

MALAYSIA CORAL REEF CONSERVATION PROJECT: PULAU PAYAR

REPORT TO THE DEPARTMENT OF MARINE PARKS, MALAYSIA.

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EXECUTIVE SUMMARY

- Development in Malaysia is concentrated in the coastal zone that places direct threats 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 2004 Coral Cay Conservation were invited to conduct a series of surveys on such a Marine Park; Pulau Payar in the west coast state of Kedah on Peninsular Malaysia.
- One hundred and forty six point intercept transects were conducted around the Pulau Payar Marine Park to assess the composition of the benthic communities. Additionally, belt transects were also undertaken at these survey sites to assess the abundance of fish and motile invertebrates.
- The data collected has been used to identify seven discrete habitat types that are key to the ecological functioning of the coral reef systems. Of these seven habitat types, three are shallow reef crest habitats found on the upper transect surveys and four are found on the mid and lower reef slope. Reefal development around Pulau Payar was found to be restricted to shallow waters on average above 14 meters deep.
- Signs of impacts are presented in the data; fishing activities are still present within the Marine Park and areas in which development has occurred such as around the Marine Park Centre which receives thousands of visitors annually show signs of human impact such as solid waste pollution
- 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.
- Comparison between the data presented in this report and a previous study in 1998 shows that at comparable survey sites, there has been a significant loss in live hard coral cover. In tandem with this loss there has been a significant increase in abiotic or non-living cover of especially rubble, the erosive derivative of coral skeletons. Whilst the cause of this impact has not been directly identified by this study as it occurred outside of the study period, it is indicative of the impacts within the Marine Park and forms an evidence base illustrating the necessity for strong management of the natural resource.
- Plans for a collaborative venture between CCC, Marine Parks and Malaysian Centre for Geospatial Data Infrastructure (MaCGDI) are currently being discussed. These plans involve the provision of a fully integrated GIS system that will use the data presented in this report.
- This GIS will allow improved management planning through the identification of key management areas in which development needs to be tightly controlled as well as more general use zones in which development can be controlled through proper mitigation initiatives.

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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 in 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-sectoral 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 (MCRCP), 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 Pulau Payar Marine Park

The Pulau Payar Marine Park is situated off the state of Kedah, between Pulau Langkawi and Pulau Penang (Figure 1.1). The Marine Park is commonly accessed through the ports at Kuala Kedah, Pulau Langkawi and Pulau Pinang, each of which are 15, 19 and 32 nautical miles respectively (Lim, 1998).

There are four Islands within the jurisdictional area of the Marine Park (Figure 1.2); Pulau Payar is the largest with an area of (2.9 km²) hectares and an approximate length of 1.6 km. The remaining Islands in order of decreasing land area are, with their areas in brackets; Pulau Lembu (0.67 km²), Pulau Segantang (0.15 km²) and Pulau Kaca (0.01 km²).

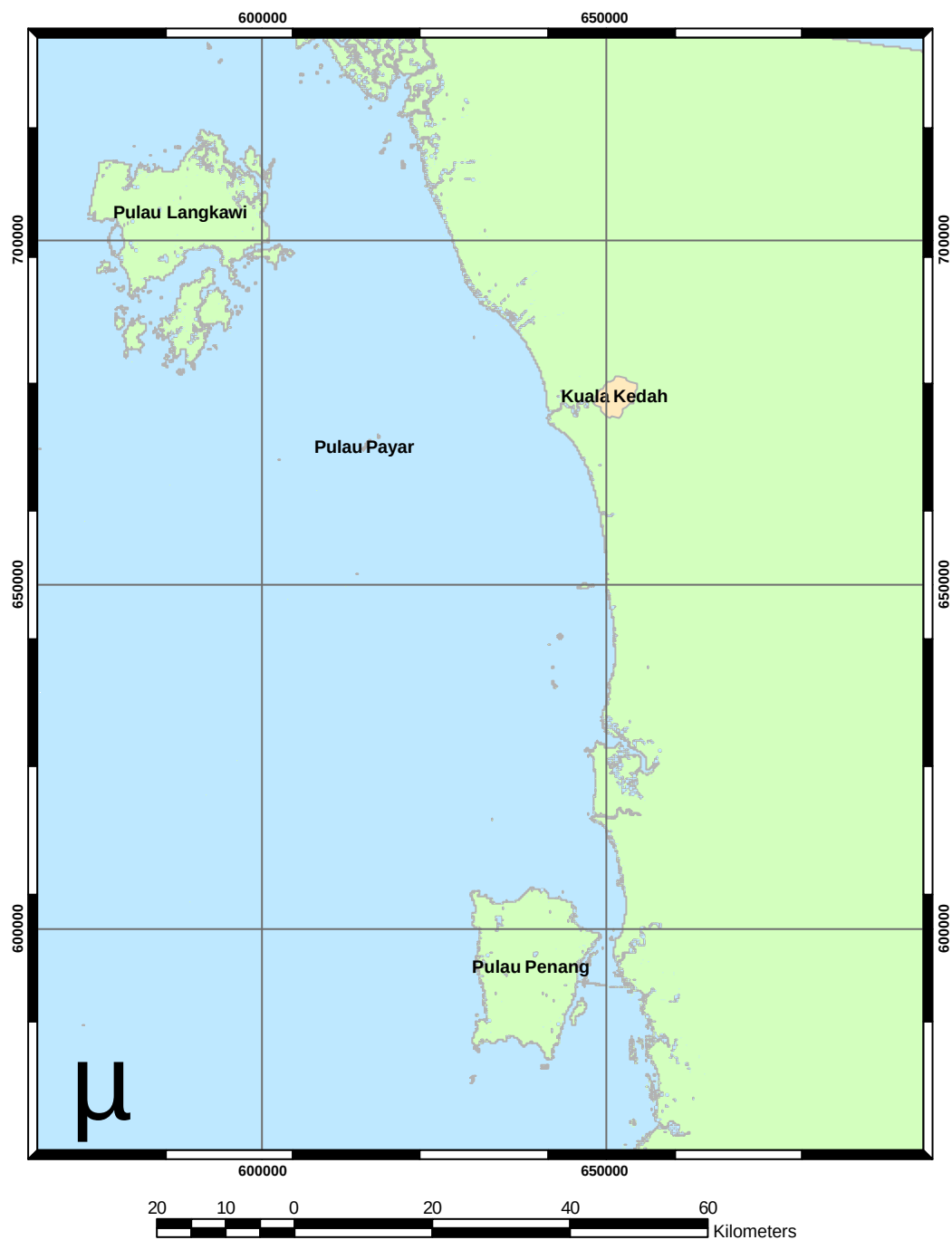


Figure 1.1 The West coast of Peninsular Malaysia incorporating Pulau Penang, Langkawi and Payar Marine Park in relation to the urban area of Kuala Kedah.

