SB

Prepared by Coral Cay Conservation

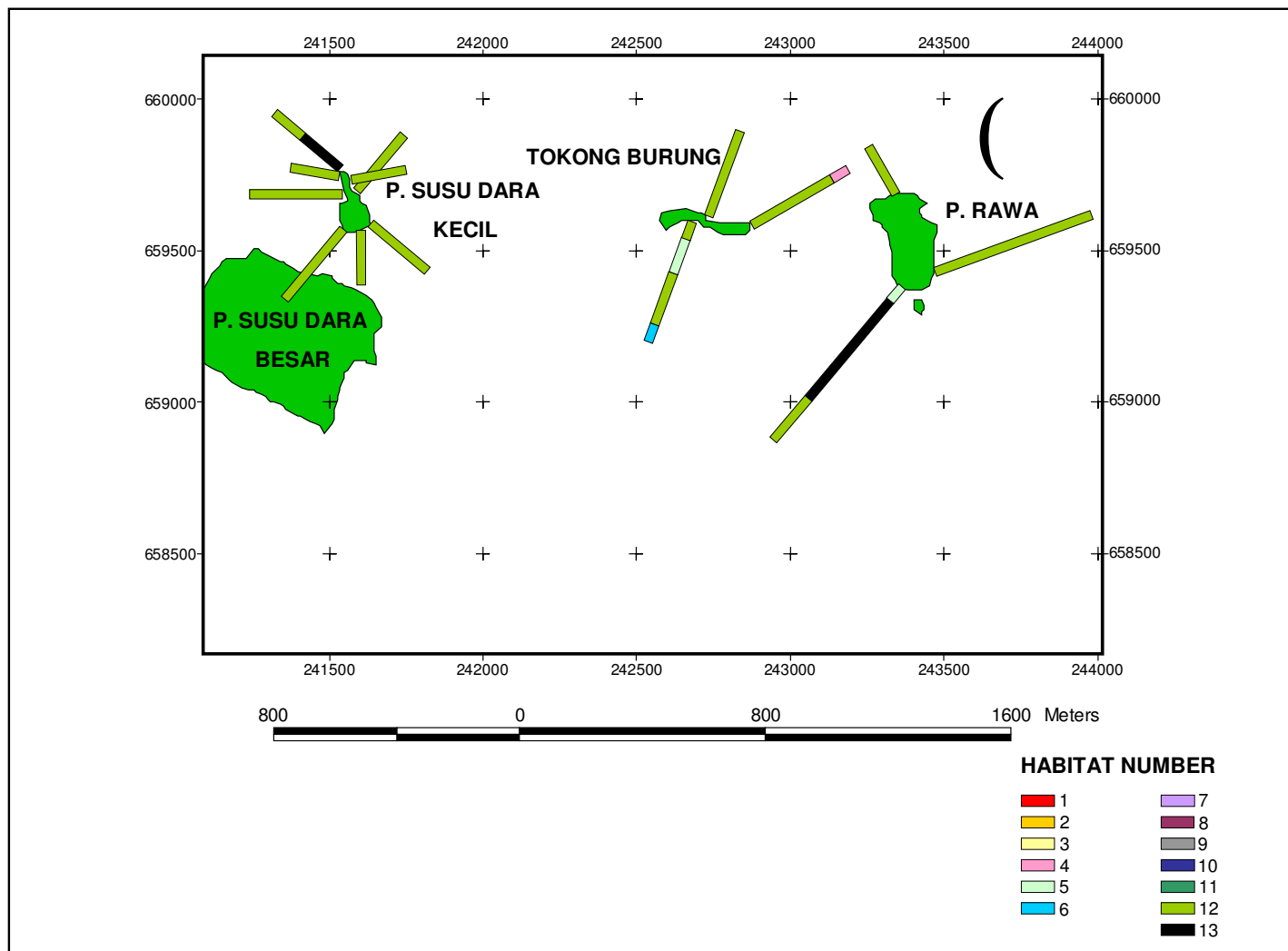


Figure 3.31. Benthic habitat distribution within Survey Sectors PK, TB and PR

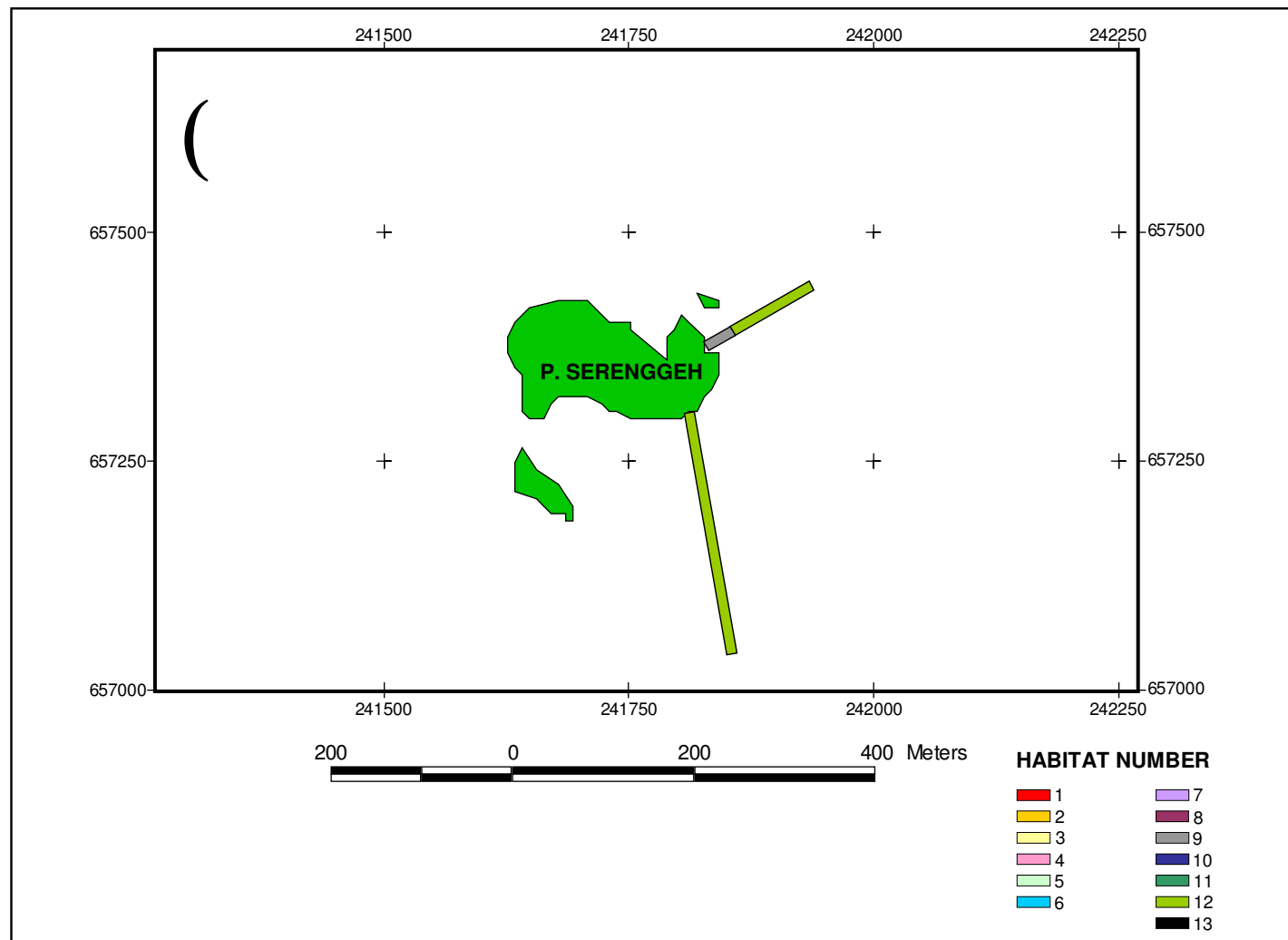


Figure 3.32. Benthic habitat distribution within Survey Sector PS

3.6.3 Univariate Measures of Habitat Biodiversity

Table 3.3 represents a range of univariate measures of coral reef biodiversity based on the Site Records of benthic and sessile organisms that have been defined as belonging to each benthic class.

Three habitats stand out as having the highest number of species identified from the target species list employed in the CCC Baseline transects; habitats 6, 10 and 12 which have 115, 112 and 147 species respectively in the dataset. It is interesting to note that whilst habitats 6 and 10 have a high species number, they do not have a particularly high live benthic cover as represented by the sum of abundance ratings. Habitat 12 does however have a high live benthic cover; with a sum of abundance ratings of all benthic and sessile organisms of 35.

Perhaps the single most widely accepted biodiversity measure is the Shannon-Weiner Index as it accounts for both the species diversity as well as the evenness of the population structure. Again, the same three habitats have the greatest Shannon-Weiner indices; habitats 6, 10 and 12 in ascending order with calculated diversity values of 4.0, 4.0 and 4.3 correct to one decimal place for these habitats respectively. Habitat 12 is therefore the most biodiverse habitat found in this study.

Habitat	Species Number	Sum of abundance ratings	Marglef Index of species richness	Pielous Evenness Index	Log _e Shannon-Weiner Index	Simpsons Diversity
1	5	5	2.49	1.0	1.609	1.0
2	66	5	39.17	0.761	3.189	1.106
3	47	12	18.29	0.928	3.572	1.051
4	47	6	25.80	0.911	3.507	1.153
5	75	18	25.44	0.858	3.703	1.016
6	115	16	41.35	0.843	4.0	1.036
7	41	24	12.56	0.948	3.521	1.008
8	41	26	12.35	0.909	3.375	0.997
9	61	24	18.93	0.924	3.8	1.016
10	112	24	34.74	0.856	4.039	1.019
11	57	27	16.96	0.912	3.687	1.005
12	147	35	41.13	0.867	4.325	1.012
13	67	21	21.63	0.876	3.681	1.015

Table 3.3. Univariate biodiversity measures of the thirteen Benthic Classes derived from Cluster Analysis from data collected during the Pilot Phase of the MRICP.

3.7 Fish Populations

A total of one hundred and twenty seven species of fish have been positively identified during the Malaysia Coral Reef Conservation Project at Pulau Perhentian. These species include representatives from 71 genera and thirty-seven families. All but one of these species belonged to the class Osteichthyes (bony fish), with one shark species of the order Chondrichthyes observed. Species lists are given in appendix IV.

The mean abundance values of the major reef fish taxa observed during the MRICP are depicted in Table 3.4. Across all CCC Baseline surveys, by far the most commonly observed fish family was the Damselfish (Pomacentridae). It was twice as abundant as the next most commonly observed family; the Wrasse (Labridae) (1.08 and 0.58 respectively).

Fish Taxa		Mean Abundance	S.D.
Damselfish	Pomacentridae	1.08	1.42
Wrasse	Labridae	0.58	0.89
Parrotfish	Scaridae	0.43	0.78
Rabbitfish	Siganidae	0.29	0.49
Spinecheeks	Nemipteridae	0.20	0.41
Fusiliers	Caesionidae	0.18	0.64
Butterflyfish	Chaetodontidae	0.17	0.41
Groupers	Serranidae	0.17	0.39
Chromis spp.	Pomacentridae	0.14	0.60
Snappers	Lutjanidae	0.10	0.37
Cardinalfish	Apogonidae	0.10	0.39
Gobies	Gobiidae	0.10	0.37
Angelfish	Pomacanthidae	0.05	0.21
Goatfish	Mullidae	0.02	0.14
Filefish	Monacanthidae	0.02	0.15
Surgeonfish	Acanthuridae	0.01	0.10
Anthias	Serranidae	0.01	0.10
Triggerfish	Balistidae	0.01	0.09

Table 3.4. Calculated mean abundance ratings assigned to each major fish family (or subfamily for Serranids) during CCC Baseline surveys of the MRICP. Mean values $\pm$ SD given correct to 2 D.P.

Parrotfish (Scaridae) was the next most commonly observed family, with an average abundance of 0.43. There is then a big drop in the mean abundances to Rabbitfish (Siganidae) and Spinecheeks (Nemipteridae) with average abundance of 0.29 and 0.20 respectively. Surgeonfish (Acanthuridae), Anthias (Serranidae, Athinidae) and Triggerfish sp. (Balistidae) were the least abundant families of all reef fish recorded, with an average abundance on the semi-quantitative scale of only 0.01.

One key feature of all the calculated mean values however is that they have a large degree of variance (S.D.) around them. This means that the observations were

extremely heterogeneous in nature and were varied both in the frequency and the abundance of reef fish in each individual observation.

3.7.1 *Fish Assemblage variation between Survey Sector*

Figures 3.33 and 3.34 represent the average abundance of the more common and less frequently recorded fish families respectively in each of the survey sectors. Damselfish (Pomacentridae) dominate Figure 3.33 as the overall most abundant fish family across all survey sectors. However their recorded abundance varied considerably between sectors. P. Serenggeh, Tokong Laut and Tokong Burung all had greatest observed abundances of Damselfish with mean abundances of 3.1, 2.5 and 2.3 at these survey sectors respectively. Wrasse populations also showed a similar trend in this disparity between population size by geographic area; being observed most commonly in sectors B1 and B2 with mean abundances of 1.6 and 1.4. Amongst the other more commonly observed fish families, there is no obvious trend in differences in population size between geographic areas.

The rarer fish families observed are dominated by members of the Grouper and Cardinalfish families. Groupers were recorded most often at Pulau Serenggeh and Tokong Laut whilst Cardinalfish were most abundant in Survey Sectors B1, B5 and K2. Filefish were most commonly observed at Pulau Rawa, with an average abundance on survey transects there more than three times greater than at all other survey sectors. Finally, Gobies were most commonly observed in sectors B1, K2 and K3.

3.7.2 *Fish Assemblage Variation Between Habitats*

Of the seventy-eight pair wise comparisons made between the fish assemblages found associated with different habitats, fifty-three were significant (Table 3.5). This indicates that within the survey data collected in the Perhentians, there is a highly significant link between the fish assemblages and the habitats in which they were found. The habitats with the most significant differences in terms of the pair wise analysis are habitats 3, 4 and 11 with 11, 11 and 9 respectively pair wise comparisons that are significantly different than the fish assemblages found with other habitats. Whilst these habitats appear to have closely determined and associated reef fish populations, which in itself is a strong indicator of management importance, it does not mean that the specified habitats have the commercially or ecologically most valuable fish populations associated with them.

Reef fish composition in terms of the abundance of the major families associated with each defined habitat is markedly less heterogeneous than the assemblages associated within geographically distinct survey areas (see Figures 3.33 and 3.34 for associations with geographic areas and Figures 3.35 and 3.36 for associations with discrete habitat types). Once again, Damselfish were observed with the greatest abundance across all habitats. Five of the thirteen habitats share an equally high proportion of Damselfish in their associated fish assemblages. These habitats are 5, 7, 8, 10, 11 with recorded mean abundance ratings of 1.8, 1.9, 2.5, 2.4 and 2.5 respectively. No Pomacentrids were recorded in habitat 4 whilst habitats 2, 3 and 13 had low mean abundances associated with them; 0.2, 0.2 and 0.4 respectively.

In many cases, where abundances are less variable, some of the major groups are completely absent from the observed fish assemblages associated with a habitat. Amongst the more commonly observed fish families, Butterflyfish were not recorded in habitats 1, 2, 4, 7, 11 and 13; Fusiliers from habitats 1, 3, 4, 7, 9, 11 and 13; Rabbitfish from habitat 1; Wrasse from habitat 11, Parrotfish from habitats 7, 11 and 13 and finally Spinecheeks were absent from the fish assemblages in habitats 1, 3 and 7 (Figure 3.35). From this list above, habitats 1, 3, 4, 7, 11 and 13 appear regularly and have lowered diversity at the fish family level.

For the more rarely observed fish families these absences are even more marked (Figure 3.36). Surgeonfish and Triggerfish were only recorded in two habitats each; 9 and 12 and 4 and 12 for the respective families. Grouper populations were observed with the greatest abundance and frequency in areas associated with habitat 11 (0.6 average abundance) whilst Gobies were recorded with greatest abundance in habitat 2 (0.5 average abundance).

	1												
2	0.01 0.6	2											
3	0.84 0.001*	0.11 0.03*	3										
4	0.71 0.001*	0.31 0.001*	0.18 0.04*	4									
5	0.35 0.001*	0.19 0.001*	0.23 0.001*	0.35 0.001*	5								
6	0.06 0.8	0.10 0.001*	0.18 0.001*	0.26 0.001*	0.02 0.731	6							
7	1.0 0.001*	0.07 0.87	0.67 0.001*	0.59 0.001*	0.05 0.183	0.23 0.999	7						
8	1.0 0.001*	0.06 0.13	0.21 0.059	0.21 0.073	0.03 0.629	0.01 0.423	0.99 0.002*	8					
9	0.43 0.001*	0.04 0.10	0.20 0.012*	0.36 0.001*	0.04 0.137	0.05 0.849	0.19 0.04*	0.03 0.027*	9				
10	0.93 0.001*	0.68 0.001*	0.46 0.001*	0.52 0.001*	0.24 0.001*	0.38 0.001*	0.79 0.001*	0.15 0.906	0.28 0.003*	10			
11	0.93 0.001*	0.01 0.55	0.89 0.001*	0.67 0.001*	0.17 0.001*	0.237 1.000	0.61 0.001*	1.0 0.001*	0.47 0.001*	0.74 0.001*	11		
12	0.06 0.197	0.45 0.001*	0.34 0.001*	0.37 0.001*	0.05 0.055	0.21 0.001*	0.20 1.00	0.10 0.105*	0.03 0.274	0.22 0.001*	0.15 1.00	12	
13	0.02 0.39	0.13 0.05	0.69 0.001*	0.63 0.001*	0.27 0.001*	0.06 0.947	0.01 0.455	0.71 0.001*	0.34 0.002*	0.84 0.001*	0.23 0.001*	0.02 0.710	13

Table 3.5. Pair wise multivariate comparison between fish assemblages associated with each habitat.

Note: Values in normal font indicates the calculated R-value correct to 2 D.P.; values in bold indicate P-values correct to 3 D.P. P-values marked with an asterisk indicate a significant difference in the fish assemblages found associated with the two habitats concerned.

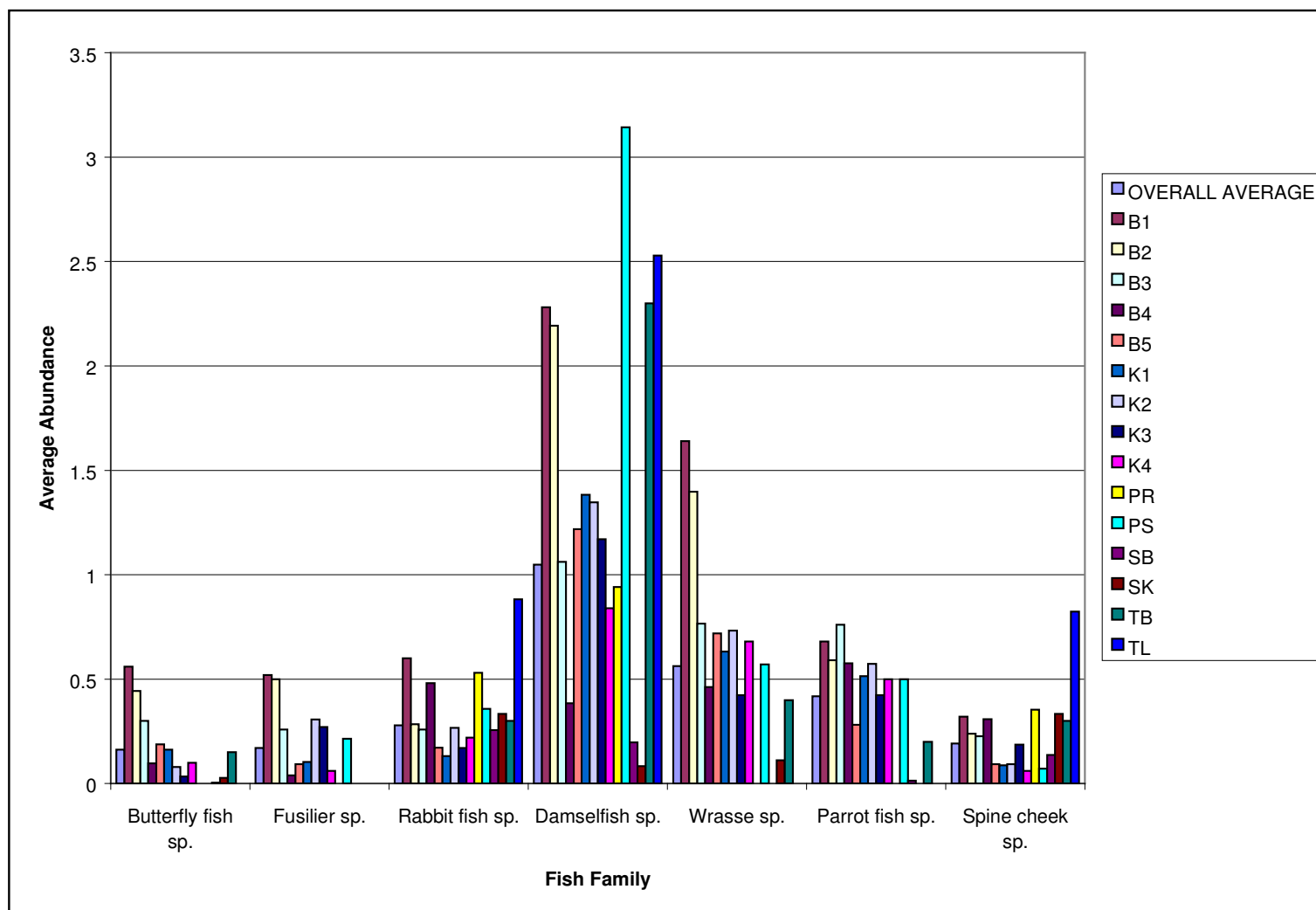


Figure 3.33. Commonly encountered fish families in each survey sector. See Figure 3.1 for survey sector locations.

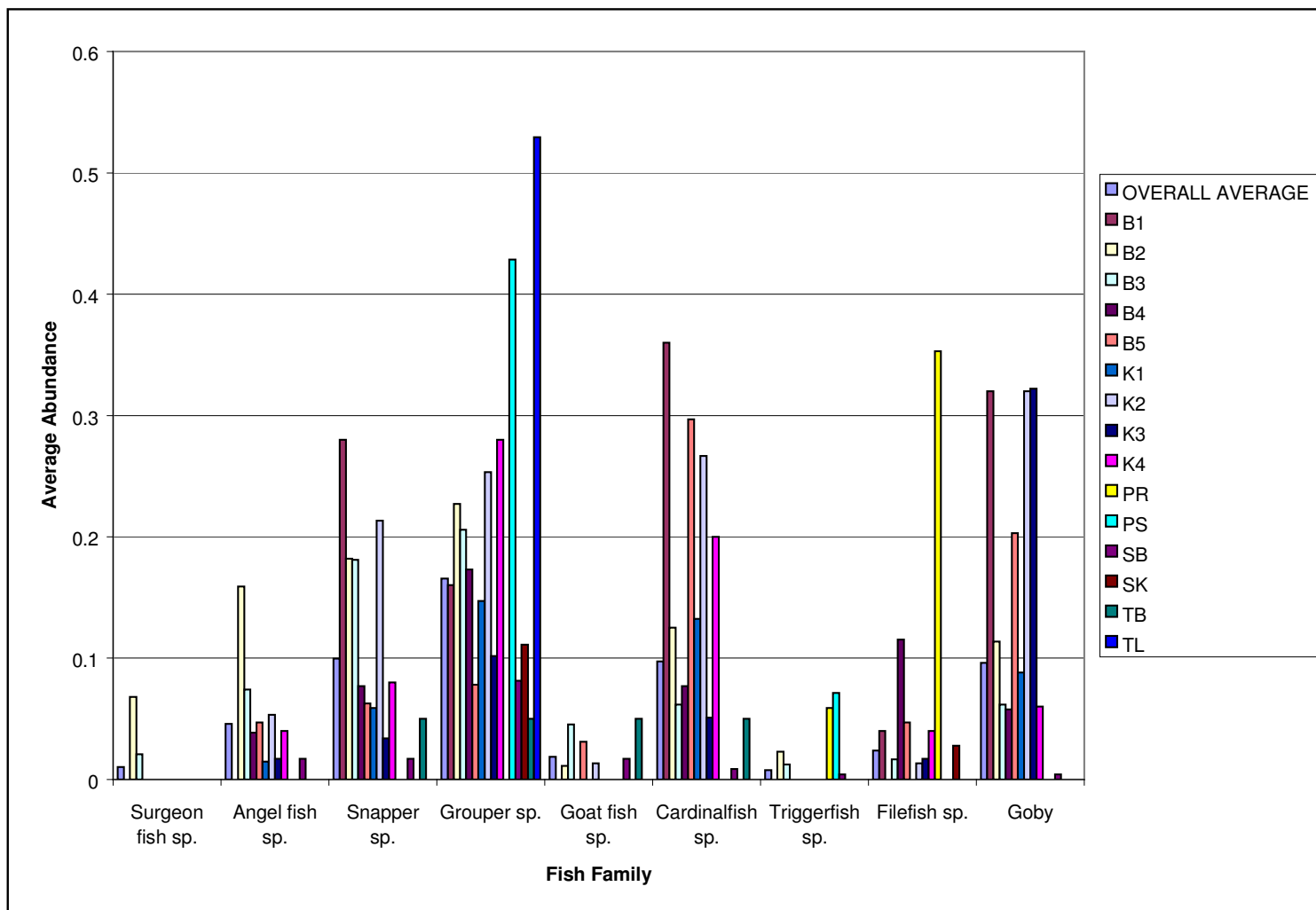


Figure 3.34. Less frequently encountered fish families in each survey sector. See Figure 3.1 for survey sector locations.

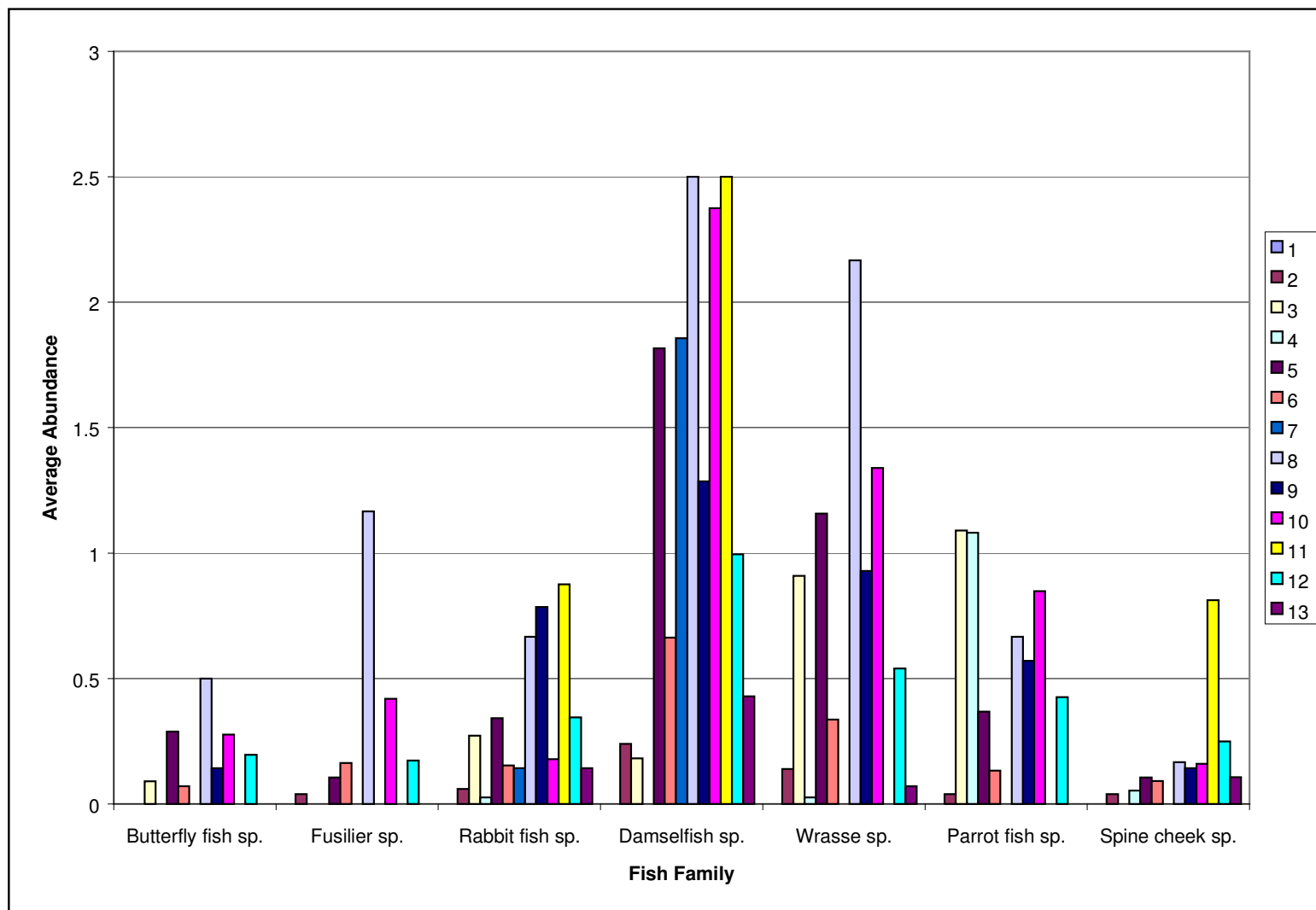


Figure 3.35. Commonly encountered fish families found associated with each habitat

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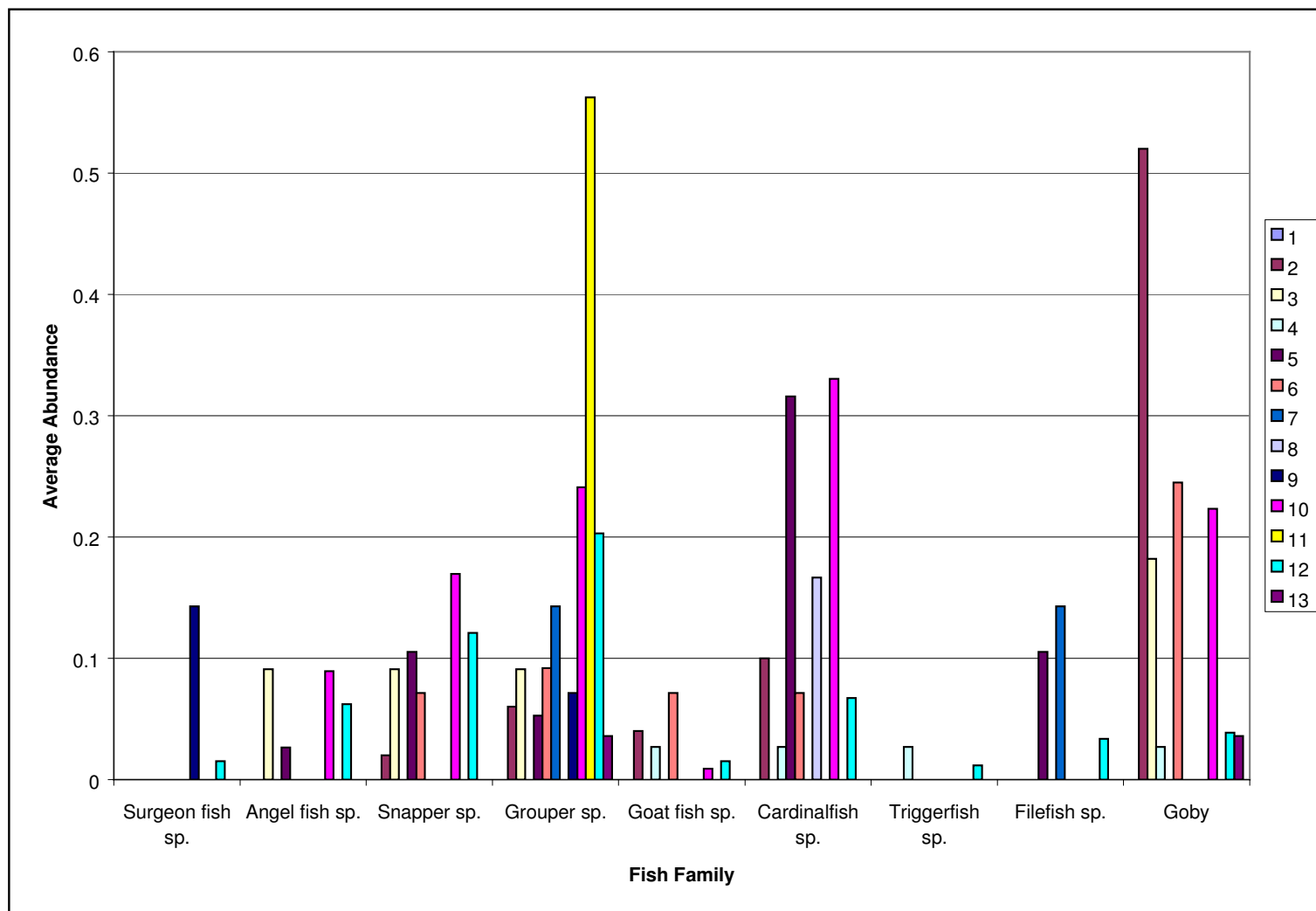


Figure 3.36. Less frequently encountered fish families found associated with each habitat

3.7.3 Biodiversity of fish assemblages found associated with each habitat

The number of reef fish species recorded and associated biodiversity indices for each habitat are depicted in Table 3.6. The greatest recorded species number was found within the fish assemblage associated with habitat 12. By contrast, only six fish species were recorded in areas of habitat 1. In terms of the overall abundance of reef fish habitat 12 had only a moderate density of fish found associated with it, whilst habitats 11, 7 and 8 had sum abundance ratings of 22, 21 and 21 respectively. This is reflected in the Pielous evenness statistic which for habitat 12 is only 0.81 and is 0.87, 0.92 and 0.83 for habitats 7, 8 and 11 respectively. Finally, the Shannon-Weiner diversity index which is often used as the best rating of overall biodiversity indicates that habitat 8 revealed the most diverse fish assemblage associated with it. Habitats 12 and 6 having slightly lower overall diversity with calculated diversity indices of 3.85 and 3.83 respectively.

Habitat	Species Number	Sum of abundance ratings	Marglef Index of species richness	Pielous Evenness Index	Log _e Shannon-Weiner Index	Simpsons Diversity
1	6	5	3.16	0.75	1.34	0.85
2	44	3	37.85	0.87	3.29	1.39
3	37	9	16.62	0.91	3.28	1.07
4	50	7	24.58	0.81	3.18	1.08
5	61	15	22.06	0.87	3.59	1.03
6	82	9	36.95	0.87	3.83	1.09
7	31	21	9.92	0.87	2.99	0.98
8	23	21	7.21	0.92	3.89	0.98
9	37	12	14.56	0.89	3.23	1.04
10	72	15	26.09	0.80	3.41	1.01
11	42	22	13.34	0.83	3.09	0.98
12	119	15	43.12	0.81	3.85	1.03
13	52	15	18.71	0.79	3.13	0.99

Table 3.6. Univariate biodiversity measures calculated for fish assemblages found associated with each habitat defined from data on benthic populations presented in this study. Species number and sum of abundance ratings are given as integers; calculated diversity indices are given correct to 2 D.P.

3.8 Invertebrate Populations

3.8.1 Overall Invertebrate Populations

Data on invertebrate abundance collected on the semi-quantitative scale by CCC divers during the MRICP, presented in Table 3.7, present the most dominant invertebrate taxa recorded throughout the entire survey area of the Perhentians. Individual species of invertebrates have been simplified into major taxonomic groupings to include; Holothurians (sea cucumbers), Echinoderms (sea urchins and

sea stars), Crustaceans, Tunicates, Bivalves, Cephalopods (octopus, squid and cuttlefish) and Gastropods. The presence of Crinoid featherstars and Crown of Thorn Seastars (*Acanthaster planci*) have been assessed individually at the species level because of their abundance and corallivorous nature for the two species respectively.

Taxa	Mean abundance	SD
Holothurians	0.38	0.65
Sea Urchins	0.32	0.67
Crinoid Featherstars	0.27	0.60
Tunicates	0.17	0.46
Crustaceans	0.14	0.44
Bivalves	0.13	0.40
Sea stars	0.09	0.35
Cephalopods	0.04	0.21
Gastropods	0.02	0.16
Crown of Thorns (<i>Acanthaster planci</i>)	0.01	0.12

Table 3.7. Calculated mean abundance ratings assigned to each major invertebrate taxa during CCC Baseline survey dives during the MRICP. Mean values $\pm$ SD given correct to 2 D.P.

The most commonly observed invertebrate during baseline surveys by CCC divers were Holothurians. Both urchins of the genus *Diadema sp.* and their short spined relatives were the second most commonly observed invertebrate along with the Crinoid featherstars, having mean abundances of 0.32 and 0.27 respectively. Crown of Thorns starfish and members of the order Gastropoda were least frequently observed; with mean abundances of 0.01 and 0.02 respectively.

All of the calculated mean values contain large variance (S.D.) indicating that the distribution of the invertebrate taxa identified is heterogeneous between geographic areas. This is particularly the case in some of the less commonly seen invertebrate taxa such as the Crown of Thorns, Gastropods and Cephalopods where the standard deviation is of the order of one magnitude greater than the calculated mean abundances.

3.8.2 Invertebrate Populations by Survey Sector

Figures 3.37 and 3.38 depict the mean abundances of observed invertebrate populations within each survey sector for the more commonly (Fig. 3.37) and less frequently observed (Fig. 3.38) invertebrate taxa.

Amongst the more frequently observed invertebrate taxa, sea urchins show the most heterogeneous geographic distribution. They were most commonly found within the Tokong Laut survey sector with a mean abundance of 1.9. Holothurians have a much

more even distribution, with a standard deviation of 0.65 around a mean abundance across all areas of 0.38. They were however notably rarely observed within sector B3, with a mean abundance of 0.05. Tunicates were not recorded on the transects conducted in sectors B1, B3, B5, K1, PR, PS, SB and SK.