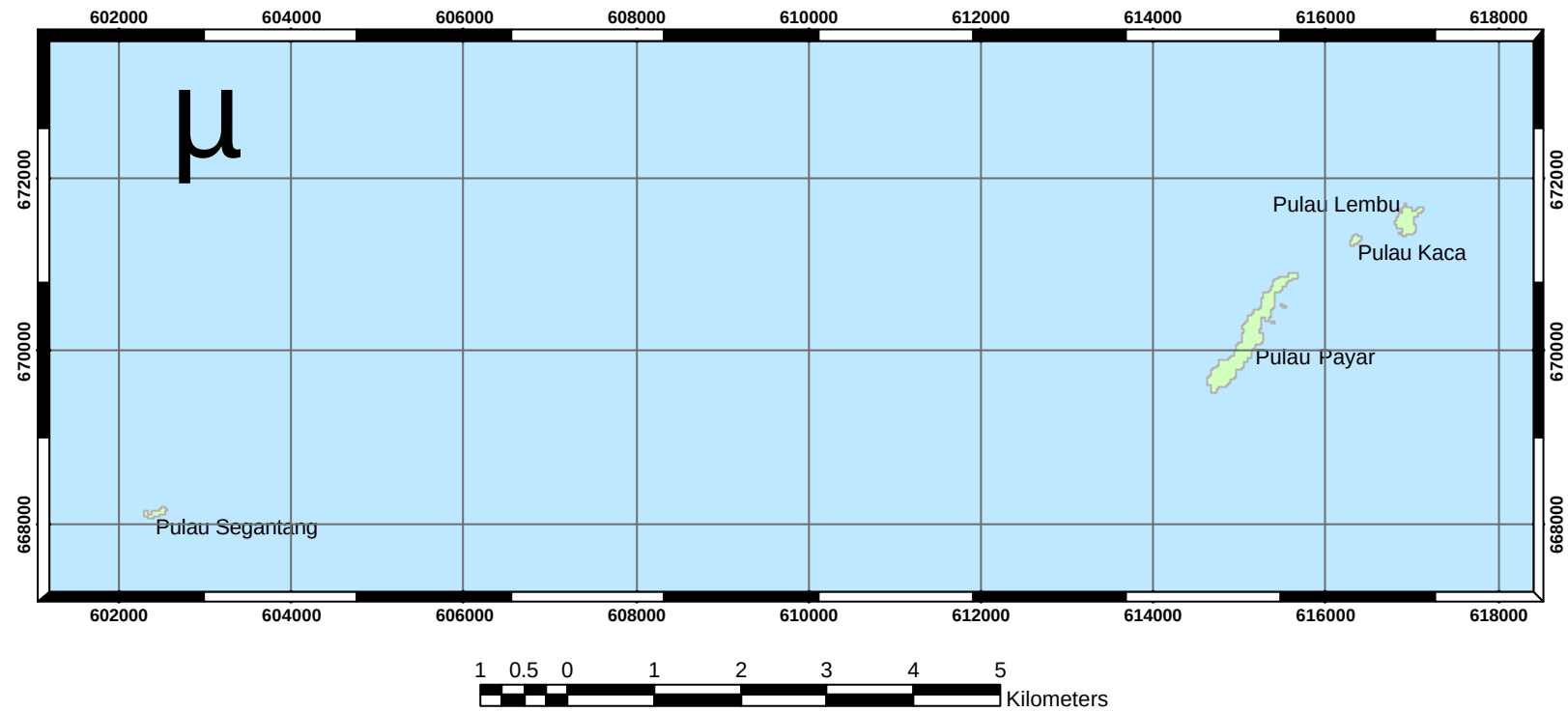


Figure 1.2. The Islands in the Pulau Payar Marine Park system

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 on the West coast of Peninsular Malaysia. 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 MCRCP are to provide a baseline information set on the condition and status of the coral reefs around the Pulau Payar Marine Park in 2004 (see Table 1.1 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 Pulau Payar Marine Park in 2004. 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 1.1. Main aims, objectives and anticipated outputs of the Pulau Payar phase of the Malaysia Coral Reef Conservation Project.

AIM	OBJECTIVE	ANTICIPATED OUTPUTS
➡ Resource assessment.	❶ Undertake an initial scientific survey of target coral reefs. ❷ Conduct preliminary human impact assessment studies. ❸ Establish a baseline database. ❹ Provide preliminary management tools and recommendations.	📄 Initial baseline database. 📄 Description of reef habitat types. 📄 Documentation of gross anthropogenic impacts. 📄 Conservation management rating map. 📄 Preliminary management recommendations.
➡ Training and conservation education.	❶ Provide scientific and SCUBA training for CCC volunteers and local counterparts. ❷ Heighten awareness of marine resources, their use and protection. ❸ Begin to develop a sense of community stewardship in managing the coastal zone.	📄 Increased awareness amongst local communities.

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 MCRCP, 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 2.3). 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).

Table 2.1. CCC Skills Development Programme timetable for CCC volunteers during the MCRCP.

	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 ► O ₂ 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) <u>Lecture 6ii</u> ► 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. (Continued). CCC Skills Development Programme timetable for CCC volunteers during the MCRCP.

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
	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

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 island.

2.2.1 *The Concept of ‘Survey Sites’*

During the Pulau Payar phase of the MCRCP, 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. These survey sites are illustrated in Figure 2.1. Surveys at each site generate a standardised data set that will facilitate characterisation of each area and also allow 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).

The standard *CCC 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.

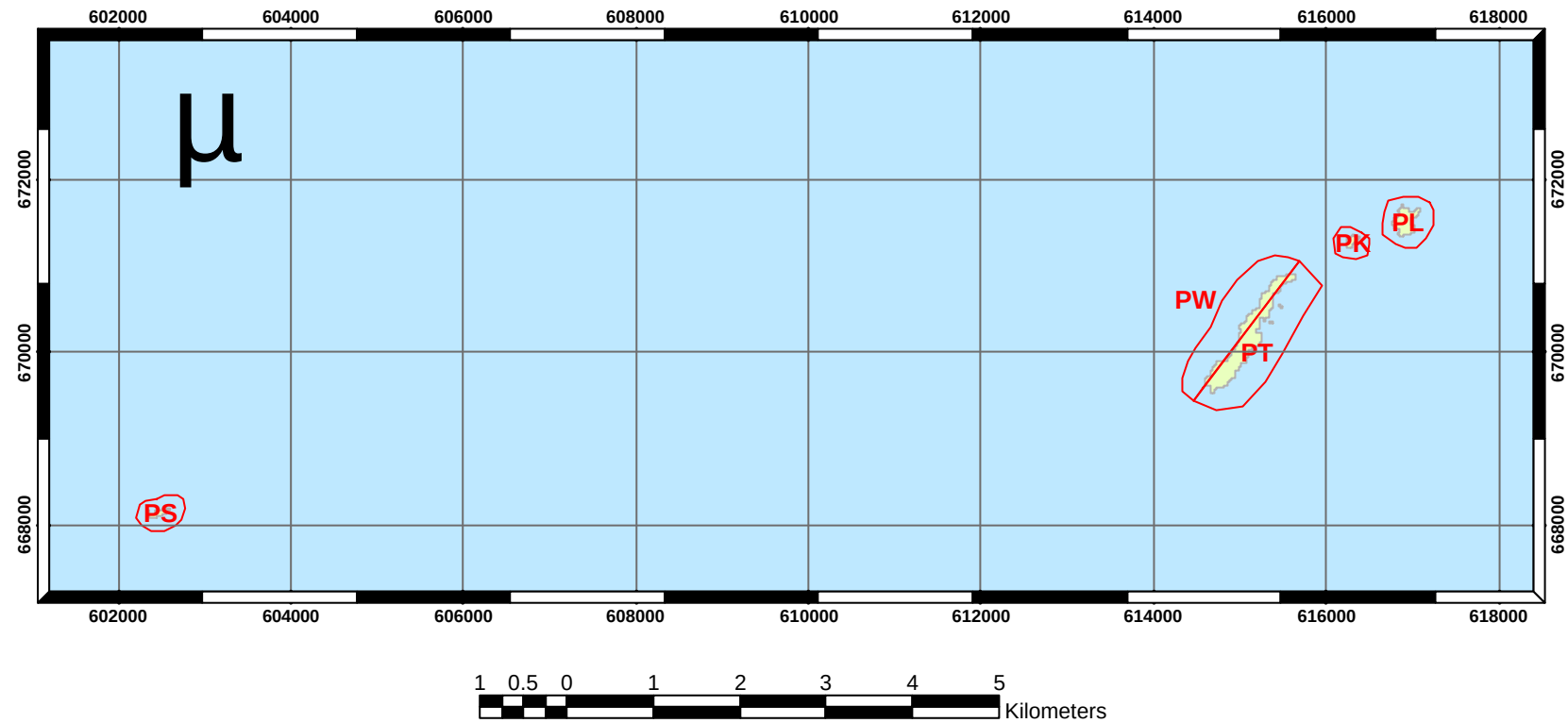


Figure 2.1. Location of the survey sectors delineated for purposes of data collection, analysis and reporting in this document. Two-character code refers to database codes assigned to identify each area.

2.3 Baseline transect technique

The surveys of Payar Island during the Malaysia Coral Reef Conservation Project (MCRCP) utilised a point intercept transect technique 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.

The technique employed involved the deployment of a 50 meter transect line along the reef depth contour. Two survey lines were laid; the shallow transect at a depth between 2 and 6 meters and a deep line between 8 and 14 meters. Along these lines, three survey divers conducted the survey.

The first of these divers recorded the substrate or biological cover at each meter point along the line. Substrate and biological cover categories are shown in table 2.2 below.

Additionally, if the biological cover was deemed to be one of the target species of organisms selected by CCC to be of important ecological, commercial or scientific importance, its presence was also recorded at each survey point. The target species of sessile organisms, mobile invertebrates and fish are given in appendix 1. Collecting the data in this manner allows a quantitative assessment of both the biotic and abiotic components of the coral reef system to be undertaken.

Table 2.2 Life form categories used by CCC survey divers along point intercept transects during the MCRCP Pulau Payar survey program

Variable	Description
Bedrock	Substrates
Sand	
Mud	
Dead Coral & Algae	
Dead Coral	
Rubble	
Cyano-Bacteria:	Algae and Angiosperms
<i>Chlorophyta</i> :	
<i>Phaeophyta</i> :	
<i>Rhodophyta</i> :	
Sea Grass	
Mangroves	
Molluscs	Invertebrates
Tunicates	
Bryozoans	
<i>Porifera</i> :	
Soft Coral Forms	Live Hard Coral
Other Cnidarians	
Acropora branching	
Acropora encrusting	
Acropora sub-massive	
Acropora digitate	
Acropora tabulate	
Non-Acropora branching	
Non-Acropora encrusting	
Non-Acropora foliose	
Non-Acropora massive	
Non-Acropora sub-massive	
Non-Acropora mushroom	
Fire coral (Milleporidae)	
Blue coral (Helioporidae)	
Organ Pipe coral (Tubipora)	

The second diver was responsible for recording the numbers of individuals of mobile invertebrates to be found two and a half meters either side of the transect line. The survey effort of the invertebrate survey diver was split into two contiguous twenty-five meter sections along the fifty-meter line.

The final survey diver recorded the absolute number of fish individuals seen one meter either side of the transect line and in a arc of two meter radius above the transect line. Again, the survey effort of the fish diver was divided into two contiguous twenty-five meter sections along the 50-meter line. All fish were identified to family level and their abundance recorded. An additional list of target species were

also taught to the survey divers and their abundance was recorded along the transect line.