Amongst the less frequently observed invertebrates, Cephalopods have the most notable patchiness to their distribution, being absent from B4 and K4, yet having an abundance of 0.6 in the sector around Pulau Rawa

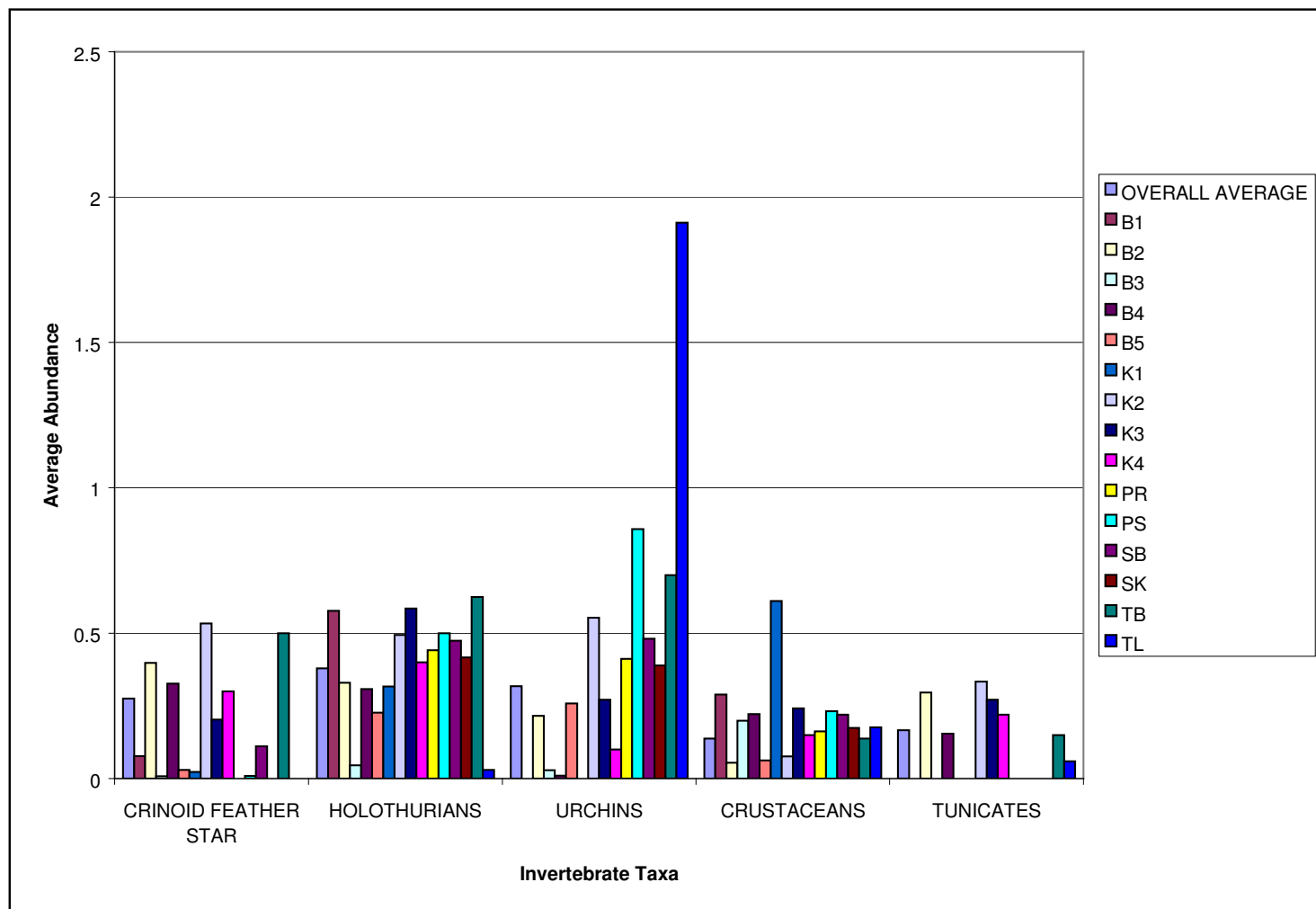


Figure 3.37. Commonly encountered Invertebrate Taxa in each Survey Sector. See Figure 3.1 for Survey Sector locations.

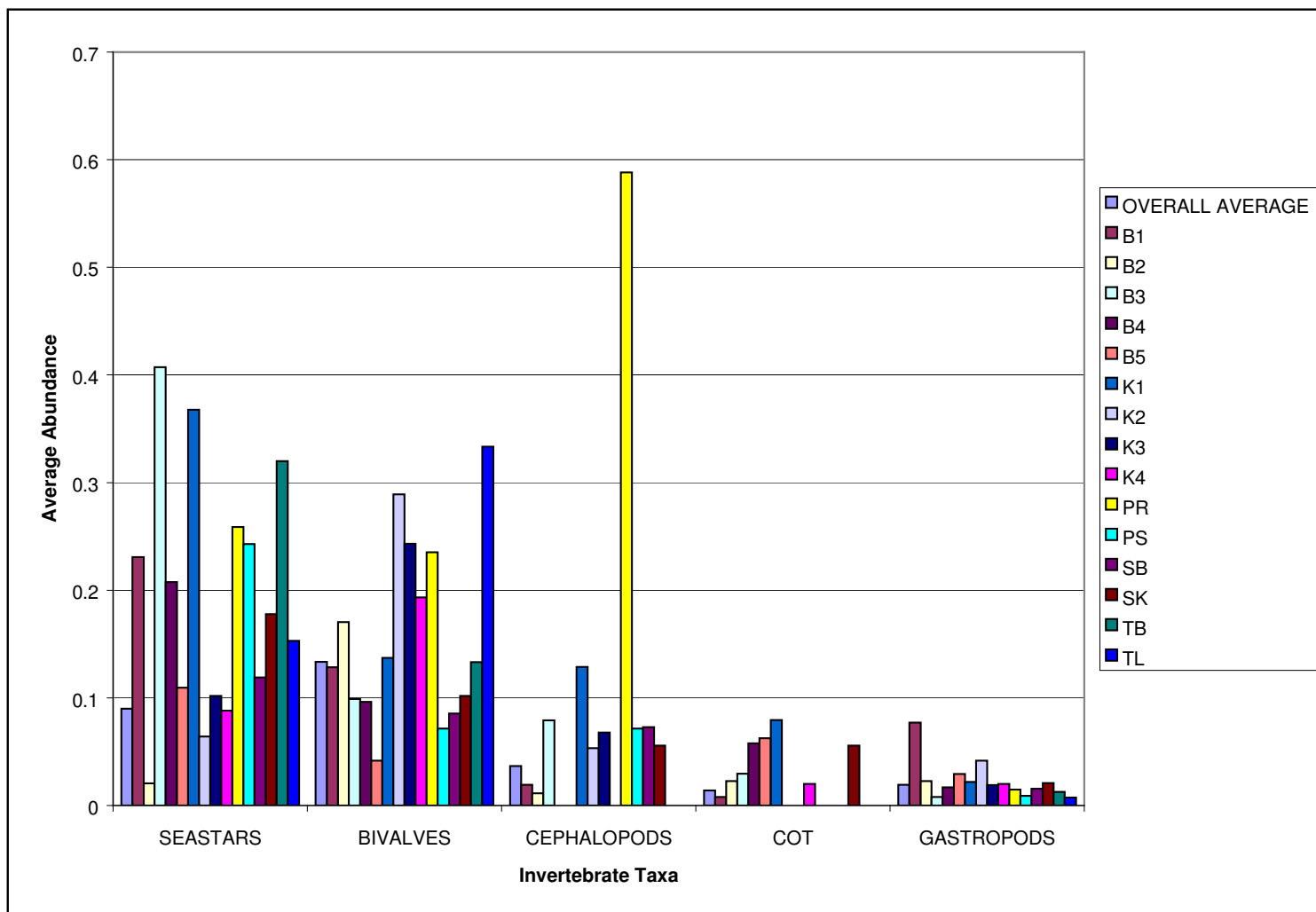


Figure 3.38. Less frequently encountered Invertebrate Taxa in each Survey Sector. See Figure 3.1 for Survey Sector locations.

3.9 Management Value

Table 3.8 briefly summarises the major biological characteristics (reef health indicators) of each defined habitat and gives each habitat a 'score' in terms of the number of occasions a habitat's biological attributes exceed the average values. Using this ranking system three habitats (5, 10 and 12) all have five reef health indicators that are above the calculated averages across all habitats. Examination of the quantitative habitat descriptions reveals that habitats 10 and 12 are found on the mid reef slope whilst habitat 5 is a healthy reef crest habitat. All three habitats have diverse and high hard coral cover. Habitats 1, 2, 7, 8 and 11 all score low on this management rating scheme, with zero for habitat 1; and 1 for the remaining four habitats of the reef health variables above the calculated average.

Habitat	BENTHIC COVER			ASSOCIATED FISH ASSEMBLAGES		No. of variables > average
	No of species	Log _e Shannon-Weiner Index	Total live hard coral cover	No of species	Log _e Shannon-Weiner Index	
1	5	1.61	0.00	6	1.34	0
2	66	3.19	0.30	44	3.29	1
3	47	3.57	1.19	37	3.28	2
4	47	3.51	1.82	50	3.18	3
5	75	3.70	2.77	61	3.59	5
6	115	4.00	1.01	82	3.83	4
7	41	3.52	1.71	31	2.99	1
8	41	3.38	2.00	23	2.89	1
9	61	3.8	1.71	37	3.23	3
10	112	4.04	1.83	72	3.41	5
11	57	3.68	1.31	42	3.09	1
12	147	4.33	2.06	119	3.85	5
13	67	3.68	1.96	52	3.13	3
AVERAGE	67.77	3.54	1.51	50.46	3.16	

Table 3.8. Calculated values for five reef health indicators; three for benthic and sessile organisms and two for fish assemblages, found associated with each habitat defined. Average values across all habitats for each variable are shown. **Values in red exceed the calculated average value for that variable in that habitat.** Final column represents the number of reef health variables that are above average for each habitat.

Using the spatial data on the distribution and composition of each survey transect conducted, an overall average reef health has been calculated for each of the survey transects completed. Using the spatial information collected with this data, it has been possible to construct a map showing the management potential of each of these survey transects with their geographic position. This map is shown as Figure 3.39

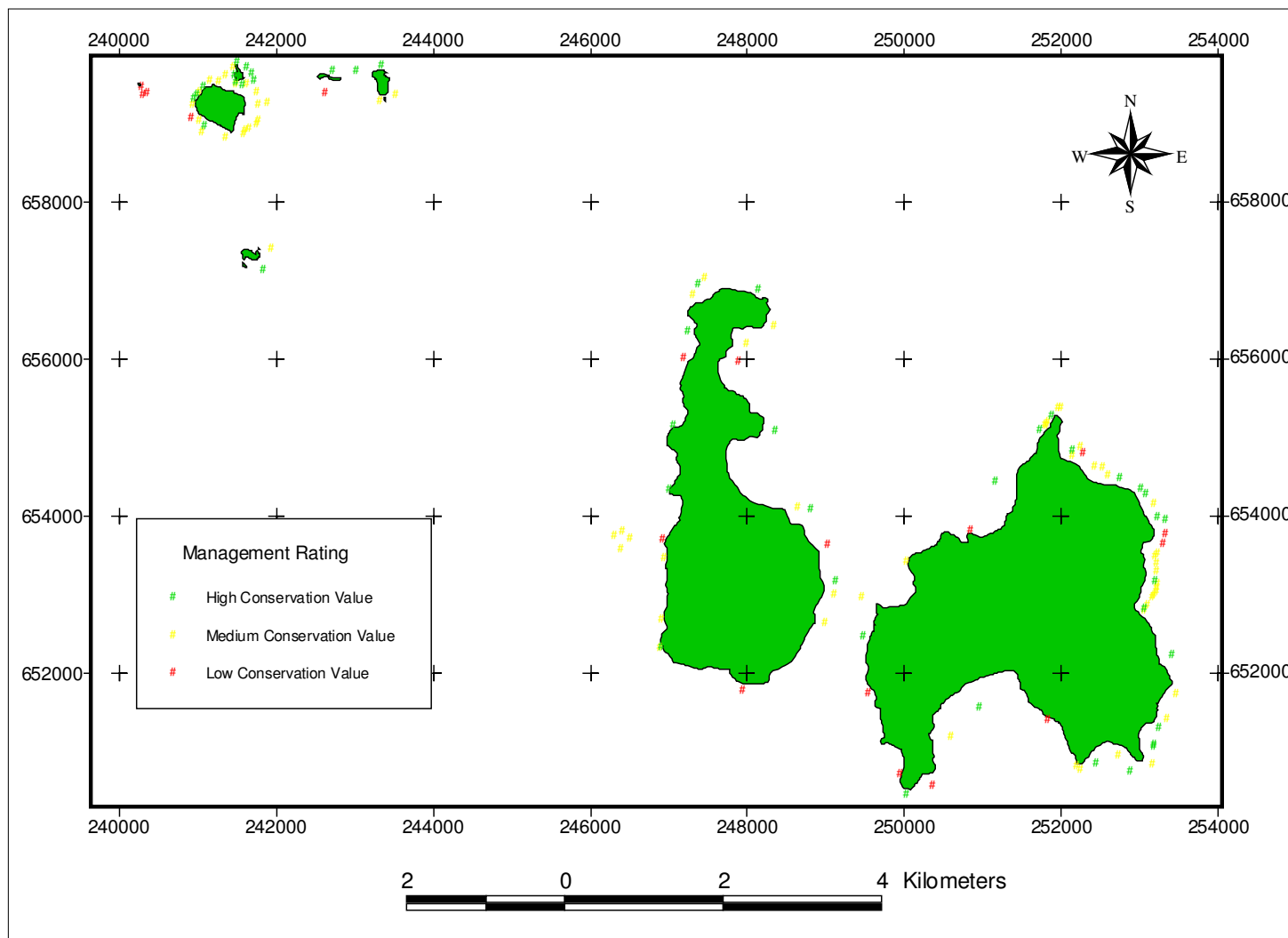


Figure 3.39. Calculated Management values for each survey transect completed during the Pilot Phase of the MRICP

Prepared by Coral Cay Conservation

The map of management value sites indicates that the distribution of coral reef habitats of varying health around the Perhentians is very heterogeneous with each type of conservation value being present across the whole island group. To enable better interpretation of geographic patterns of reef health, Figure 3.40 shows the proportion of transects within each survey sector that are graded as of high, medium and low conservation value out of the total number of transects graded using this system

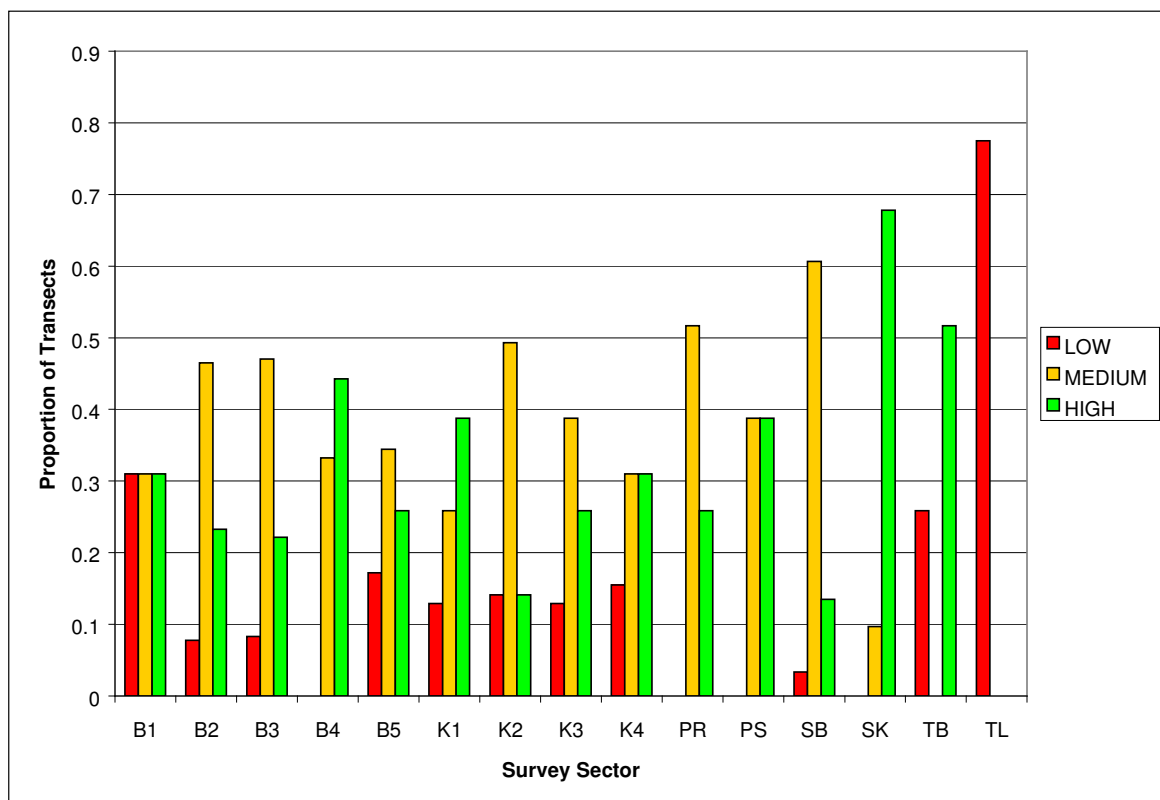


Figure 3.40. Proportion of transects rated as of high, medium and low conservation value in each survey sector as a proportion of all transects rated using this system. . See Figure 3.1 for Survey Sector locations. Sample size; B1=5, B2=10, B3=28, B4=7, B5=9, K1=6, K2=11, K3=6, K4=5, PR=3, PS=2, SB=23, SK=8, TB=3 and TL=3.

To normalise the relative concentration of survey transects rated as of high, medium and low conservation value in each survey sector for the survey effort undertaken in each locality, the number of occurrences of each grading in each survey sector was divided by the total number of transects and then multiplied by the number of transects undertaken in that survey sector. The resulting values are without units, but represent the proportion of transects assigned to each conservation class in each survey sector.

Three survey sectors have the highest proportion of transects rated as of high conservation value; B4 on the east coast of Perhentian Besar and the survey areas around the outlying Islands in the archipelago; Pulau Sereggeh, Susu Dara Kecil and

Tokong Burung. Sectors around Susu Dara Besar, Pulau Rawa, sector K2 and B3 also contain a large proportion of transects rated as of medium conservation value (0.61, 0.51, 0.49 and 0.47 respectively).

By contrast, Tokong Laut was found to have only transects that have been rated of low conservation value, with a proportion of 0.78 rated as of low value and found in the Tokong Laut survey area.

From these results, the most important survey areas in terms of the conservation values of the reef that they contain would be, in descending area, SK, B4, PS, TB, B3, SB and K2.

3.10 Reef Check

3.10.1 Reef Check Survey Progress

Between the 18th of June and the 12th of July 2003, the Malaysian Coral Reef Conservation Project (MCRCP) completed 12 Pilot Phase Reef Check survey dives.

The locations of the Reef Check transects carried out are shown in Figure 3.1 and Table 3.9.

Site code	Site name / General location	Depth (m)
PPK 1	Pulau Perhentian Kecil- Teluk Kurma (D'Lagoon)	10
PPK 2	Pulau Perhentian Kecil- Teluk Kurma (D'Lagoon)	6
PS 1	Pulau Serenggeh	7.6
PS 2	Pulau Serenggeh	6
TB 1	Pulau Perhentian Besar- Tanjung Basi	11
TB 2	Pulau Perhentian Besar- Tanjung Basi	3

Table 3.9. Locations and depth contours of Reef Check transects carried out during the Pilot Phase of the MRICP.