Information on the depth of the transect line, together with its compass bearing were recorded by the divers underwater. Using a buoy to the surface, the GPS position of the start and end point of the transect were recorded from on-board the surface cover boat using a handheld GPS unit. This unit was set to record data in Universal Transverse Mercator on a WGS-84 datum that is subsequently used in all mapping and GIS outputs.

Following the dive, all survey data was transferred to recording sheets before being entered into a MS Access database established specifically for the project. This database was in turn linked to a fully compliant Geographic Information System (GIS), allowing fast and accurate assessment of the field data.

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 2.2). 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.

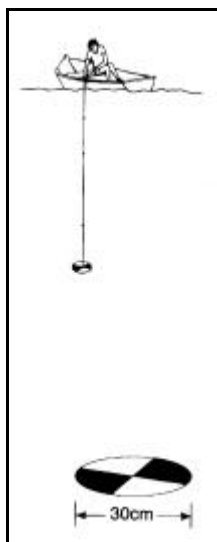


Figure 2.2. The use of a secchi disc to assesses vertical water clarity. The secchi disc is lowered into the water until the black and white quarters are no longer distinguishable. The length of rope from the surveyor to the disc is then recorded. *Source: English et al. (1997).*

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 present /absent 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).

2.4 Data analysis

2.4.1 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 survey 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 habitats.

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 habitat. 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 habitat.

Finally, the habitat 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 habitat 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.

3. RESULTS

3.1 Coral Reef Survey Progress

A total of one hundred and forty six survey transects were conducted around the Pulau Payar Marine Park between October 2004 and March 2005. In total along these lines, 7300 point intercept points were surveyed and 6500 fish and invertebrate observations were made. The location of CCC baseline surveys completed in Pulau Payar Marine Park is depicted by Figure 3.1.

All maps reproduced in this report have been digitised from a Landsat ETM+ image acquired on 17th of January 2002. 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).

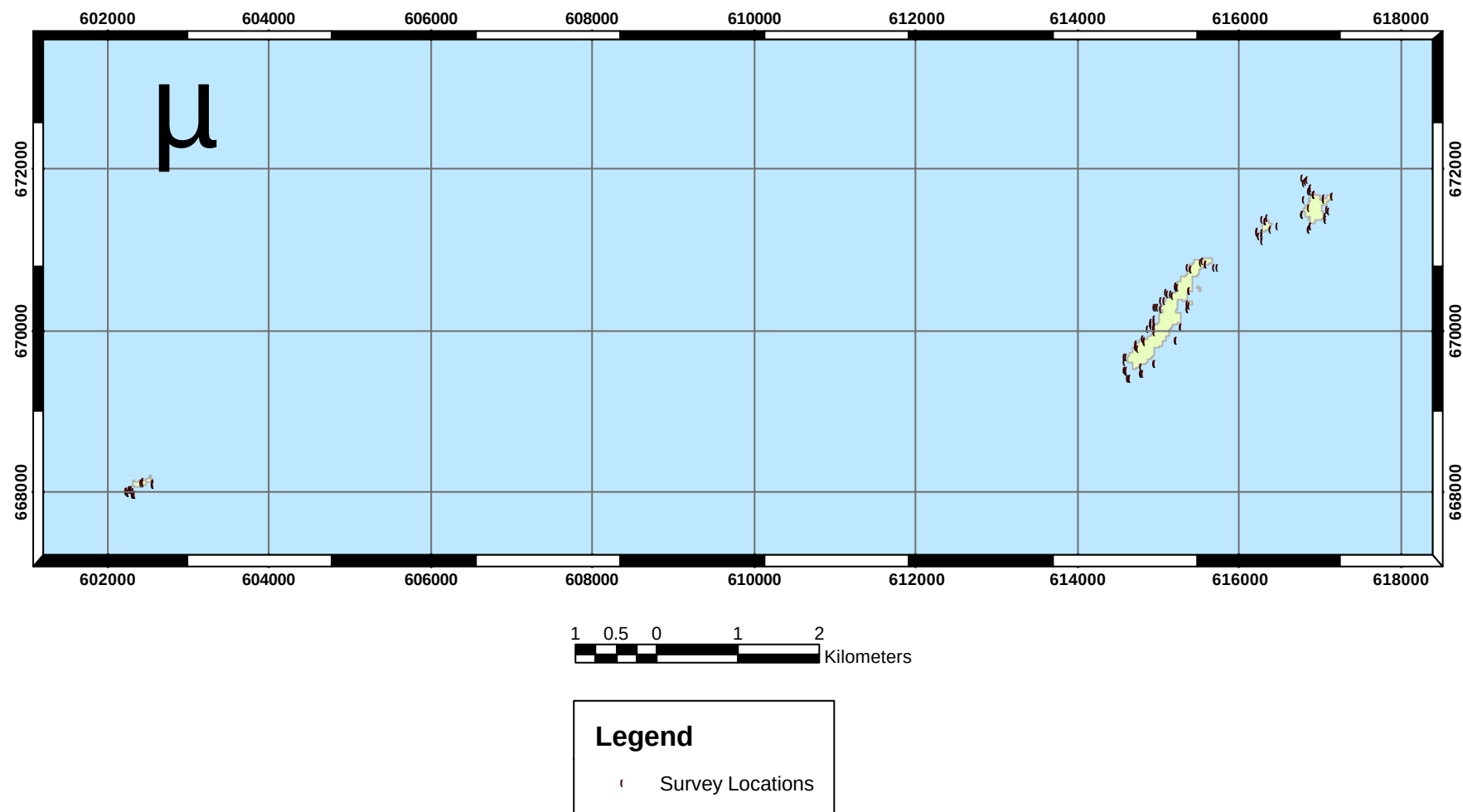


Figure 3.1. Location of start points (red symbols) of Baseline Transects conducted by CCC within the Pulau Payar Marine Park between October 2004 and March 2005. The data collected is presented in this report.

3.2 Oceanographic data

3.2.1 Wind speed and Direction

The highest number of recordings made was ‘moderate’ wind speed and occurred 41 times out of the 112 observations made. The prevailing wind direction was from the north and north-east, with 38 and 45 of the observations respectively, originating from the north and north-east. (Figure 3.2).

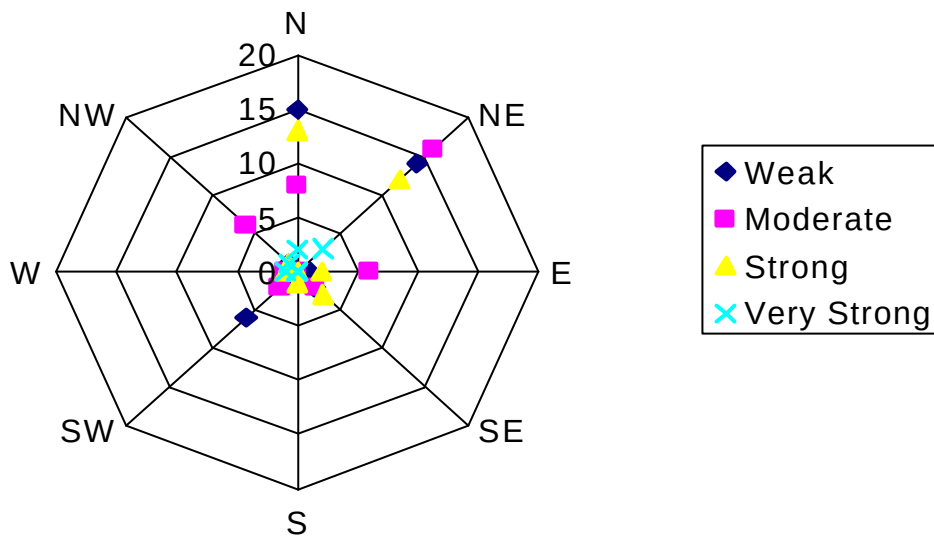


Figure 3.2. Radar diagram showing the prevailing winds recorded during MCRCP. Points represent the frequency of occurrence of combinations of wind direction and strength.

3.2.2 Salinity

The mean salinity value for all depths recorded during the CCC baseline surveys was 28.70 ‰ (n = 140, S.D. = 0.602‰). Overall there is a trend of increasing salinity with increasing depth in the water column, to the maximum depth recorded, 17.9m. Increased salinity recordings were found at the water surface with a mean surface salinity of 28.61‰ (n=140, S.D = 0.845‰) (Figure 3.3).

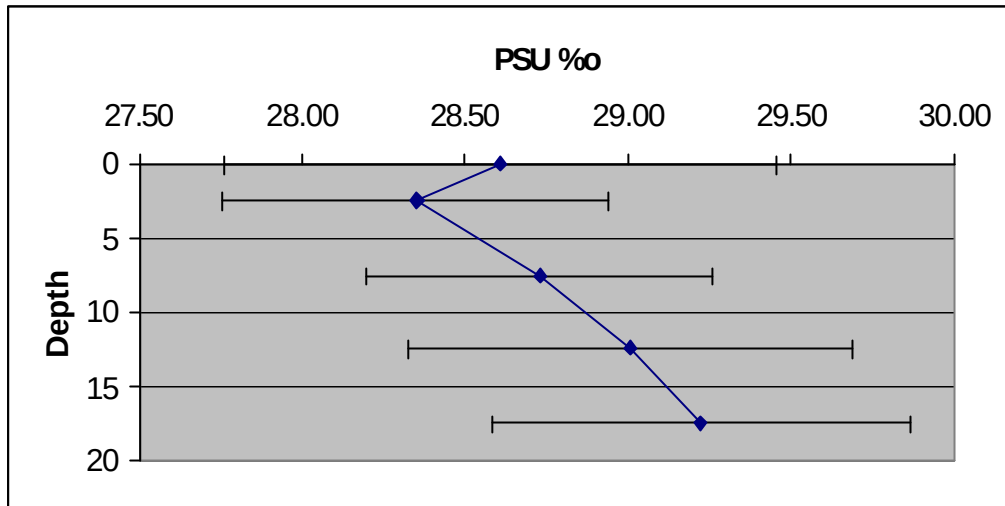


Figure 3.3. Mean salinity recordings for all surveys in the project area in 5m depth classes throughout the water column. Horizontal bars represent standard deviations around the calculated mean. Sample sizes: 0m = 140; 0.1-5m = 43; 5.1-10m = 56; 10.1-15m = 36; 15.1-20m = 5.

3.2.3 Water Temperature

A total of 292 temperature readings were recorded, both at surface and at the depth where survey was conducted (figure 3.4). The mean total temperature was 29.09°C (regardless of depth). The temperature at the surface averaged the highest value, 29.8°C. A constant decrease of temperature levels can be observed as depth increases. Temperature was noted to stabilize deeper than 12.5m. This could be explained by the presence of a thermocline in some geographical areas.

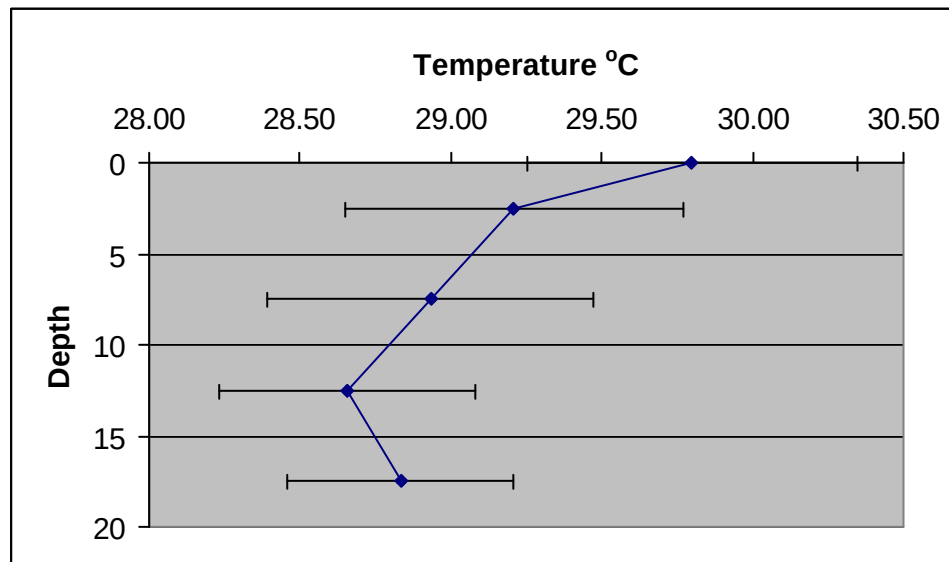


Figure 3.4. Mean water temperatures for all surveys in the project area in 5 metre depth classes throughout the water column. Horizontal bars represent standard deviations around the calculated means. Sample sizes: 0 m = 146; 0.1 – 5 m = 43; 5.1 – 10 m = 59; 10.1- 15 m = 38; 15.1 – 20 = 6.