3.10.2 Quantitative assessment of reef health

Benthic cover

A summary of the parameters recorded along each transect line during the Reef Check surveys in the Pilot Phase of the MRICP are shown in Tables 3.10 – 3.11. Figures 3.41 and 3.42 show a comparison of the mean benthic cover recorded between shallow and medium depths.

The highest coral cover was recorded at shallow sites (means for all sites of 65.67 % and 36.01 % total hard coral cover at shallow/medium depths respectively). At shallow depths, the TB site had the highest hard coral cover and PPK the lowest (88.1% and 54.4% respectively). At medium depths PS had the highest hard coral cover (50.63%) with PPK and TB indicating a similar abundance (approximately 35%). However, the standard deviations of coral abundance at each site shows

considerable overlap, indicating that there may be less overall difference between sites.

Shallow sites had a greater mean percent cover of both non-*Acropora* and *Acropora* (Figure 6). Shallow *Acropora* was greatest at TB and lowest at PPK (62.3% and 11.88% respectively). Shallow non-*Acropora* was greatest at PPK and lowest at TB (42.5% and 25.62% respectively). Although medium non-*Acropora* was fairly consistent between sites, overall abundance was low (approximately 30%). *Acropora* at medium depths had the lowest abundance, particularly at PPK site (3.75%).

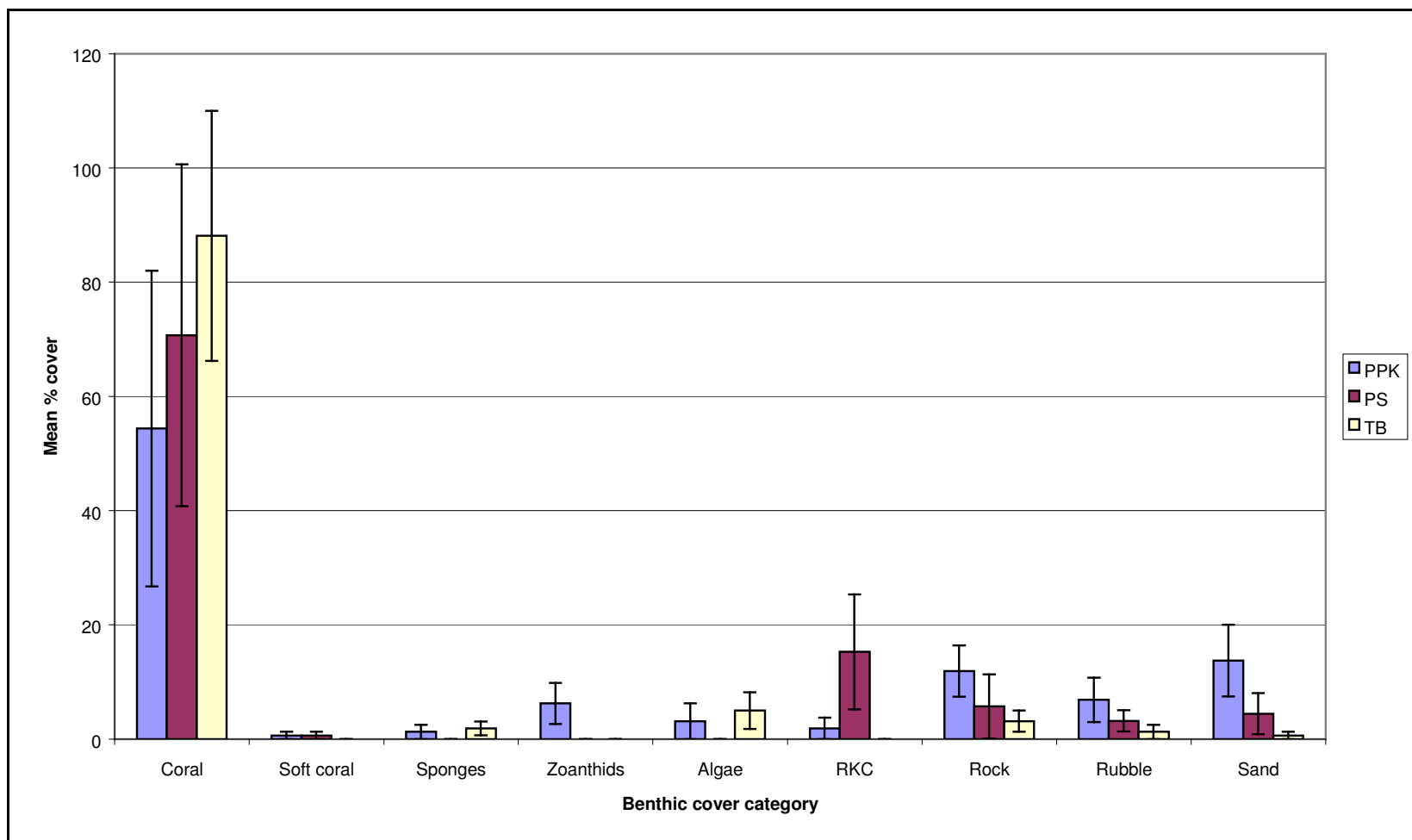


Figure 3.41. Mean percent cover of different benthic classes recorded at shallow survey stations during the Pilot Phase of the MCRP. PPK- P. Perhentian Kecil, PS- P. Serenggeh, TB- Tanjung Basi (P. Perhentian Besar). Error bars indicated SD around the calculated mean values.

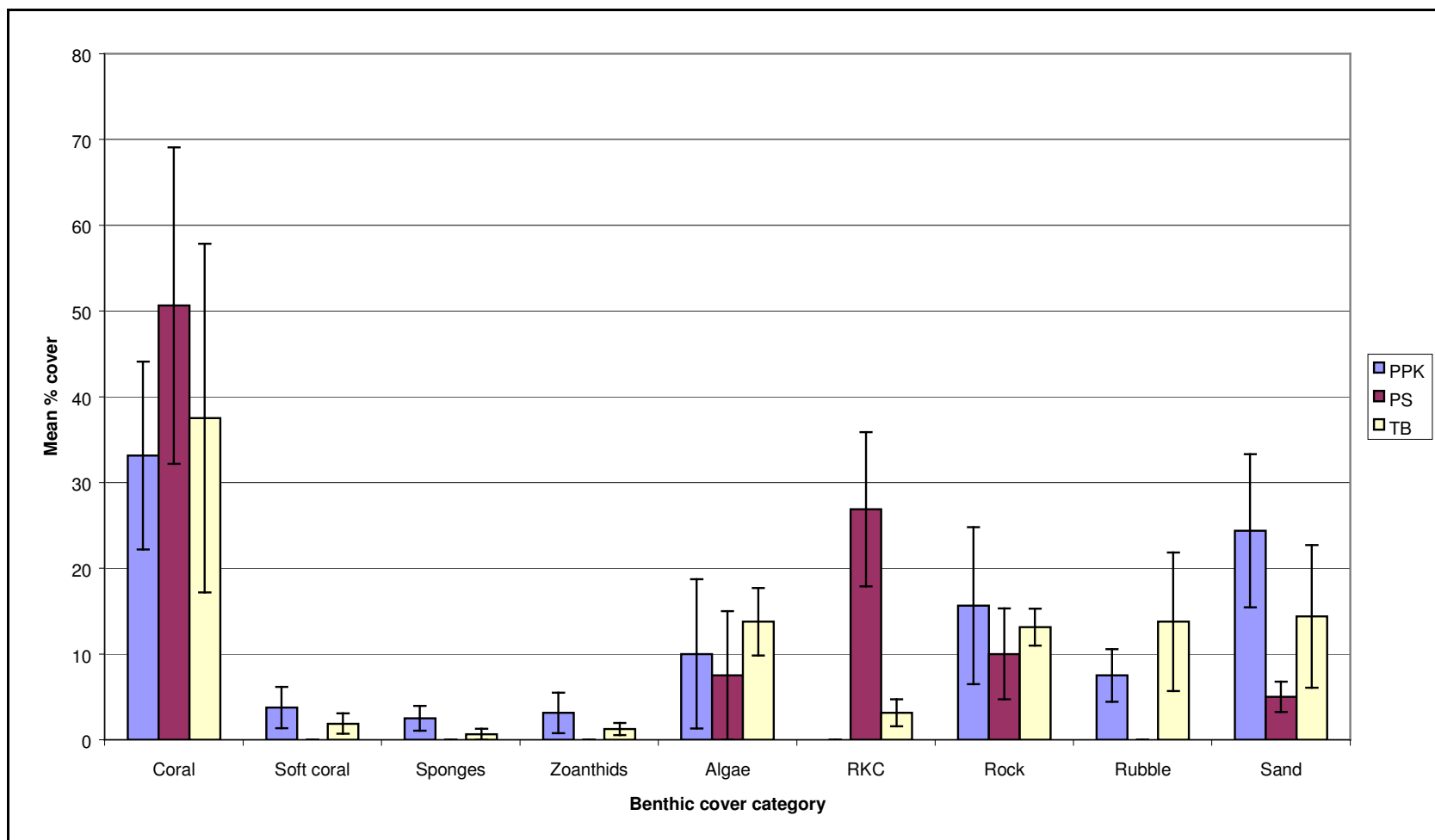


Figure 3.42. Mean percent cover of different benthic classes recorded at medium depth survey stations during the Pilot Phase of the MRICP. PPK- P. Perhentian Kecil, PS- P. Serenggeh, TB- Tanjung Basi (P. Perhentian Besar). Error bars indicated SD around the calculated mean values

a) Shallow

Indicator Group	PPK		PS		TB		All sites combined
	Mn.	S.D.	Mn.	S.D.	Mn.	S.D.	Mn.
<i>Acropora</i> branching	8.75	11.09	16.25	4.79	21.88	9.66	62.76
<i>Acropora</i> digitate	0.63	1.25	0	0	0.63	1.25	2.5
<i>Acropora</i> tabulate	2.5	2.04	21.88	20.85	40	10.8	87.27
<i>Non-Acropora</i> branching	3.75	1.44	11.25	9.47	1.25	2.5	27.16
<i>Non-Acropora</i> encrusting	11.25	9.68	2.5	5	4.38	5.16	32.81
<i>Non-Acropora</i> foliose	4.38	4.27	7.5	4.57	16.25	10.1	36.96
<i>Non-Acropora</i> massive	11.88	8.99	5	4.09	3.75	4.33	33.70
<i>Non-Acropora</i> submassive	11.25	16.52	1.25	2.5	0	0	31.52
<i>Non-Acropora</i> mushroom	0	0	3.13	6.25	0	0	9.38
<i>Millepora</i>	0	0	0.63	1.25	0	0	1.88

b) Medium

Indicator Group	PPK		PS		TB		All sites combined
	Mn.	S.D.	Mn.	S.D.	Mn.	S.D.	Mn.
<i>Acropora</i> branching	2.5	2.89	11.88	6.58	11.25	13.62	35.09
<i>Acropora</i> digitate	1.25	2.5	0.63	1.25	0	0	5.63
<i>Acropora</i> tabulate	0	0	3.75	4.79	0.63	1.25	9.16
<i>Non-Acropora</i> branching	1.25	1.44	11.25	7.77	1.25	2.5	22.97
<i>Non-Acropora</i> encrusting	2.5	2.89	2.5	2.04	5.63	1.25	15.55
<i>Non-Acropora</i> foliose	5	2.04	4.38	3.75	1.88	2.39	17.04
<i>Non-Acropora</i> massive	17.5	5.40	1.25	1.44	11.88	12.81	37.47
<i>Non-Acropora</i> submassive	3.13	4.73	1.88	3.75	3.75	4.33	17.23
<i>Non-Acropora</i> mushroom	0	0	13.13	5.55	0.63	1.25	19.30
<i>Millepora</i>	0	0	0	0	0.63	1.25	0.63

Table 3.10. Summary of percentage cover of hard corals per 20 m section at two depth bands on Reef Check line transects at three survey sites. Note: No *Acropora* encrusting, *Acropora* submassive, *Heliopora* or *Tubipora* was recorded, and has been omitted for clarity.

There was no clear difference in the values of benthic substratum types between sites (Figure 3.41-42). However, PPK generally had the lowest hard coral cover, except for *non-Acropora* massive (approximate mean at both PPK depths of 14.5%), which was greatest at this site. *Acropora* branching was consistently high between the sites at each depth. *Acropora* tabulate dominated at shallow PS, and particularly TB sites (21.88% and 40% respectively, although standard deviations overlapped considerably). *Non-Acropora* mushroom was present mainly at PS, and was fairly abundant at the deeper site (13.13%). There were no recordings of either *Acropora*

encrusting, *Acropora* submassive and very few *Acropora* digitate at all sites and depths.

The mean percent cover of other benthic substratum types was considerably lower than hard corals, covering only a few percent similar and to soft coral cover (Figure 4). There was a clear increase in recently killed corals (RKC) at PS sites at both depths (shallow/medium, 15% and 26.88% respectively).

Algal cover was generally low at all sites, although there was greater algal cover at medium compared with shallow depths (approximately 10.4% and 2.7% respectively). Rock, sand and rubble cover was slightly greater at medium depths compared to shallow depths at all sites. Sponges, soft corals and zooanthids were rarely seen on the transect lines (all had mean coverage of approximately 1 %). No silt was recorded at all.

Reef Fish Targets

Fish abundance was dominated by two main taxa at each depth (Table 3.11). Fusiliers (Caesionidae) were abundant at both shallow and medium depths, particularly at the PS site (41.75% and 38.5% per 500m³ respectively), and at TB site (7.5% and 15% respectively). However, this species was not recorded at any PPK site

Barracuda was most abundant at the PPK shallow site (31.8% per 500m³) and rabbitfish at medium depth (31.3% per 500m³). However, Barracuda was nearly absent at medium depths, whilst rabbitfish were similarly absent at shallow depths. Butterflyfish (Chaetodontidae) were equally present at all sites and depths, although in lower abundance (approximately 7% per 500m³). Most other indicator groups were recorded at all sites and depths in very low abundance (<2% per 500m³). Sweetlips were only recorded at TB sites at both depths, although in abundance <1% per 500m³.

No Tuna, Mackerel or Moray Eels were seen on any of the surveys. There was no significant variation in fish abundance between depths (Mann-Whitney Rank Sum Test: T = 68.0, n = 8, p>0.05), or between sites ($\chi^2 = 0.211_{(2)}$, p>0.05).

a) Shallow

Indicator Group	Survey Site						All Sites combined
	PPK		PS		TB		
	Mn.	S.D.	Mn	S.D.	Mn	S.D.	Mn
Butterflyfish (<i>Chaetodontidae</i>)	7.75	6.8	3.25	1.26	11.3	4.99	6.06
Sweetlips (<i>Haemulidae</i>)	0	0	0	0	1	2	0.2
Snapper (<i>Lutjanidae</i>)	3.25	5.25	1.5	1.91	1.25	0.96	2.63
Groupers >30cm TL (<i>Serranidae</i>)	1	1.46	1.75	0.5	1	0.5	1.14
Fusiliers (<i>Caesionidae</i>)	0	0	41.75	59.5	7.5	15	21.8
Surgeonfish (<i>Acanthuridae</i>)	0	0	0	0	0.75	0.96	0.15
Rabbitfish (<i>Siganidae</i>)	4.75	5.12	0	0	1.25	1.89	2.23
Other Parrotfish >20cm TL (<i>Scaridae</i>)	1.75	2.36	1.75	0.96	5.5	5.2	2.46
Barracuda (<i>Sphyraenidae</i>)	31.8	39.1	0	0	0	0	14.2
Jacks / Trevally (<i>Carangidae</i>)	0	0	1.75	2.87	1	1.41	1.12

b) Medium

Indicator Group	Survey Site						All Sites combined
	PPK		PS		TB		
	Mn.	S.D.	Mn.	S.D.	Mn.	S.D.	Mn.
Butterflyfish (<i>Chaetodontidae</i>)	3.5	2.65	10.8	0.96	2.25	2.06	4.03
Sweetlips (<i>Haemulidae</i>)	0	0	0	0	0.25	0.5	0.05
Snapper (<i>Lutjanidae</i>)	4.25	2.63	1.25	1.41	2.25	2.5	2.36
Groupers >30cm TL (<i>Serranidae</i>)	1.25	1.54	6.75	2.63	0.5	1	2.53
Other Parrotfish >20cm TL (<i>Scaridae</i>)	7.25	4.5	1.5	2.38	1.5	1.91	3.43
Fusiliers (<i>Caesionidae</i>)	0	0	38.5	40.2	15	23.6	18.7
Surgeonfish (<i>Acanthuridae</i>)	0	0	0	0	0	0	0
Rabbitfish (<i>Siganidae</i>)	31.3	26.6	4.25	5.06	0	0	13.4
Barracuda (<i>Sphyraenidae</i>)	0	0	0.25	0.5	0	0	0.15
Jacks / Trevally (<i>Carangidae</i>)	0.75	0.96	5.25	3.77	0.25	0.5	2.19

Table 3.11. Summary of abundance of each fish taxa per 500 m³ section of the a) Shallow b) Medium Depth Reef Check belt transect at each site (See Table 3.9 for the location of each site). Note: No Tuna / Mackerel or Moray were recorded, and have been omitted for clarity.

Target Invertebrates

Most of the invertebrate taxa targeted by the Reef Check surveys were only seen in shallow depth sites (Table 3.12). However, the number of *Diadema* urchins was abundant at the PS medium site (mean of 49.75% per 500m³), although nearly absent from other sites at this depth. Commercially important sea cucumbers were recorded at all medium sites in low abundance (<10% per 500m³), and giant clams in very low

abundance (<2.5% per 500m³). Crown of thorn starfish, which can cause considerable damage to the hard corals, was recorded at the medium PS and TB in abundance <1% per 500m³, and was absent at PPK.

At shallow sites, PPK had the greatest abundance of invertebrates, dominated by the giant clam and sea cucumber (29.25% and 12.75% respectively per 500m³). The PS site had equal abundance (approximately 4% per 500m³) of sea cucumber, giant clam and *Drupella* sp. TB site had few target invertebrate taxa, although giant clams (*Tridacna* spp.) and sea cucumbers (*Holothuria*) were recorded in very low abundance (4% and 1% respectively per 500m³). *Diadema* urchins were present at PS and TB shallow sites in very low abundance <1% per 500m³. All other invertebrate taxa were absent from each site and depth. No Crown-of-Thorns sea stars (*Acanthaster planci*) were recorded in shallow sites, or Triton trumpet shells (*Charonia tritonis*), a natural predator of the corallivorous COT.

a) Shallow

Indicator Group	Survey Site						All Sites combined Mn.
	PPK		PS		TB		
	Mn.	S.D.	Mn.	S.D.	Mn.	S.D.	
<i>Diadema</i> urchins	0	0	1	1.41	0.5	0.58	0.58
Sea cucumber (edible only)	12.8	6.65	4.75	5.19	1	1.15	6.07
Crown-of-thorns star (<i>Acanthaster planci</i>)	0	0	0	0	0	0	0
Giant clam (<i>Tridacna</i>)	29.3	5.32	5	4.08	4	3.65	9.53
<i>Drupella</i> sp	0	0	3.5	2.38	0	0	1.18

b) Medium

Indicator Group	Survey Site						All Sites combined Mn.
	PPK		PS		TB		
	Mn.	S.D.	Mn.	S.D.	Mn.	S.D.	
<i>Diadema</i> urchins	0	0	49.8	47.4	1	1.15	19.6
Sea cucumber (edible only)	11	5.35	3.75	1.26	3	3.83	4.87
Crown-of-thorns star (<i>Acanthaster planci</i>)	0	0	0.25	0.5	0.5	1	0.25
Giant clam (<i>Tridacna</i>)	2.75	1.7	0.75	0.96	0.25	0.5	1.28
<i>Drupella</i> sp	0	0	0	0	0	0	0

Table 3.12. Summary of abundance of each Invertebrate taxa per 100 m² section of the a) Shallow b) Medium Depth Reef Check belt transect at each site (See Table 3.9 for the location of each site). Note: No banded coral shrimp, triton, squid, lobster, or octopus were recorded and have been omitted for clarity.