3.2.4 Current Strength and Direction

The most frequently observed currents during the MCRCP were classed as weak by the survey divers, with 72% (n =100) of the current observations in this category. These were evenly distributed between two predominant headings of north/northeast and south/southwest. Moderate current strength accounted for 26% of observations that travelled predominately towards the south and west. Strong currents were only encountered on only 2% of dives and were headed towards the south and southeast. From the data collected there appears to be a bi-directional overall pattern in terms of the prevailing current direction in the survey area (Figure 3.5), with the greatest number of recordings heading south/southwest 38% (n=38) and east/northeast 36% (n=36). Interestingly, only 1% (n=1) current observation was recorded with a heading of southeast but this was also one of the only two strong currents recorded.

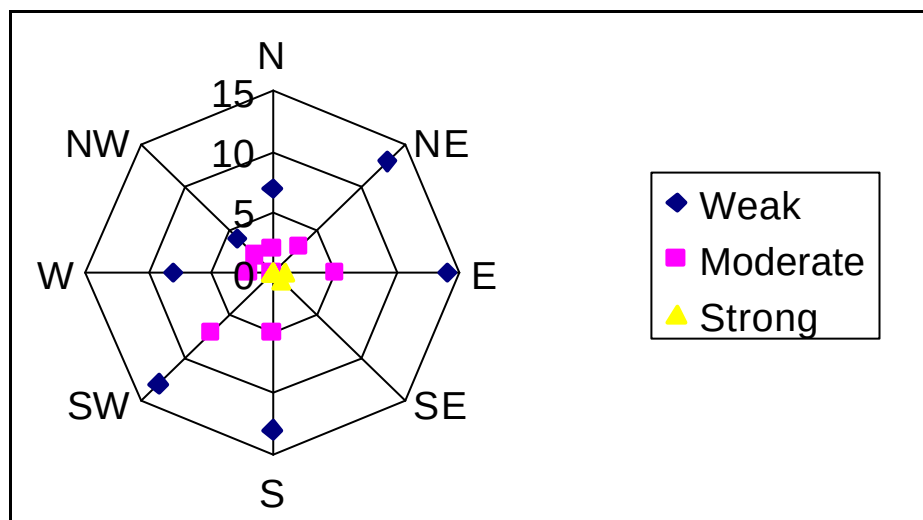


Figure 3.5. Mean underwater current strength and direction recorded in the Pulau Payar Marine Park during surveys. Points represent the frequency of occurrence of combinations of current direction and strength. Symbols represent current strength from weak to strong.

3.2.5 Underwater Visibility

Underwater visibility was observed in two ways during the MCRCP. 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 graphically in Figures 3.6 and 3.7

Mean vertical visibility of 10.97m (Std Dev $\pm$ 2.05m) and 10.56m (Std Dev $\pm$ 2.34m) were recorded by Secchi disc at sites PS and PT respectively, (Figure 3.6). The site with the lowest mean visibility and therefore the highest turbidity was PW with vertical visibility of 6.93m (Std Dev $\pm$ 1.28m).

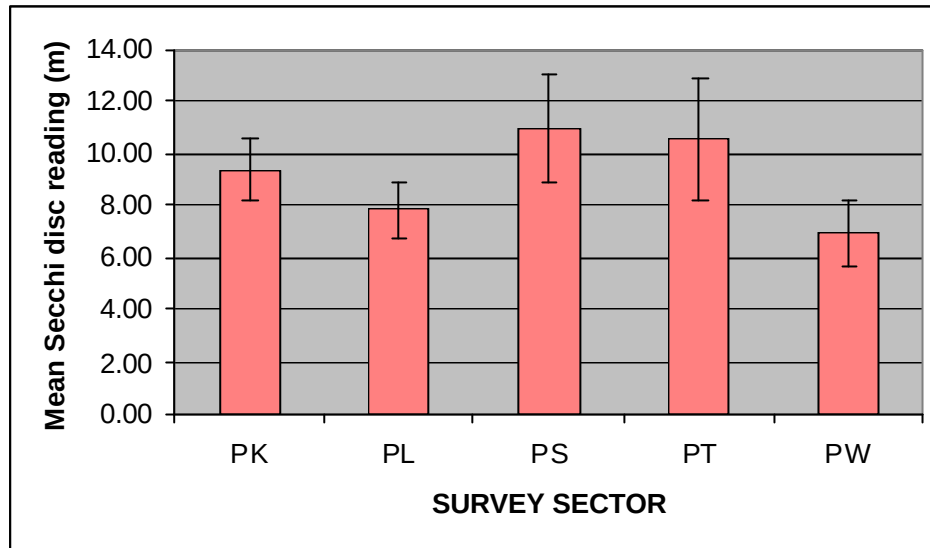


Figure 3.6. Mean Secchi Disc recordings of vertical visibility in metres ($\pm$ S.D.) for each survey sector

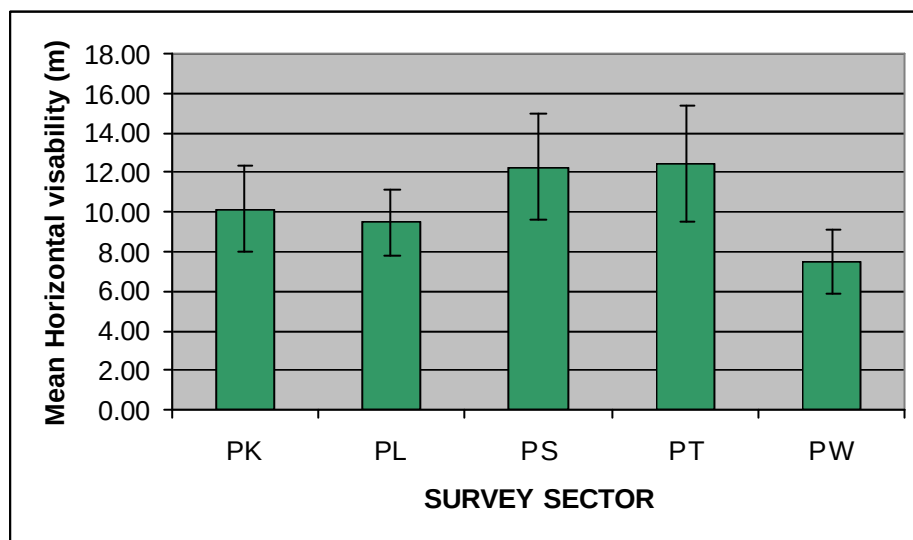


Figure 3.7. Mean horizontal visibility recordings by divers in metres ($\pm$ S.D.) for each survey sector.