4 DISCUSSION

4.1 Training

The training programme used during the MRICP Pilot-Phase has proved to be appropriate for volunteer survey work in Malaysia. For example, the results in the tests and in water validation exercise were excellent and, therefore, the data collected during survey work are likely to be accurate and consistent. The training schedule has been deemed appropriate for novice divers as well as relatively experienced divers.

4.2 Oceanography and Anthropogenic Impact

Wind speed and direction data recorded during the Pilot Phase of the MRICP indicates a clear pattern between the occurrence and strength. Winds blowing offshore from the mainland were rarely observed and lower in their mean strength than winds on the more exposed east side of island group. This is largely due to the meteorological conditions that prevail in the P. Perhentian region, with a short fetch from mainland to the islands and a much larger fetch over which air movement can gain energy coming across the South China Sea to the east. This facet of the prevalent environmental conditions is important in determining the distribution, zonation and morphological features of the shallow water resources of the area.

The observations of water temperature indicate the clear presence of a well-developed and often prevalent thermocline in the Perhentians. The occurrence of these thermoclines is due to a number of contributory environmental conditions. Perhaps most importantly, the water column must remain stable for a period of time allowing the water to become stratified. In addition, the observation of cold, fresh water leaching through the substratum below the carbonate reef areas indicates a direct link between the water table on the land mass and that which enters the nearshore marine environment. This has important implications in terms of the integrated management of the Perhentian Islands in terms of the activities that are occurring on land and how these affect the health of the coral reef areas. These implications are discussed in more detail in the following management sections.

The apparent patterns in observed under water visibility measured both vertically and horizontally through the water column indicate the spatial variation in the quantity of suspended sediments present in the water column. Around the main islands of Perhentian Besar and Kecil, there appears to be a link between the presence of development activities and the increase in turbidity in the water column. This is particularly apparent within the confined and sheltered water mass around Teluk Dalam and also in the areas on Perhentian Kecil around the village development. Whilst both are likely caused by development pressure, the agents of change are likely to be different. Development on the inclines towards the rear of the village has led to visible signs of land erosion. Following periods of heavy rainfall, surface runoff is clearly visible entering the sea in front of the village and is laden with a large quantity of terrestrial sediment. Around Teluk Dalam, there is no such obvious routing for the sediment present in the water column. The extensive carbonaceous reef flat in this area is largely devoid of live benthic cover. In addition, the presence of deep channels allowing boat passage to the resort development will enhance tidal flushing around

these areas. This flushing, in addition to the exposure of soft and mobile sediments by the dredging of the channels, has likely led to the mobilization of sediments that were previously deposited on the reefal platform. This may account for the reduced under water visibility observed within the bay system at Teluk Dalam.

The coral reefs around the Perhentian Islands are subject to a wide and varied degree of anthropogenic impacts. Individual impacts are discussed in the following section and then placed in a geographic context linked to individual sites of impacts in Figure 4.1 and Section 4.7.

The graphs of subsurface impacts indicate that signs of sedimentation have been recorded in survey sectors B1, B5, K3, PS, SB and TL. Interpreting this data with the recordings of underwater visibility these sectors appear to have the lowest visibility observations. This data indicates that the reduced underwater visibility caused by increased suspended solids in the water column is impacting on the coral reef communities of these areas. The impact of sedimentation is a complex one and is often hard to distinguish in all but extreme cases. Recordings of sedimentation impacts made by CCC divers are based on the evidence of sediment lying on the surface of colonies of hard, reef building corals. When this occurs, coral communities undergo a range of changes. One mechanism that corals have to deal with increased sedimentation is to secrete a layer of mucous over their polyps that catches the sediment and is then subsequently sloughed off, removing the settled sediment. This has two effects; firstly, the production of this mucous is itself directly energetically expensive. Secondly, whilst encased in the mucous cocoon, the quantity of energy polyps can derive is reduced through the reduced ability of food capture as well as the reduced level of incoming solar irradiance utilised for energy synthesis by the symbiotic photosynthetic algae that the polyps contain. Thus in areas of high sediment load, coral colonies have a reduced energy quota available for growth and reproduction and consequently the health of the whole reef system suffers. In extreme cases, necrosis or death of the living polyp tissue can be observed when the energetic expenditure of dealing with sediment settlement exceeds that that can be derived by the polyp.

Much of the boat traffic that has been observed in the Perhentians is based around the centres of development; namely around the village on Perhentian Kecil and around the resort centres of Teluk Dalam and Teluk Aur. The majority of these boats have been classed as being engaged in commercial activities supplying the resorts themselves with the resources they need to operate. The occurrence of fishing boats in the more remote areas of the Marine Parks around Susu Dara Besar and Tokong Laut indicates the need for an increase in the quantity and perhaps more importantly, the geographic range over which Fisheries enforcement patrols occur. In addition, whilst many of the fishing activities observed were subsistence and not commercial in nature, there needs to be a clarification and consequential enforcement effort so that fishing per se is effectively outlawed.

The main impact observed on the water surface throughout all survey sectors was litter. The occurrence of observations of floating litter was not closely linked to the occurrence of development centres as might be expected. It is likely that this is more a reflection on the current directions and velocity in the area that are carrying litter from

its original origin to where it was observed. Indeed, both these areas are likely to be characterized by eddy and gyre formation, which would act to trap floating litter as well as jetsam and flotsam. This concept of currents acting to concentrate floating material in these areas is further indicated by the presence of driftwood, floating macroalgal mats and sewage material in these areas. The overall impression of the areas surrounding both inhabited islands is that there is a large quantity of floating debris some of which is natural in origin, though much is of anthropogenic origin.

Underwater the occurrence of discarded fishing gears was found to be concentrated around the sector to the southwest corner of Perhentian Besar. Many of these nets, presumably discarded by fishing vessels that aggregate in this area, were still acting to catch fish; the so-called phenomenon of ‘ghost fishing’. Whilst many of the fish traps observed were no longer in service, some appeared to be in good condition and contained fish of the Wrasse and Snapper families.

4.3 Benthic Data

A total of thirteen benthic habitats have been defined from the Baseline data collected during the Pilot Phase of the MRICP. These thirteen statistically discrete habitats are likely to be a fair representation of all of the habitats that can be found around the Perhentian Islands based on the geographic spread and quantity of data collected. Indeed, habitats are found based on the prevalent environmental regime in an area and the survey strategy has been designed to examine the full range of environmental conditions from the exposed coastline on east Perhentian Besar to the depositional environments in places like Teluk Dalam.

The range of habitats include those that are dominated by substrate that is unsuitable for the settlement and subsequent growth of benthic cover, such as sand and rubble through to those areas that support a high cover of benthic organisms. Amongst the reefal classes, two major distinctions can be made, those areas of reef that are developed on terrigenous granitic material and those developed on carbonaceous platforms. As a general trend, the habitats found on granitic bedrock are found at more exposed sites and in shallower areas whilst those coral reef communities established on calcium carbonate platforms tend to be in more sheltered sites or occur below the granitic reefs at more exposed sites.

The geomorphology and reef form of the reefs around P. Perhentian is relatively simple with narrow, shallow fringing reef the dominant reef type around all of the islands and seamount type reefs around both Terumbu Tiga and Tokong Laut. This formation is primarily due to the shallow continental shelf on which the Perhentians are situated and their close proximity to the mainland. However, having found thirteen benthic classes or discrete habitat types around the Perhentians indicates that there is a high level of habitat diversity and the maps of management importance indicate that this diversity of habitats is extremely patchy and heterogeneous in its distribution. Situated not far from the most biodiverse region of coral reefs; the Wallacea Bioregion or ‘coral triangle’, the reefs around the Perhentians may support up to 80% of the biodiversity found in this region. This indicates that the islands themselves are an important biodiversity resource for the surrounding ecoregion and for Malaysia

4.4 Fish Data

The total number of species of fish positively identified during this study was considerably lower than that identified by Harborne *et al.* 2000. (298 against 127 in this study). There are two possible explanations for this; the first is that the 2000 study examined a much larger geographic area that contained a wider variation of habitats. In this study a clear link has been shown that fish assemblages in the Perhentians are statistically linked to the habitat in which they are found. With a greater variation of habitats, it would therefore be expected to observe a greater number of species. The second possible reason for this disparity is that during the 2000 study there was greater taxonomic expertise in the field team and dives were specifically conducted to assess the diversity of the fish populations present. In this study however, no dives were conducted specifically for this purpose. The observations made in this instance have been during the normal Baseline and Reef Check surveys when more cryptic species of fish are not apparent. In addition, only positively identified fish species have been included in this list. In many instances, sightings of new species could not be accredited and therefore to avoid doubt, the species has not been recorded as a new sighting.

Although it appears that fish populations in the Perhentian Islands are fairly low in their abundance, there is a good representation of all of the major families. Particularly abundant were the Rabbitfish (Siganidae) whilst Surgeonfish (Acanthuridae) were sighted infrequently. The presence of Groupers (Serranidae) across most areas and in particular in abundance around Tokong Laut and Pulau Serenggeh survey areas indicates that fishing pressure on these species is low despite the sighting of fishing activities occurring in these areas. In addition, mature Bumphead Parrotfish (*Bolbometopon muricatum*) were a common sighting on survey dives and individuals were seemingly undeterred from grazing on corals by the presence of dive teams. This is quite in contrast to areas where spear fishing is common and large, commercially viable fish are very alert to presence of humans in the water.

The clear and definite relationship between fish assemblages and the habitat type in which they were found strengthens the need to protect areas that have been defined as a benthic class that supports high diversity and abundant fish populations. The conservation value procedure instigated for this project accordingly takes into account both the number of fish species found and the diversity of the fish assemblages found associated with the habitats on each transect when rating the transect area as a conservation class.

4.5 Invertebrate Data

Invertebrate populations throughout the Perhentian Islands have been shown to be heterogeneous in their geographical distribution. This occurs because of two reasons; firstly that invertebrate populations are closely linked with the habitat types of an area, which in turn have their distribution, controlled by prevalent environmental conditions. In addition, amongst many of the less frequently observed and mobile invertebrates there is clear pattern in the data that indicates that populations are both

temporally and spatially distributed, Particular reference is made to the seemingly large Cephalopod population at Pulau Rawa which has come about because of one survey dive where between six and twenty individual reef squid were observed.

The feeding mechanisms of invertebrates are extremely widely varied and include herbivores, omnivores and carnivores as well as filter, suspension and sediment feeder. This has an affect on where populations of different groups of invertebrates were observed. Urchin populations for example appear to be inversely linked to abundance of hard corals, and in areas such as Tokong Laut where bare bedrock dominates, their population is abundant. This is as a result of their herbivorous nature and the dense cover of filamentous macroalgae that was found covering bare bedrock. By contrast the Holothurians main means of nutrition s through the extraction of organic matter covering the surface of sand particles. Consequently, Holothurians were most commonly observed in area, such as on the sheltered west side of Perhentian Besar where sand formed the dominant substrate.

Holothurians support a commercially viable fishery in Malaysia where the main target species is *Stichopous horrens* that is used in the manufacture of gamat oil. However, Holothurians were the most commonly observed invertebrate taxa in this study. This indicates that the fishing and extraction pressure on these species is, at present, low in the Marine Park of the Perhentians. In addition, the large numbers of *Tridacna spp.* clams, which are also commercially viable species, indicates that the invertebrate population is well protected and/or unexploited in the Perhentians.

Crown of Thorns starfish (*Acanathaster planci*) populations were found to be low throughout all areas surveyed, with the maximum average observed population of less than 0.1 per ten meter section of transect or 50meters squared. Crown of Thorn population outbreaks can be severely damaging to hard coral cover on the reef where the invertebrate is a voracious corallivores. Outbreaks are not uncommon in the Marine Park Islands of the East coast of Peninsular Malaysia where outbreaks were recorded in Pulau Lima and Pulau Ekor Tebu during the late 1970s (Rahman and Ibrahim, 1996). Indeed, during this same period, the Perhentians also suffered a population outbreak. The Marine Parks Section considers normal population densities of COTs to be 6 per square kilometre of reef (Rahman and Ibrahim, 1996). However, the observed densities in this study equate to only two individuals per square kilometre of reef, well below the threshold indicating the presence of any outbreak threat and encouraging for the population control measures employed by the Marine Parks.

4.6 Reef Check Data

Live Scleractinian coral cover is often used as a gross surrogate of reef health and the data presented here indicate that the selected sites are at least in 'fair' condition, using the criteria of the ASEAN-Australia Living Coastal Resources project (>75% = excellent, 75-50% = good, 50-25% = fair and <25% = poor; Chou et al., 1994). Of the three Reef Check sites examined in this programme, two, Teluk Kurma and Tanjung Basi, can therefore be classified as being of 'good' health using this system of grading and one, Pulau Serenggeh, can be classified as 'excellent' in health.

Hard corals were found to cover much of the available hard substratum at all of the sites. The reduced hard coral cover occurring at the medium depth contours was replaced by substrata such as sand and unconsolidated rubble that are unsuitable for the settlement, attachment and subsequent growth of planulae larvae into new coral colonies.

The coral colonies at Tanjung Basi and Pulau Serenggeh were composed predominately of species of *Acropora* that is considered to be the dominant genera of shallow coral reef communities in the Indo-Pacific region. By contrast massive growth forms of the genus *Porites* and Non-Acropora encrusting lifeforms dominated the reef at Teluk Kurma at medium depth. This indicates that the reef system in this area is exposed to a different environmental regime than that at the other two sites.

The presence of an increased amount of recently killed coral at both the shallow and medium depth contours at Pulau Serenggeh suggests the occurrence of some type of impact. Under the definition categories used with for substrata in the Reef Check methodology, recently killed coral is classified as standing dead coral where the corallite definition is still visible. This dates the damage in this area to within the near past. Exactly what vector is causing this damage is unknown, though data on anthropogenic impacts in this area indicates the presence of signs of sedimentation damage accompanied by bleaching on the coral colonies. The widespread bleaching event of 1998 may also be responsible for some of the intact dead coral skeletons present.

No Tuna or Mackerel were recorded during the three Reef Check surveys conducted. Whilst these species are more pelagic in habit and are less likely to be seen directly inhabiting the reef, it would be likely to make at least one sighting of these species in the twelve Reef Check survey dives done. Indeed, sightings of Tuna and Mackerel were equally rare during the large quantities of Baseline surveys conducted. Both these fish species are economically very valuable to fisheries and the absence of individuals may indicate the degree of fishing pressure that there has been in the Perhentians. A sure sign of success in fisheries enforcement activities would therefore be an increase in abundance of both these fish taxa in the future. The presence of corallivorous Butterflyfish (Chaetodontidae) can be taken as an indicator of coral reef productivity and health as the many species are dependent on hard coral as their main food source. The highest observed occurrence of Butterflyfish was accordingly recorded at Pulau Serenggeh medium depth and Tanjung Basi shallow contour, both of which had high hard coral cover.

The high population density of giant clams (*Tridacna spp.*) at Teluk Kurma is an indicator of good low suspended solids in the water column as well as low commercial fishing pressure, with the giant clams being a commercially viable and fished species. The prolific corallivorous Crown of Thorns Seastar (*Acanthaster planci*) was absent throughout all shallow survey contours and present at only low densities at the medium depth contour surveys. This is a good indicator as COTs can be a great threat to coral colony health when outbreak densities are reached. Likewise, the low abundance of another corallivores, *Drupella* at all sites is encouraging.

4.7 Management findings by region

This section describes particular regions of the Perhentian Islands in terms of the extent of anthropogenic impacts and the health and status of the coral reef environment. The locations discussed are depicted in Figure 4.1.

1. Teluk Dalam

Teluk Dalam or Flora Bay has extreme levels of development pressures acting on it. Much of the nearshore is developed with no less than four resort developments. The data presented in this study indicates that whilst the deeper slope leading onto this platform is largely healthy, with a high cover and diversity of hard coral, the reef platform and back reef areas are themselves devoid of live biotic cover. Indeed, this area is only one of two characterised as the habitat with the lowest overall diversity and live hard coral cover. Accordingly, the transect conducted onto the reef platform, whilst indicated as being of high management rating in the scheme used for the definition purposes, is under real and apparent threat.

A number of issues arise from the reef crest and back reef areas being severely denuded in addition to the observations of apparent threats in place in this area. The first is that the reef platform itself is carbonaceous in composition, despite being in area of granitic intrusive rocks. This indicates that this entire shallow reef platform is biogenic in nature and has been formed by the calcium carbonate deposition of hermatypic corals. The reef in this area was therefore once very much alive and was the site of a high rate of calcium carbonate deposition. In addition, this shallow reef crest and back reef area should be the one of the highest productivity and growth rate of hard corals.

This is obviously not the case based on the data presented in this report, where the dominant substrate found associated with the habitat found in this area being rubble reduced from the once alive calcium carbonate structure of coral colonies.

The apparent demise of this area can be associated with a number of activities all linked with development occurring there. Immediately behind this beachfront development, much of the maritime vegetation has been removed to allow these developments to extend landward. This vegetation naturally would act as an important filter to prevent sediment from terrigenous sources being carried onto the nearshore fringing reef system. In addition, such vegetation in its natural state provides a unique environment providing an ecosystem that has components of both marine and terrestrial organisms

To allow access to the resorts, a number of channels have been cut through the calcareous reef platform. As discussed, these passages act to upset the hydrology of the shallow back reef and reef crest environments, accentuating into small areas the exchange of water with the rise and fall of the tide. This has two effects. Firstly, these channels expose areas of soft sediment through the removal, of the overlying hard substrate. Water movement is concentrated into the channels themselves, leading to suspension of sediments into the water column. In addition, they act to reduce the inundation of the back reef and reef crest areas by tidal induced water exchange that is

important to the health of hard corals by bringing a supply of planktonic food as well as the exchange of water of the optimum concentration of nutrients and dissolved oxygen.

The data and observations on the prevalence of thermoclines and variable salinity water bodies around the Perhentian Islands indicates that the terrestrial water table is closely linked to the marine environment through the passage of fresh water between the two. Resort development brings the issue of wastewater removal, which in the resort developments along Teluk Dalam is stored in septic tanks. Whilst as a method of wastewater handling, septic tanks can be effective, they are prone to leaching water, rich in nutrients, into the surrounding water table. If this is occurring, then hydrostatic pressure on the water table caused by the high relief of the Perhentians will be forcing a portion of the contents of the groundwater store onto the nearshore fringing reef, carrying with it the nutrient loaded leachate from the septic tanks of the developments. On a shallow reef platform such as that at Teluk Dalam, with limited tidal flushing, this would lead to eutrophic conditions, with macroalgae becoming ecologically more competitive than hard corals and ultimately leading to the demise of the coral reef in favour of a macroalgal dominated community.