Mean horizontal visibility peaked at sectors PT and PS at 12.44m (S.D $\pm$ 2.94) and 12.24m (S.D $\pm$ 2.66) respectively. The poorest horizontal visibility was recorded at site PW with visibility recorded at 7.52m (S.D $\pm$ 1.65).

3.3 Anthropogenic data

3.3.1 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 MCRCP is presented in Figures 3.8 and 3.9. Overall, 61 boats were observed during 146 visits. The greatest amount of boat traffic of all sectors, with an average of 1.72 boats observed within 1 km per visit (Fig. 3.8) was at site PT which corresponds with the location of the main Marine Park centre. Less than 0.44 boats per visits were observed at the other survey sectors. 55% of all observed boats were engaged in tourism activities (pleasure and diving), with diving accounting for 23% of sighting and pleasure, (which includes snorkeling and swimming) accounting for 33% of boats observed. These were observed at survey sectors PT and PW which are located on the island of P. Payar where the Marine Park centre is located. Commercial boats represented 33% of boats observed and were located in all survey sectors except PS.

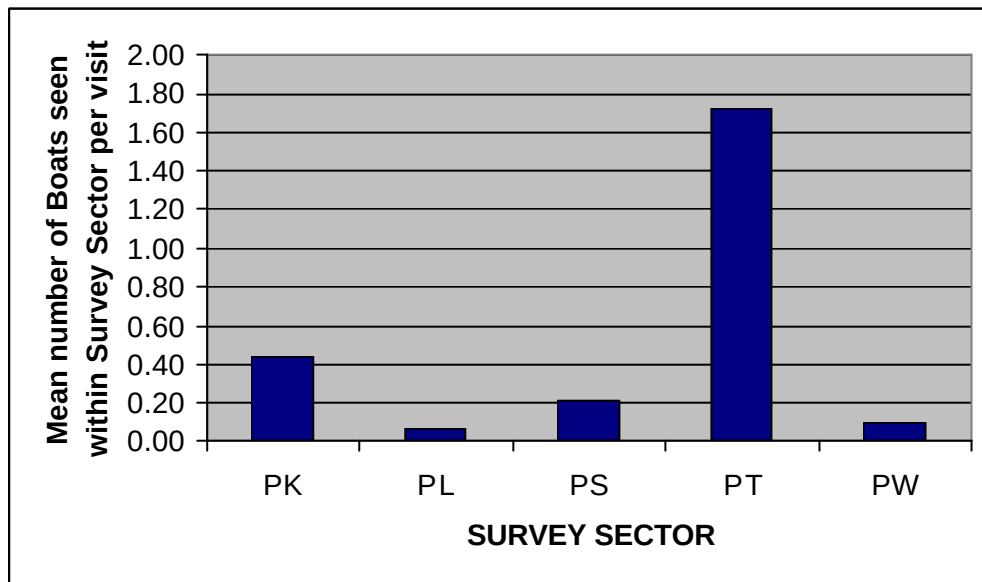


Figure 3.8. Mean frequency of boat sightings within 1 km of survey sites for each survey sector.

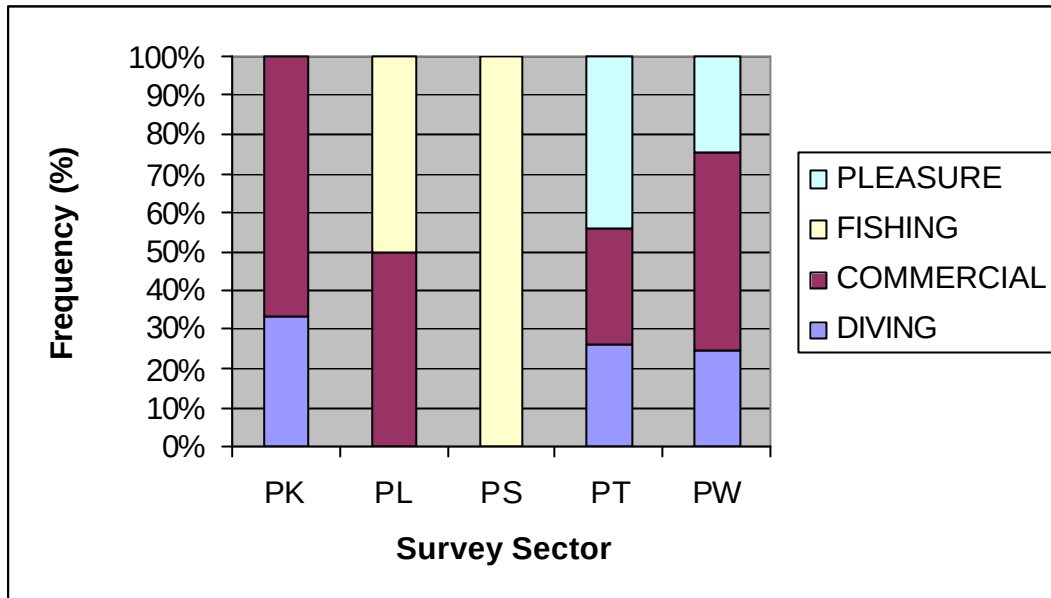


Figure 3.9. Percentage boat activity recorded within each survey sector.
Sample sizes; PK n=14, PL n=34, PS n=29, PT n=25, PW n=44.