2. Tanjung Tukas Darat

This enclosed bay is similar in its hydrograph to its close neighbour Teluk Dalam. The sides of Tanjung Tukas are composed of granitic rock faces that are in turn covered in hard coral communities of moderate cover and diversity; habitats 5 and 10 from the classification used in this report. The shallow area in the middle of the bay has high hard coral cover dominated by *Acropora* species. The development of a resort in this bay brings with it the range of threats of impacts that are seen in Teluk Dalam. The beach at Tanjung Tukas is also believed to be an important turtle nesting area, with turtle tracks visible on the beach. In addition, the MRCP's sister project looking at the terrestrial flora and fauna of the Perhentian Islands made observations of the Nicobar Pigeon, a CITES red list named species in the maritime vegetation surrounding the fresh water creek to the east side of the bay at Tanjung Tukas. This vegetation that is so important as providing a unique habitat for the pigeon is now being removed for development purposes. In addition, it is likely that the disturbance caused by both the development and subsequent commercial activities that will be apparent at Tanjung Tukas will also discourage the normal nesting activities of sea turtles on the beach. In the area surrounding Tanjung Tukas, there are a number of active fish traps that have been observed both underwater and also being collected and emptied.

3. Tukas Laut and 4. Teluk Gadong

This area is characterised by high and diverse coral communities that in shallower areas are developed on the exposed granitic bedrock of the coastline and in deeper areas on the calcium carbonate substrate that has been formed by the biogenic activity of hermatypic corals. The habitats found in this area are some of the most diverse and health according to the management scheme used in this report. Consequently, of the twelve baseline surveys conducted in this area, half have been rated as being of high management importance, with the other half being of medium management

importance. In addition, this area has a very low occurrence of anthropogenic impact. It should accordingly be viewed as a key area of management importance.

5. Penang Seribu

Although only a small enclosed bay, Penang Seribu is surrounded by granitic rocks that support coral communities characterized as being of high coral cover and good overall health, with areas of 100% live hard coral cover immediately to the south of the bay.

6. Jalan Naga

The coral reef communities around Jalan Naga are similar to those seen around Tukas Laut and Teluk Gadong. High in live hard coral cover and diversity, shallow reef growth is concentrated on granitic bedrock, whilst deeper areas are developed on biogenic calcium carbonate. Surveys conducted along this region of coastline indicate that this entire region is of high management importance.

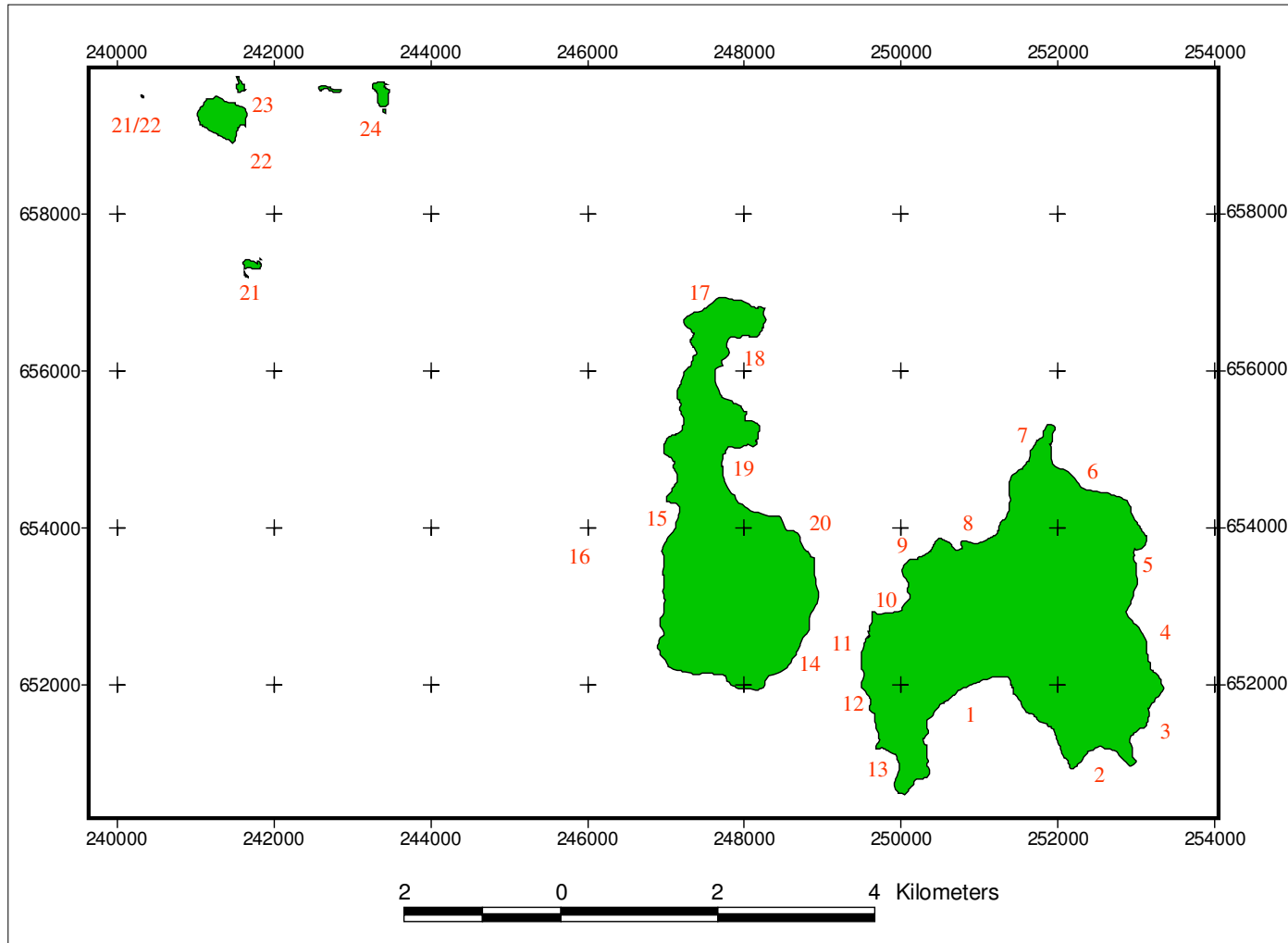


Figure 4.1. Key management areas of the Perhentians

6. Jalan Naga (continued)

The exposed eastern coastline of Perhentian Besar has been shown by the data collected to encompass some of the healthiest coral reef areas throughout the whole of the Perhentian archipelago. This health is measured both in terms of the degree of live hard coral cover, the biodiversity of the benthic communities found in the area, as well as the biodiversity of and abundance of fish and non-sessile invertebrate populations. This stretch of coastline is the most exposed of that found around the Perhentians and is likely to be in good condition because of this reason. Coral reefs, like all natural ecosystems are controlled by environmental conditions. At one end of the spectrum, harsh environmental conditions and disturbance to the community reduces overall community health and productivity, whilst a stable environment which never causes any disturbance to the natural ecosystem produces a community where a few species that are beneficially adapted to the environment out compete all others. The situation in between is known as the optimal disturbance hypothesis, where occasional environmental disturbance to the community prevents one species becoming competitively dominant over all others. The community that then exists is healthier both in terms of its productivity and its biodiversity. In the case of coral reefs, the main disturbance agent is the presence of the destructive physical forces of storm waves (Aronson and Precht 1995). Being on the exposed side, the coastline on the east side of Perhentian Besar more often receives disturbance from large storm waves, invoking the intermediate disturbance hypothesis and leading to the diverse and health coral reef communities that are found in this area.

7. Tanjung Basi

The area around Tanjung Basi has extremely high live hard coral cover in the shallows. It is however at present suffering impacts of recreational use, and perhaps more importantly, these impacts will become more severe if the number of recreational users in the Perhentians continues to rise. Over 80% of the boat traffic seen within survey sector B2 has been classified as engaged in diving activities, with the vast majority of these seen around Tanjung Basi. On a typical survey it was not uncommon for five or more dive boats to be seen at this site. There is also evidence of some consequential damage to the coral found in this area, with coral damage being recorded on 37% of all survey dives in this survey sector. The introduction of a series of mooring buoys at Tanjung Basi has undoubtedly done a lot to alleviate the threats posed to the resources of this area by mass recreational use. However, there still remains a degree of damage from physical contact between divers and snorkelers at such a site. Mitigation activities for these impacts include the introduction of limits in both the number of visitors that can use a resource. Such initiatives are discussed in more detail in the final section of this report.

8. Tiga Ruang Kecil and Besar

This area is at present afforded extra protection as an important beach for the nesting activities of sea turtles. This stretch of coastline is largely sheltered and is an area of deposition of sediments. The reef structure in the area is accordingly regulated by the presence of available hard substrate. The survey transect conducted in this area was

dominated by habitat number 2 from the classification scheme; sandy substrate supporting little biotic cover except for marine algae and seagrass that is able to attach to the soft sediment. Around the more exposed headlands at the north, centre and south of Tiga Ruang and closer into shore, where exposed hard substrate of terrestrial granitic bedrock occurs, there is a change in the benthic community to one of moderately high hard coral cover. The management potential rating scheme used in this report indicates that this area is of low management importance, with this being a reference to its health as a coral reef community. In this case however, Tiga Ruang has a high importance in terms of the turtle nesting beaches it contains. According to the observations made, the two main anthropogenic impacts in the area of Tiga Ruang are the presence of litter as a surface impact and the presence of discarded fishing nets underwater.

9. Batu Laya

The southern area of Batu Laya rock is characterized in the management rating scheme of being of moderate management value. The transect conducted here was found to be composed of habitats 6 and 10. The sand dominated habitat 6 was found below the hard substrate areas closer to shore, with the community becoming increasingly composed of biotic cover associated with habitat 10 further along the transect.

10. Teluk Paus

The bay at Teluk Paus is one of a sandy substrate brought about by the depositional nature of this sheltered environment. The rocks, Batu Apa, to the southern end of Teluk Paus have an area classified from the transect carried out there as being of very high hard coral cover in the shallow water. Overall the reef area around these prominent rock outcrops has been classified as of moderate conservation value, for whilst they have high hard coral cover, the community is not of particularly high biodiversity. This area is impacted heavily upon by snorkelers. It is used as a sheltered site to snorkel from, though the strong currents that occur here do not make this site a particularly suitable place for inexperienced snorkeler. Evidence can be seen in the shallow areas of damage to coral colonies likely through the impact of direct physical contact made by recreational users of the area.

11. Tanjung Gerting

Tanjung Gerting shares many of the management issues with Teluk Dalam. Like Teluk Dalam, much of the reef platform now has very reduced live biotic cover, with rubble being the dominant substrate. It too has dense development on the nearshore and a number of channels cut through the shallow reef crest and back reef to allow access to the developments. Other impacts caused by this development are likely to be similar or the same as those discussed for Teluk Dalam.

12. Pasir Sebrang Tengah

Pasir Sebrang Tengah has dense development however unlike both Teluk Dalam and Tanjung Gerting, it does not have an extensive and shallow reef platform. Instead, it has shallow and patchy fringing reefs. The one reef system in particular immediately in front of the Marine Park office is more extensive in nature. It is however characterized as fairly low in terms of its overall hard coral cover and diversity and is ranked as being of low management importance. It does however provide an interesting comparison with the impacts observed on the reefs around Teluk Dalam and Tanjung Gerting. Despite being as close to dense development, it is in better health. This is probably because it is more of an exposed environment with the enclosed water body seen within the reef crest and back reef areas of the heavily impacted sites. This reef area is exposed to the damaging activities of snorkelers residing at the nearby resorts and chalets on the beach. Snorkelers can often be observed making physical contact with the coral, especially at times when the tide is low and much of the reef is at less than one meter in depth. In addition to this impact coming from onshore, this area of reef has been shown to have heavy boat traffic and a high occurrence of litter, both on the surface and underwater.

13. Teluk Ke Ke

The beach at Teluk Ke Ke seems to act as a repository for floating rubbish and debris. In addition to that which is washed up on the strand line of the beach, underwater there is a large amount of debris including discarded fishing gear which is acting both to become ensnared on the reef and has also been observed to be ghost fishing where fish continue to get trapped in discarded nets long after their useful life is finished.

14. Pasir Hantung and surrounding area- 20

The beach immediately in front of the village development does not support coral reef development. The range of anthropogenic impacts that originate from here do however pose a risk to surrounding reefal communities. Out of all Survey Sectors, K3, the one encompassing the village, has the highest boat traffic. In addition, underwater it has the highest observed occurrence of litter, coral damage, discarded fishing gear as well as being having bleaching observed on 27% of all survey dives conducted in this area. The land-based development that is occurring in the village is providing a source of terrestrial, land based sediments that can be observed running into the shallow area immediately after heavy rainfall. Consequently, the underwater visibility within this Survey Sector is greatly reduced, with evidence of sedimentation impact on the nearby coral reefs being recorded on 27% of all survey dives in the area.

Despite this range of impacts, of the six transects conducted along the coastline to the north of the village development, only one is dominated by a habitat (habitat 7) that shows obvious signs of being degraded. All of the remaining five transects are dominated by habitat 12, a habitat that is above average on all univariate reef health statistics calculated in this study.

Indeed based on the management ratings scheme used in this study, two of the transects are graded as being of high management values, three as being of medium management value and only the one transect mentioned above being graded as of low management value.

This area can therefore be considered of high importance in terms of its management status, being exposed to such a suite of anthropogenic impacts, it is likely to be able to act as a barometer of reef health

15. Teluk Aur

Teluk Aur is similar in its reef structure as Teluk Dalam and Tanjung Gerting. Immediately outside of the enclosed bay area the dominant substrate is sand that supports only patch biotic cover confined to the available hard substrate. This area of the transects has been found through the analysis methods used to be characterised as being of habitat 2, a habitat dominated by bare sand. With decreasing depth the cover of sand reduces and is replaced firstly by rubble and then by bedrock that supports a moderate cover of hard coral.

Development within Teluk Aur is dense, with much of the shoreline having development activities on it. The bay itself is shallow and is therefore likely to have limited tidal flushing and water exchange, In addition, boat traffic is high with one main man-made passage through the reef at the southern end of the bay and recreational users can be observed going snorkelling on the reefal areas within the bay. Teluk Aur is therefore exposed to many of the same impacts as those found in Teluk Dalam and Tanjung Gerting; those associated with nearshore development as well as a recreational use and boat traffic.

16. Sea Bell Reef

The offshore reef platform of Sea Bell reef supports a moderately healthy community of hard coral. There is a clear difference between the deeper areas around the reefal platform and those areas that are shallower. The deeper areas around the periphery of the mount are dominated by sand and support a patchy distribution of benthic cover. Shallower in towards the top of the mount, the hard coral cover increases and become dominated by *Acropora* species. All four transects conducted with orientations towards the centre of the seamount at Sea Bell have been graded as of moderate management value.

The survey sector containing both Teluk Aur and Sea Bell reef has the highest incidence of floating litter of all sectors recorded in this study. However, underwater very few impacts were observed in this area, with litter being observed on only 5% of all survey dives conducted here. This indicates that the origin of this litter is not within this sector, but that it is instead brought to the area most probably by wind driven surface currents.

17. Batu Teluk Kerma Laut

The rocky area at Batu Teluk Kerma Laut the north end of Perhentian Kecil supports a reefal platform with high hard coral cover. Two of the four transects conducted in this area have been categorised as being of high management value with the other two being of moderate management value. The reef begins at eighteen metres and the reef slope is a diverse region in terms of the hard coral communities it supports. Though there is no defined shallow reef crest, areas of reef above six metres are dominated by hard corals of the genus *Acropora* that in places covers over 90% of the available substrate. The topography and reef structure of this area is similar in nature that found around the east coast of Perhentian Besar. Both sites share the exposed aspect and again it is likely that the hard coral community found here is due largely to this exposed nature of the site and the principle of the intermediate disturbance hypothesis.

In addition to these healthy reef areas, the Survey Sector in which this reef lies is exposed to a low amount of anthropogenic impact.

This area should therefore be seen as of key management importance in maintaining overall reef health, diversity and productivity in the Perhentians.

18. Teluk Kurma

Teluk Kurma or D'Lagoon has a well-developed reef system that is extensive in nature. It is an extremely popular dive site where 45% of the boats observed in the Survey Sector were engaged in diving activities. The reef itself begins at 12 metres and is of moderate hard coral cover and diversity. Empirical evidence from residents on the island suggests however that the reef has become degraded in recent years. The Reef Check survey conducted there had the lowest overall hard coral cover of all of the sites surveyed- 54% and 33% on the 10 and 6 metre transects respectively. Of the two Baseline transects conducted in Teluk Kurma, one was rated as being of medium and one as of low management value. Never the less, this area is an important recreational use zone and therefore effective management is necessary here to mitigate the impact of its use. Impacts that occur here come both from the use of the area as a recreational zone and also as a result of the development that is found on the beach at the northern end of Teluk Kurma.

19. Pasir Panjang

Pasir Panjang has perhaps the densest development of all sites in the Perhentians. Within the bay itself there is however little reef development. The headland to the north of Pasir Panjang, Batu Nissan rocks, supports an extensive dense and diverse coral community characterised as habitat 12 using the habitat definition scheme in this study. It has been graded as being of high management potential. Located so close to the tourism development on Pasir Panjang, the main anthropogenic impact in evidence is the occurrence of floating litter on the water surface that was observed on 17% of all survey dives conducted here.

21. Pulau Serenggeh and Tokong Laut

Pulau Serenggeh and Tokong Laut have the lowest underwater visibility recordings of all survey sites during the study at the Perhentian Archipelago. In addition, survey divers recorded evidence of sedimentation impacts on the coral communities here. Undoubtedly therefore, the incidence of high quantities of suspended solids in the water column is having a negative impact on the reef health in this area.

Around the outer islands in the Perhentian archipelago there is an obvious trend of decreasing underwater visibility towards the west; towards the mainland. The main river systems of Besut and Keluang are immediately inshore from these islands. The net current in the area is believed to be in a south-north alongshore direction. What impact the sediment flux from these rivers has on the visibility around these islands is not at present known, though the data presented in this report would appear to suggest there is a clear link between the distance from these river mouths and the degree of turbidity experienced.

The management initiatives that can be taken to prevent this impact are however complex. The initial step needs to be to assess the extend of the sediment fluxes from these rivers, to establish that they are the main source of the sediment load and to examine if any sediment flux is affecting not just the outlying islands of P. Serenggeh and Tokong Laut but have far wider effect on the main islands of Perhentian Besar and Kecil. Analysis techniques now exist that make this kind of analysis possible and if a direct link is found then mitigation measures need to be taken to prevent the introduction of suspended solids into the water courses within the river basins in question.

22. Susu Dara Besar and Tokong Laut

The most apparent impact around these two islands is the presence of fishing boats where of all the boats observed here, 59% and 50% for the two islands respectively were seen actively engaged in fishing activities. Whilst these fishing activities were primarily of a subsistence nature, occasional sightings were made of commercial fishing activities. Susu Dara Besar was found to have some coral damage which in turn was apparently caused by the activities of fishing boats ensnaring coral in their gears.

Both Susu Dara Besar and Tokong Laut are within the jurisdictional boundaries of the Perhentians Marine Park and therefore fishing activities are not permitted here. Fisheries enforcement patrols therefore need to increase in their frequency, but perhaps more importantly, the geographic range over which they operate to include these outlying islands.

23. Pulau Susu Dara Kecil and Susu Dara Besar

These two islands have been shown using the conservation classification scheme to be of high value when taken in the context of the coral reef systems around the rest of the Perhentian Islands. They should therefore be considered as of key management

importance in the conservation of biodiversity and reef health in the Perhentians. Some of the impacts that are apparent on these islands are discussed in preceding sections.

24. Pulau Rawa

The reefs around Pulau Rawa are exceptional in their hard coral cover in the shallows. However, Pulau Rawa is severely degraded. Coral bleaching was observed on 66% of dives. This occurrence is of particular concern. Bleaching in isolated occasions such as this is unlikely to be as a consequence of a widespread fluctuation of environmental conditions such as that seen during El Nino Southern Oscillation (ENSO) events. Instead the cause of this localized phenomenon is more likely to be as a result of the predatory activities of corallivores or coral disease. Indeed, within this Survey Sector, coral disease was noted on 33% of all dives conducted. Disease followed by widespread bleaching like that observed around Pulau Rawa is an indicator that the coral reef communities in this area is under extreme stress, and since these observations seem limited to Pulau Rawa only, it is a localized phenomenon with a localized cause.

Although no boats were observed around Pulau Rawa, this is more likely to be as a consequence of the limited number of times that this site was visited in the course of the survey activities. Pulau Rawa is known locally as a center of day or half-day snorkeling activities. The evidence of coral damage in 33% of the survey dives conducted around Pulau Rawa indicates that the likely cause of much of the damage occurring in this area is from the direct physical damage caused by snorkeler trampling and contact with the reef. The ultimate effect of this on isolated patches of coral communities is to reduce the overall health and ability of the colony to grow in a healthy manner. Disease outbreaks often occur in colonies that have been subjected to direct physical contact and ultimately, areas affected by disease become necrotic, leading to the high occurrence, though localized in its occurrence, of bleaching.

As a result of this damage and the degradation in reef health that Pulau Rawa has undergone, of the three survey transects conducted here, one was of high management value whilst the two conducted near to where snorkeling activities are concentrated were graded as having only medium conservation value.

Pulau Rawa should be seen as a case study in the effects that such concentrated recreational use of an area could have. Undoubtedly, the occurrence of disease and bleaching will subside and the reef system here will recover, but only if the stressing agent is removed to allow natural recovery.

4.8 Management Recommendations

Both the rate and the manner at which development is preceding the Perhentian Islands is likely to be unsustainable. The signs and symptoms of resource degradation are presented in this report and accentuate and support many of the views aired by residents of the Perhentian Islands. The matter is however a complex one and to use the quote of Lorah (1996), the use of the coastal zone in the Perhentian Islands is more marked than at many other localities where development is occurring.

“The fact that the expansion of the tourism infrastructure is likely to be confined to the narrow coastal zone makes sustainable development all the more difficult. Coastal ecosystems are already under stress, and shortsighted development goals and governmental mismanagement poses a clear threat to their sustainable use.”

Tourism's Vulnerability to Environmental Decline in Antigua, Paul Lorah (1996)

Whilst under the strictest definition of the coastal zone, the whole landmass of the Perhentian Islands is included. However the problem of development in this case is restricted and confined to the nearshore environments, the areas of land upon which it is suitable to construct. What is advocated here is not a complete cessation of development, of the closure of one industry that could provide an income to the local population, instead it is the controlled and, to use the key word, ‘sustainable’ development of the island resources.

Two main stakeholder groups operate in the Perhentian Islands, those engaged in tourism and those engaged in fishing. The impacts of fishing can be severely degrading to the marine resources of an area, as has been shown through numerous case examples in the literature. There is evidence presented in this report that fishing in the Perhentian Islands continues despite all areas surveyed being within the 2 nautical mile jurisdiction of the Marine Park. Whilst the majority of these fishing activities can be classed as subsistence in nature, commercial fishery activities were observed around the more remote areas of the Perhentians.

The biggest perceived threat to the Perhentian Islands come from the second group of stakeholders; those engaged in tourism activities. Tourism is now recognized as both the largest and fastest growing industry in the world. Of course tourism suffers glitches on its path of growth, but the trend is one of increase, with the human population having ever-greater amounts of disposable income and time. Tourism now generates 11% of global gross domestic product, employs 200 million people worldwide and engages 700 million tourists annually. These figures are predicted to double by 2020. The resources of the Perhentian Islands are a great draw to the tourist, but at the same time, unless managed carefully and in a sustainable manner, they will not provide a long-term financial and social gain to the area.

Management activities recommended for the Perhentian Islands can be divided into three key categories:

- **Education and Awareness**

Ensuring that public awareness of coral reef ecosystems is maintained can prevent the majority of the impacts that occur in the Perhentians. This can be implemented by public education and awareness programmes. Such programmes need to be aimed at all stakeholders in the area.

Recreational users of the Marine Park must become better informed. This can be done in a number of simple ways; through education workshops at the resorts and chalets that they are staying at and through interactive exhibitions such as the one already present at the Marine Park centre.

People employed directly in providing recreational services on the islands depend on the continued health of the marine resources for their livelihoods. They are a major group at which awareness and education needs to be focussed. Before such initiatives can be brought about though, there is a need to simply inform them of the threats to the reefs on which their livelihoods depend upon. In essence, it is about encouraging and nurturing a sense of stewardship and ownership so that once properly informed, as the major stakeholder group in the Perhentian Islands they will continue to ensure that everything possible is done to minimise impacts to the reefs.

- **Jurisdiction**

Many activities can be clearly classed as non-sustainable. One of the key activities and goals of the establishment of the Marine Parks jurisdiction was the control of commercial and destructive fishing activities. The legislation behind the Fisheries Act of 1985 has provided adequate powers to prevent the occurrence of such activities and the evidence collected and compiled in this report indicates fishing activities are now geographically heterogeneous and is still taking place in many of the more remote areas of the archipelago. Increased patrol activities in terms of man-power and sea hours are therefore essential to curb this activity, but perhaps more importantly, the geographic zone over which these patrols are carried out needs to be extended to cover the more remote areas of the Marine Parks jurisdiction.

What is lacking from the jurisdictional powers behind the Marine Park at present is the power to enforce Integrated Coastal Zone Management. This concept is based around the realisation that sea cannot be considered remote from land and that the activities that occur on land, such as development, are intrinsically linked to the health and long-term sustainable use of the marine resources.

More stringent control on the development activities needs to be brought about. Environmental Impact Assessment provides an important and internationally recognised method for identifying potential impacts of development and methods for mitigating these impacts. All developments above a threshold magnitude within the Coastal Zone of the Perhentian Marine Park must have a relevant EIA; one that examines the impact that the proposed development may have on the nearshore fringing reef systems of the islands as well as on the terrestrial environment. In turn, this Impact Statement needs to be considered by Marine Park management staff for its integrity and content as well as its findings. Only when recognised impacts can be mitigated against so that they would bring about an acceptable level of local environmental change should the development be allowed to proceed.

- **Mitigation**

Tourism as an industry can either act as the saviour to a natural resource by realising its potential economic value or it can be the cause of final degradation through uncontrolled and unmanaged over-development. The difference between these two contrasting outcomes is one simply of the way in which tourism develops. Developing sustainably and the best-case scenario can be brought about; developing unsustainably then tourism can cause the demise of the natural resource.

In turn, the definition between sustainable and non-sustainable is not a clear one. Instead, development can often be judged to cause changes and degradation of the natural resource either in excess of, or less than, a level that is acceptable- the concept of maximum acceptable change on which concepts such as carrying capacity are built.

Often the difference between the severity of impacts caused by the development of a tourism industry is the degree to which impacts are mitigated against in the management planning stage.

Recommended mitigation measures can be divided into those that affect infrastructure development and those that act directly to preserve the coral reef resources in the Perhentians.

Mitigation is an important part of Environmental Impact Assessment and using the jurisdiction discussed previously, the EIA stage in development planning can be used to introduce mitigation concepts into the development. This report has shown that of particular importance to the Perhentian Islands are the issues of waste water and solid waste disposal as well as the provision of adequate, but environmentally sound methods for gaining access across sometimes shallow reef areas to the resort developments.

Instigating mitigation measures at the EIA stage would enable control and minimisation of impacts caused by all new developments. However, it would not help lessen the impacts of the developments that are already in place in the Perhentians. Stakeholder education and awareness campaigns and introducing a sense of stewardship and

ownership as discussed previously could begin to deal with the problem and bring about reform. However it is often seen that some incentive is given to install mitigation measures, existing developments do not comply. Such schemes have now been put in place in Caribbean regions where resort developments are graded on their level of environmental compatibility by an independent review panel of technical experts (pers comms, Kurt Cordice, Manager, Tobago Cays Marine Park, St Vincent and Grenadines, 2002). Resorts with high ratings are afforded tax exemptions whilst those with low ratings and which therefore do not take action to mitigate environmental degradation are subject to additional taxation. These schemes provide the economic incentive to be more in tune with the surrounding natural resources. The Caribbean areas where such schemes have been introduced are showing signs towards the mitigation of impacts, though the process of natural recovery of the denuded natural ecosystems is likely to be a longer-term process. Though such a scheme may be legislatively hard to introduce in Malaysia, it could provide a long-term solution to the problem.

The initiatives outlined under public education for increasing awareness of coral reef protection issues do not however guarantee that all tourists will become informed. In addition therefore a system of environmental guides is recommended. Paid for by tourist operators in the area, each resort or recreational operator will employ its own guide who's responsibility it is to conduct workshops and to be present when recreational activities are occurring to ensure that damage to the marine resources are minimised. Such a scheme would have two benefits; the obvious benefit to the environment of reducing recreational use impact as well as providing sustainable alternative livelihoods for the local community; seemingly a win-win solution. The extra manpower provided would also free-up resources of Marine Park staff so that their role of enforcement could be carried out more efficiently. Any person employed in such a capacity would have to undergo an accredited training scheme to ensure that their understanding of the issues was sufficient to facilitate them being able to perform their job.

Finally, the resource use pressures that have been observed in place in the Perhentian Islands are both temporally and spatially distributed. Popular dive locations such as Tanjung Basi act as foci for recreational use and therefore impact, and within any given day period there are also temporal patterns of when resource use is greatest. Recreational use such as this undoubtedly has an impact and focussing the recreational use patterns inevitably creates epicentres of impact. Perhaps the most obviously seen example of this in this study has occurred around Pulau Rawa where coral damage, bleaching and disease are focussed. Whilst not conclusively attributable to the recreational use pressures of this area, it is likely from empirical evidence that the carrying capacity of this environment has been repetitively and severely exceeded leading to the degradation seen in this study. In addition to recreational use patterns having patchy spatial distributions, the habitats and health of the coral reefs of the Perhentians has been shown to be patchy in its distribution.

Both these factors together indicate that the Perhentians would benefit from a zoning scheme that would mitigate some of the anthropogenic impacts occurring here. Similar schemes have been shown to work in places with similar foci of impact such as on the Great Barrier Reef Marine Park. Broad categories of use proposed would include development zones where the level of acceptable change discussed earlier is higher than surrounding areas; recreational use zones where only recreational activities are permitted and reserve zones that are considered to be out of bounds to all uses. Reserve zones are based on the theory that the ‘good’ areas will be important in facilitating recovery of the ‘poor’ areas via production of coral and fish larvae.

The recreational use zones in turn would need to be dynamic in nature, changing their geographic locations over time to allow recovery of denuded areas. Whilst such a plan may at first be unpopular and hard to implement, it would ensure the continued sustainable use of the marine resources in line with the objectives of the Marine Park.

The data contained in this report represent the first in-depth study to examine the coral reef communities within the Marine Park of the Perhentian Islands. It should be used to facilitate localised planning activities by acting as a source of information on the spatial distribution and ecological value of discrete areas within the designated Marine Park. The data presented are in a readily accessible format for potential use in the compilation of documents such as Environmental Impact Assessments. It can also be used in future temporal comparisons as there is now a record of the condition of reef resources in the Perhentians in 2003. In addition, the management recommendations proposed are intended to provide a framework around which more general management initiatives can be constructed.

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APPENDIX I
CCC BASELINE SURVEY RECORDING FORMS

BOAT FORM

DATE: _____ **COX:** _____
STUDY: _____ **BM:** _____
TRANSECT: _____ **BUOY:** _____
SUBZONE: _____

COORDINATES

START: _____ **GPS Unit:** _____
Datum: _____

	Latitude(UTM)	Longitude(UTM)	Time	Est. error	Waypoint
1.					
2.					
3.					

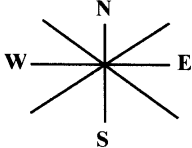
END:

	Latitude(UTM)	Longitude (UTM)	Time	Est. error	Waypoint
1.					
2.					
3.					

**CURRENT
STRENGTH**

none
weak
medium
strong

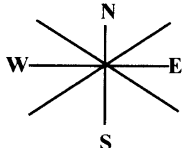
**CURRENT
DIRECTION (towards)**



**WIND
STRENGTH (1-12)**

1 5
2 6
3 7
4 8

**WIND
DIRECTION (from)**



Temperature: _____ **°C at depth of:** _____ **m** **Surface temperature:** _____ **°C** **Secchi disc:** _____ **m**
Salinity: _____ **at depth of:** _____ **m** **Surface salinity:** _____

SURFACE ACTIVITY

BOAT	No. OCCUPANTS	PROXIMITY (m)	ACTIVITY eg. diving/fishing/pleasure/commercial
1.	_____	_____	_____
2.	_____	_____	_____
3.	_____	_____	_____
4.	_____	_____	_____

SURFACE IMPACTS

LITTER

(please tick) ☐

SEWAGE

☐

DRIFTWOOD

☐

ALGAE

☐

NETS/POTS

☐

Other Impacts/Details:

OTHER COMMENTS:

<u>PHYSICAL RECORDING FORM</u>		Study. Transect No. Zone Code.																						
Date: ____/____/____		Start Time: _____ End Time: _____																						
Recorder's Name: _____	Phys. _____ Fish _____ Corals _____ Algae/Inverts. _____	Depth Limits - Min: _____m - Max: _____m Underwater visibility _____m Repeat visit? Y/N																						
<u>TYPE OF SURVEY</u>		<u>ZONE (Tick all that apply)</u>																						
Spot dive ☐ Transect ☐ General ☐ Mapping ☐ Photography ☐ Sounding ☐ Other ☐	☐ Backreef ☐ Reef crest ☐ Spur & groove ☐ <i>Low spur & groove</i> ☐ <i>High spur & groove</i> ☐ Forereef ☐ Escarpment	☐ Patch reef ☐ <i>Dense patch reef</i> ☐ <i>Diffuse patch reef</i> ☐ Lagoon floor ☐ <i>Shallow lagoon</i> ☐ <i>Deep lagoon</i>	☐ Litter ☐ Sewage ☐ Coral damage ☐ Lines / nets ☐ Fish traps ☐ Sedimentation ☐ Coral disease ☐ Bleaching ☐ Dynamite Other: _____																					
<i>Italics indicate a sub-class of a main class</i>																								
<u>YOUR IMPRESSION OF THE SITE</u>																								
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 30%;"></th> <th style="width: 35%;">AESTHETIC</th> <th style="width: 35%;">BIOLOGICAL</th> </tr> </thead> <tbody> <tr><td>Excellent</td><td></td><td></td></tr> <tr><td>Very good</td><td></td><td></td></tr> <tr><td>Good</td><td></td><td></td></tr> <tr><td>Average</td><td></td><td></td></tr> <tr><td>Poor</td><td></td><td></td></tr> <tr><td colspan="3" style="height: 50px; vertical-align: top;">Other comments:</td></tr> </tbody> </table>		AESTHETIC	BIOLOGICAL	Excellent			Very good			Good			Average			Poor			Other comments:			Navigation bearing: ____° Depth buoy tied: _____m Buoy colour/I.D.: _____		
	AESTHETIC	BIOLOGICAL																						
Excellent																								
Very good																								
Good																								
Average																								
Poor																								
Other comments:																								
SITE DESCRIPTION (Describe general location of the site, topography and main habitats - coral, sand, etc.) General Location _____ _____ Topography _____ _____ Main Habitats _____ _____																								

SITE PROFILE/PLAN DRAWING (Note depths, distances and habitats)

SIDE VIEW: Orientation: degrees

D
E
P
T
H
(m)

Distance (m) / Depth (m)

AERIAL VIEW:

W
I
D
T
H
(m)

Line of Transect

Distance (m)

<u>BIOLOGICAL RECORDING FORM</u>																																																			
Habitat No: _____ of: _____		Date: ____ / ____ / ____																																																	
		Study: Transect No: Zone Code:																																																	
		Database Code:																																																	
Percentage of dive: _____ %		Start time: _____ : _____																																																	
		End time: _____ : _____																																																	
First: Last: No. dives/snorkels in Fiji																																																			
Recorder's name	Phys	Depth limits: Min _____ m																																																	
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	Coral	Underwater visibility _____ m																																																	
	Algae	Cox _____																																																	
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<u>ECHINODERMS</u>		Tunas / Mackerels	940	☐	"Honeycomb" sp.	586	☐
Sea stars		Narrow-banded king mackerel	558	☐	Lyretail	946	☐
- Crown of thorns	472	☐	Fusiliers	571	☐	Soapfish	928
- <i>Linkia laevigata</i> (Blue)	478	☐	"Blue and yellow" sp.	929	☐	Anthias	642
- <i>Nardoa</i> sp. (Brown)	479	☐	Bluestreak	930	☐	Rabbitfish	579
- <i>Culcita novaeguineae</i>	474	☐	Damselfish	589	☐	Foxface	757
- <i>Protoreaster nodosus</i>	482	☐	<i>Chromis</i> sp.	590	☐	Virgate	630
- <i>Choriaster granulatus</i>	473	☐	Black bar chromis	646	☐	Uspi	896
- Other	471	☐	Blue devil	657	☐	Spinecheek	581
Brittle star	483	☐	Threespot dascyllus	671	☐	Twoline	582
Feather star	489	☐	Humbug dascyllus	767	☐	Pearly	659
Basket star	495	☐	Reticulated dascyllus	771	☐	Snapper	565
Sea urchin -short spine	502	☐	Whitebelly damselfish	654	☐	Two-spot	753
-long spine	503	☐	Staghorn damselfish	745	☐	Checkered	665
Sea cucumber - synaptid	515	☐	Black damselfish	759	☐	Black-and-white	569
- other	520	☐	Behn's damselfish	593	☐	Bluelined	925
TUNICATE	529	☐	Honeyhead damselfish	594	☐	Spanish flag	679
BRYOZOAN	526	☐	Alexander's damselfish	764	☐	Paddletail	564
Further species:		☐	Anemonefish sp.	591	☐	Dartfish	774
		☐	Sergeant sp.	656	☐	Blackfin	695
		☐	Wrasse	598	☐	Dottyback	900
		☐	Diana's hogfish	931	☐	Lined	686
		☐	Mesothorax hogfish	611	☐	OTHER MAJOR FAMILIES:	
		☐	Humphead	600	☐	Jack / Trevally	553
TOTAL INVERTEBRATES		☐	Red-banded	932	☐	Sweetlips	577
		☐	Checkerboard	725	☐	Barracuda	560
TARGET FISH		☐	Twotone	768	☐	Moorish Idol	551
Butterflyfish	540	☐	Crescent	647	☐	Emperor	924
(Big) Long-nosed	752	☐	Sixbar	744	☐	MISCELLANEOUS FAMILIES:	
Klein's	651	☐	Jansen's	678	☐	Spadefish / Batfish	595
Vagabond	541	☐	Cigar	685	☐	Cardinalfish	621
Pyramid	750	☐	Bird	610	☐	Squirrelfish / Soldierfish	619
Eastern triangle	783	☐	Cleaner	605	☐	Filefish	629
Latticed	681	☐	Parrot fish	613	☐	Lionfish	631
Redfin	760	☐	Bumphead	933	☐	Scorpionfish / Stonefish	632
Chevroned	677	☐	Goatfish	615	☐	Lizardfish	643
Saddled	899	☐	Half-and-half	648	☐	Hawkfish	902
Threadfin	674	☐	Two-barred	666	☐	Sandperch	675
Teardrop	898	☐	Dash-and-dot	781	☐	Porcupine / Puffer / Toby	634
Orange-banded coralfish	923	☐	Multibarred	934	☐	Trunk / Box / Cowfish	640
Humphead bannerfish	669	☐	Blackstriped	616	☐	Goby	749
Pennant bannerfish	939	☐	Yellowfin	897	☐	Blenny	926
Angelfish	544	☐	Triggerfish	624	☐	Sharksucker	787
Regal	663	☐	Redtooth	786	☐	Needlefish	562
Bicolour	673	☐	Orangestriped	625	☐	Pipefish	911
Pearlscale	545	☐	Clown	626	☐	Shrimpfish	790
Emperor	756	☐	Blackbelly picassofish	927	☐	Trumpetfish	664
Blue-girdled	937	☐	Pinktail	782	☐	Moray eel	637
Vermiculated	938	☐	Scthye	692	☐	FURTHER SPECIES:	
Surgeonfish	546	☐	Halfmoon	796	☐	☐	☐
Convict	547	☐	Picasso	628	☐	☐	☐
"Ringtail" sp.	548	☐	Moustache / Titan	623	☐	☐	☐
Brushtail tang	638	☐	Grouper	583	☐	☐	☐
Thompson's	747	☐	Flagtail	682	☐	☐	☐
Mimic	700	☐	Peacock	935	☐	☐	☐
Unicorn sp.	550	☐	Humpback	936	☐	TOTAL FISH	☐

Life forms

Miscellaneous

[illegible]

APPENDIX II

RECORDING FORMS USED FOR DATA COLLECTED DURING REEF CHECK SURVEYS.

NOTE THAT THESE ARE MODIFIED FROM THE STANDARD FORMS AVAILABLE AT

[HTTP://WWW.REEFCHECK.ORG/](http://www.ReefCheck.org/)

Site name and code	
Date	
Time of day that work started	
Time of day that work ended	
Longitude of Reef Check transect	
Latitude of Reef Check transect	
Orientation of Reef Check transect	N-S NE-SW E-W SE-NW
Distance of Reef Check transect from shore	_____ m
Distance of site from nearest river	_____ km
River mouth width	<10m 11-50m 51-100m 101-500m
Weather	sunny cloudy raining
Air temperature	_____ degrees Celsius
Water temperature at surface	_____ degrees Celsius
Water temperature at 3 m	_____ degrees Celsius
Water temperature at 10 m	_____ degrees Celsius
Water temperature at 20 m	_____ degrees Celsius
Water temperature at 30 m	_____ degrees Celsius
Distance to nearest population centre	_____ km
Approximate population size	_____ x 1000 people
Horizontal visibility in water	_____ m
Vertical visibility in water	_____ m
Why was this site selected?	
Is this site -	sheltered or exposed
Any major coral damaging storms in past years?	yes no unknown
How do you rate this site overall in terms of anthropogenic impact?	none low moderate heavy
What types of impact do you believe occur?	
Number of fishing boats within 500m	
Number of other boats within 500m	
Dynamite fishing	none low moderate heavy
Poison fishing	none low moderate heavy
Aquarium fish collection	none low moderate heavy
Harvest of invertebrates for food	none low moderate heavy
Harvest of invertebrates for curio sales	none low moderate heavy
Tourist diving	none low moderate heavy
Sewage pollution	none low moderate heavy
Industrial pollution	none low moderate heavy
Other forms of fishing? (Specify)	none low moderate heavy
Other impacts? (Specify)	none low moderate heavy
Is there any form of protection (statutory or other) at this site?	yes no
If yes, what type of protection?	
Other comments	

122.

REEF CHECK 2001- Please fill in all Black outlined boxes

Site Name:

Depth:

Date: Time:

Indo-Pacific Belt Transect : Fish

Data recorded by:

	0-20m	25-45m	50-70m	75-100m
Butterfly fish (ALL SPS)				
Sweetlips (Haemulidae) (ALL SPS)				
Snapper (Lutjanidae) (ALL SPS)				
Two-spot				
Checkerboard				
Black-and-white				
"Bluelined"				
Paddletail				
Barramundi Cod (<i>Cromileptes</i>)				
Grouper >30cm (Give sizes in comments) (ALL SPS)				
Flagtail				
Peacock				
"Honeycomb"				
Lyretail				
Humphead wrasse				
Bumphead parrot				
Other Parrotfish (>20cm)				
Tuna / Mackerel				
Fusiliers				
Surgeonfish				
Rabbitfish				
Barracuda				
Jacks / Trevally				
Moray eel				

Indo-Pacific Belt Transect : Invertebrates

Data recorded by:

	0-20m	25-45m	50-70m	75-100m
Banded coral shrimp (<i>Stenopus hispidus</i>)				
Diadema urchins				
Pencil urchin (<i>Heterocentrotus mammillatus</i>)				
Sea cucumber (edible only)				
Crown-of-thorns star (<i>Acanthaster</i>)				
Giant clam (<i>Tridacna</i>)				
Triton shell (<i>Charonia tritonis</i>)				
<i>Drupella</i> sp				
Squid				
Octopus				
Lobster				

For each segment, rate the following as: None=0, Low=1, Medium=2, High=3

Coral damage : Anchor				
Coral damage:Dynamite				
Coral damage : Other				
Trash : Fish nets				
Trash : Other				

Comments:

Grouper sizes (cm)				
Bleaching (% of coral population)				
Bleach (% of colony)				
Suspected disease (type/%):				
Rare animals sighted (type/#):				
Other:				

"ALL SPS" means that all individuals from that family should be counted in the box and additional target species are counted a second time on subsequent line e.g. a paddletail snapper is counted both as a snapper AND as a paddletail snapper

APPENDIX II

HARD CORAL SPECIES POSITIVELY IDENTIFIED FROM THE PERHENTIAN ISLAND
ARCHIPELAGO DURING THE PILOT PHASE OF THE MCRCP

ACROPORIDAE
Montipora foliosa
Montipora delicatula
Montipora florida
Montipora aequituberculata
Montipora undata
Montipora spumosa
Montipora digitata
Montipora stellata
Anacropora forbesi
Acropora cuneata
Acropora palifera
Acropora crateriformis
Acropora hemprichii
Acropora grandis
Acropora palmerae
Acropora pinguis
Acropora irregularis
Acropora nobilis
Acropora divaricata
Acropora proximalis
Acropora cythera
Acropora hyacinthus
Acropora globiceps
Acropora humilis
Acropora digitifera
Acropora millepora
Acropora aspera
Acropora latistella
Acropora speciosa
Astreopora myriophthalma
POCILLOPORIDAE
Pocillopora damicornis
Pocillopora verrucosa
Pocillopora eydouxi
Seriatopora hysterix
Stylophora pistellata
EUPHYLLIDAE
Euphyllia ancora
Euphyllia glabrescens
Plerogyra sinuosa
Physogyra lichtensteini

OCULINIDAE
Galaxea fascicularis
Galaxea astreata
SIDERASTREIDAE
Psammocora digitata
AGARICIIDAE
Pavona cactus
Pavona decussata
Pachyseries rugosa
Pachyseries speciosa
FUNGIIDAE
Heliofungia actiniformis
Fungia danai
Fungia fungites
Ctenactis echinata
Herplothia limax
Polyphyllia talpina
Sandalolitha robusta
Halomitra pileus
PECTINIIDAE
Mycedium elephantotus
Pectinia lactuca
Pectinia paeonia
MERULINIDAE
Hydnophora rigida
Hydnophora exesa
DENDROPHYLLIIDAE
Tubastrea micrantha
Turbinaria peltata
Turbinaria reniformis
MUSSIDAE
Acanthastrea echinata
Lobophyllia hemprichii
Symphyllia recta
Symphyllia radians

FAVIIDAE
<i>Favia speciosa</i>
<i>Favia fava</i>
<i>Favia lizardensis</i>
<i>Favites pentagona</i>
<i>Favites adibata</i>
<i>Favites complanata</i>
<i>Goniastrea edwardsi</i>
<i>Goniastrea pectinata</i>
<i>Platygyra daedalea</i>
<i>Leptoria phrygia</i>
<i>Diploastrea heliophora</i>
<i>Echinopora pacificus</i>
<i>Echinopora lamellosa</i>
<i>Echinopora horrida</i>
PORITIDAE
<i>Porites lobata</i>
<i>Porites annae</i>
<i>Porites rus</i>
<i>Porites attenuata</i>
<i>Porites cylindrica</i>
<i>Porites nigrescens</i>
<i>Goniopora djiboutiensis</i>
<i>Goniopora columna</i>
NON-SCLERACTINIAN
<i>Millepora intricata</i>
<i>Millepora platyphyllia</i>
<i>Stylasterina</i> sp
<i>Heliopora</i> sp

APPENDIX IV

FISH SPECIES POSITIVELY IDENTIFIED FROM THE PERHENTIAN ISLAND ARCHIPELAGO
DURING THE PILOT PHASE OF THE MCRCP

BUTTERFLYFISH	CHAETODONTIDAE
Orange-Banded	<i>Coradoin chrysozonus</i>
Copper-Banded	<i>Chelmon rostratus</i>
Eight-Banded	<i>Chaetodon octofasciatus</i>
Orange-Faced	<i>Chaetodon larvatus</i>
Reticulated	<i>Chaetodon reticulatus</i>
Ocellated	<i>Parachaetodon ocellatus</i>
Weibels	<i>Chaetodon weibeli</i>
ANGELFISH	POMACANTHIDAE
Vermiculated	<i>Chaetodontoplus mesdecus</i>
Blue-ringed	<i>Pomacanthus annularis</i>
Emperor	<i>Pomacanthus imperator</i>
Blue-striped	<i>Chaetodontoplus septentrionalis</i>
Six-banded	<i>Pomacanthus sexstriatus</i>
Regal	<i>Pygoplites diacanthus</i>
DAMSELFISH	POMACENTRIDAE
Staghorn	<i>Amblyglyphidodon curacao</i>
Whitebelly	<i>Amblyglyphidodon leucogaster</i>
Black	<i>Neoglyphidodon melas</i>
Javanese (Juv)	<i>Neoglyphidodon oxyodon</i>
Neon	<i>Pomacentrus coelestis</i>
Alexanders	<i>Pomacentrus alexanderae</i>
SERGEANTS	
Indo-Pacific	<i>Abudefduf vaigiensis</i>
Scissor-Tail	<i>Abudefduf sexfasciatus</i>
Maomao	<i>Abudefduf abdominalis</i>
Bengal	<i>Abudefduf bengalis</i>
CHROMIS	
Blue-Green	<i>Chromis viridis</i>
Black-axial	<i>Chromis atripectoralis</i>
Bi-colour	<i>Chromis margaritifer</i>
Yellow	<i>Chromis analis</i>
Surge demoiselle	<i>Chrysiptera leucopoma</i>
Blue Devil	<i>Chrysiptera cyanea</i>
Three-spot dascyllus	<i>Dascyllus trimaculatus</i>
Reticulated	<i>Dascyllus reticulatus</i>
Blue-Spot demoiselle	<i>Chrysiptera oxycephala</i>

ANEMONE FISH	
False clown	<i>Amphiprion ocellaris</i>
Clown	<i>Amphiprion perculata</i>
Tomato	<i>Amphiprion frenatus</i>
Red Saddleback	<i>Amphiprion ephippium</i>
Pink	<i>Amphiprion perideraion</i>
Spinecheek	<i>Premas biaculeatus</i>
Pink	<i>Amphiporan abalopsis</i>
FUSILIERS	CAESIONIDAE
Blue and Gold	<i>Caesio teres</i>
Yellowback	<i>Caesio xanthonota</i>
SURGEONFISH	ACANTHURIDAE
Convict	<i>Acanthurus triostegus</i>
Moorish Idol	<i>Zanclus cornutus</i>
WRASSE	LABRIDAE
Axilspot hogfish	<i>Bodianus axillaris</i>
Dianas Hogfish	<i>Bodianus diana</i>
Mesothorax Hogfish	<i>Bodianus mesothorax</i>
Red-Banded	<i>Chelinius fasciatus</i>
Checkerboard	<i>Halichoeres hortulanus</i>
Twotone	<i>Thalassoma amblycephalum</i>
Crescent	<i>Thalassoma lunare</i>
Sunset	<i>Thalassoma lutescens</i>
Sixbar	<i>Thalassoma hardwicke</i>
Slingjaw	<i>Epibulus insidiator</i>
Barred Thicklips	<i>Hemigymnus fasciatus</i>
Blackedge Thicklips	<i>Hemigymnus melapterus</i>
Blackstripe Coris	<i>Coris pictoides</i>
Humphead	<i>Cheilinus undulatus</i>
Wandering Cleaner	<i>Diproctacanthus xanthurus</i>
Bluestreak Cleaner	<i>Labroides dimidiatus</i>
GOATFISH	MULLIDAE
Dash and Dot	<i>Parupeneus barberinus</i>
Blackstriped	<i>Upeneus tragula</i>
Indian	<i>Parupeneus indicus</i>
TRIGGERFISH	BALISTIDAE
Titan	<i>Balistoides viridescens</i>

GROUPEr	SERRANIDAE
Peacock	<i>Cephalopholus argus</i>
Honeycomb	<i>Epinephelus merra</i>
Coral	<i>Cephalopholus miniata</i>
SOAPFISH	
Sixline	<i>Grammistes sexlineatus</i>
Two banded	<i>Diploporion bifasciatum</i>
PARROTFISH	SCARIDAE
Bumphead	<i>Bolbometopon muricatum</i>
Swarthy	<i>Scarus niger</i>
Bridled	<i>Scarus frenatus</i>
Bullethead	<i>Chlorurus sordidus</i>
Rainbow	<i>Scarus forsteni</i>
SPINECHEEK	NEMIPTErIDAE
Twoline	<i>Scolopsis bilineatus</i>
SNAPPER	LUTJANIDAE
Chequered	<i>Lutjanus decussatus</i>
Blackspot	<i>Lutjanus fulviflamma</i>
Spanish Flag	<i>Lutjanus carponotatus</i>
RABBITFISH	SIGANIDAE
Foxface	<i>Siganus vulpinus</i>
Virgate	<i>Siganus virgatus</i>
Golden	<i>Siganus guttatus</i>
Coral	<i>Siganus corallinus</i>
Magnificent	<i>Siganus magnificus</i>
Lined	<i>Siganus lineatus</i>
CARDINALFISH	APOGONIDAE
Ochre-striped	<i>Apogon compressus</i>
Orbiculate	<i>Sphaeramia orbicularis</i>
PUFFERFISH	TETRAODONTIDAE
Star	<i>Arothron compressus</i>
Black-spotted	<i>Arothron nigropunctatus</i>

GOBIES	GOBIIDAE
Yellow / Banded	<i>Cryptocentrus cinctus</i>
Blue-speckled Prawn Goby	<i>Cryptocentrus caeruleomaculatus</i>
Pink-speckled Shrimp Goby	<i>Cryptocentrus leptocephalus</i>
Gold-speckled Shrimp Goby	<i>Ctenogobiops aurocingulus</i>
Eyebar	<i>Gnatholepis anjerensis</i>
Coral	<i>Bryaninops erythrops</i>
Whip	<i>Bryaninops yongei</i>
JACK / TREVALLY	CARANGIDAE
Golden Trevally	<i>Gnathanodon speciosus</i>
Silver Pompano	<i>Trachinotus blochii</i>
SWEETLIPS	HAEMULIDAE
Painted	<i>Diagramma pictum</i>
Yellow-Striped	<i>Plectorhinchus chrysotaenia</i>
Black	<i>Plectorhinchus sordidus</i>
Dusty	<i>Plectorhinchus chubbi</i>
BARRACUDA	SPHYRAENIDAE
Pickhandled	<i>Sphyaena jello</i>
Yellowtail	<i>Sphyaena flavicauda</i>
Sawtooth	<i>Sphyaena putnamiae</i>
EMPERORS	LETHRINIDAE
Thumbprint	<i>Lethrinus harak</i>
SPADEFISH / BATFISH	EPHIPPIDAE
Teira batfish	<i>Patax teira</i>
PORCUPINE FISH	DIODONTIDAE
Spotted	<i>Diodon hystrix</i>
TRUNK / BOX / COWFISH	OSTRACIIDAE
Yellow Boxfish	<i>Ostracion cubicus</i>
BLENNY	BLENNIDAE
Cleaner mimic	<i>Aspidontus taeniatus</i>
Red-spotted	<i>Blenniella chrysospilos</i>

SWEEPER	PEMPHERIDAE
Copper / bronze	<i>Pempheris ovalensis</i>
Vanicoro	<i>Pempheris vanicolensis</i>
SQUIRRELFISH / SOLDIERFISH	HOLOCENTRIDAE
Seychelles squirrelfish	<i>Sargocentron seychellense</i>
FILEFISH	MONACANTHIDAE
Scribbled / Scrawled filefish	<i>Alutera scripta</i>
LIONFISH	SCORPAENIDAE
Zebra Lionfish	<i>Dendrochirus zebra</i>
Turkeyfish	<i>Pterois volitans</i>
LIZARDFISH	SYNODONTIDAE
Variegated / Reef Lizardfish	<i>Synodus variegatus</i>
SANDPERCH	PINGUIPEDIDAE
Yellowbar	<i>Parapercis xanthozona</i>
PIPEFISH	SYGNATHIDAE
Double-ended	<i>Trachyrampus bicoarctatus</i>
Brown Banded	<i>Corythoichthys amplexus</i>
MORAY EEL	MURAENIDAE
Giant	<i>Gymnothorax javanicus</i>
White-eyed	<i>Siderea thyrsoides</i>
RUDDERFISH	KYPHOSIDAE
Lowfin Rudderfish	<i>Kyphosus vaigiensis</i>
High-fin Rudderfish	<i>Kyphosus cinerascens</i>
REMORAS	ECHENIDAE
Shark-sucker	<i>Echeneis naucrates</i>
NEEDLEFISHES	BELONIDAE
Needlefish	<i>Strongylura incisa</i>
TRUMPETFISHES	AULOSTOMIDAE
Trumpetfish	<i>Aulostomus chinensis</i>
BAMBOO SHARKS	HEMISCYLLIDAE
Bamboo shark	<i>Chiloscyllium punctatum</i>