Fishing vessels were those engaged in fishing at the time of the observation, i.e. with onboard personnel actively fishing and not in transit. Overall, fishing accounted for only 11% of all observed boats (figure 3.9). This low value is not surprising given that this is a Marine reserve. Fishing boats were only observed in Survey sectors PS and PL. Within commercial activities were classified those fishing boats arriving and departing the villages and boats used to supply both personnel and provisions sold locally to the tourist resorts. Boats observed at survey sector PS were solely undertaking fishing activities and those observed in Survey sector PL were engaged only in fishing and commercial activities. These survey sectors represent P. Sengantang and P. Lembo which are geographically furthest away from the Marine Park centre.

3.3.2 Surface and Subsurface Impacts

Environmental impacts to the surface and sub-surface water environment were recorded during surveys and have been presented in Figures 3.10 and 3.11 respectively. Surface water impacts were observed in all survey sectors. Litter was the commonest impact, with recordings in all survey sectors except sector PS. The highest levels of litter were observed in sector PT, PW and PK where 100% of recordings related to litter. Generally speaking, the remaining surface water impacts were distributed over a smaller spatial range and were found confined to one or two survey sectors. For example, discarded fishing nets were found only in sectors PS and PL and driftwood was only found in sector PL. ‘Other’ impacts, such as dead fish and discarded fishing apparatus were only noted at sector PS. It is encouraging to note that Sewage and Algae were not recorded at any of the survey sectors.

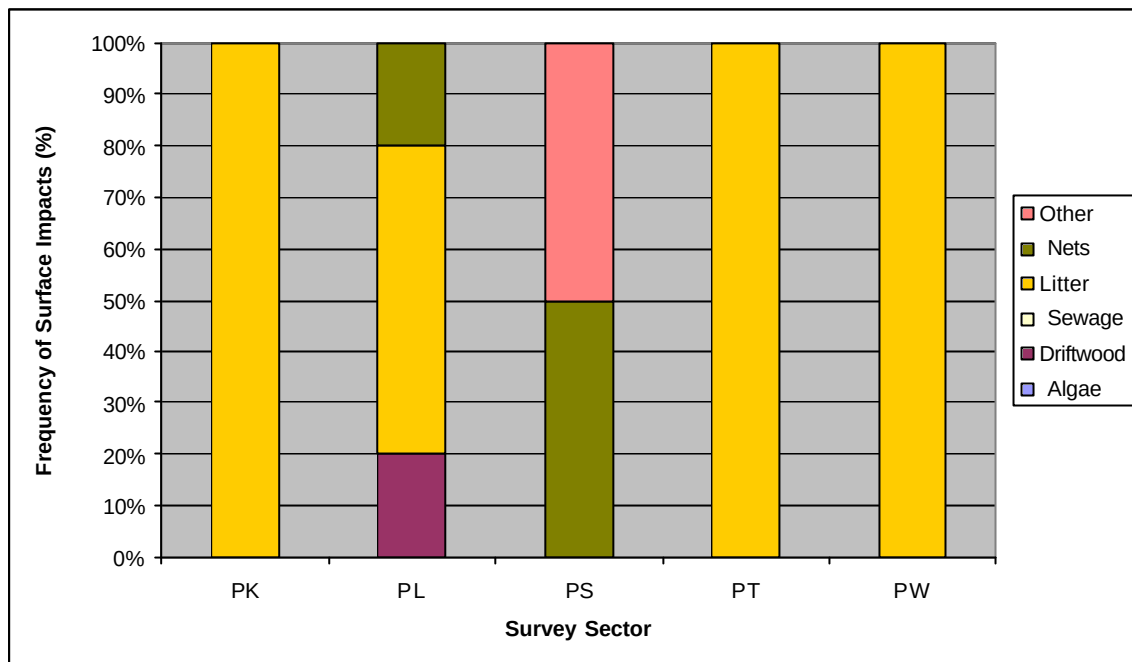


Figure 3.10. Percent frequency of the occurrence of surface impacts within each survey sector.

In comparison to surface impacts, a greater number of sub-surface water impacts were noted during surveys. Where impacts were present, they tended to occur on a higher percentage of surveys

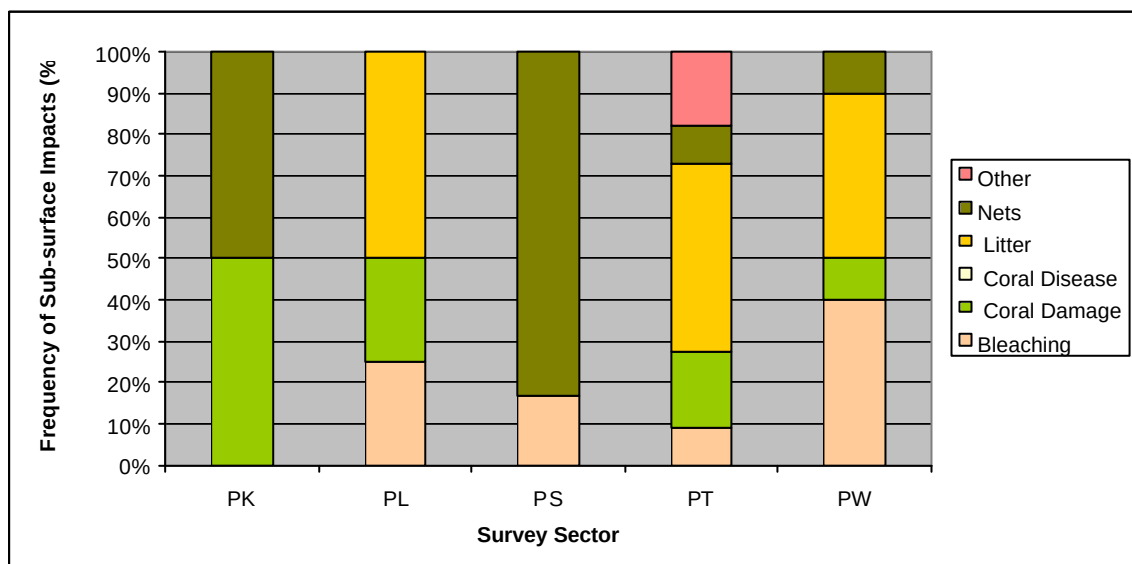


Figure 3.11. Percent frequency of occurrence of sub-surface impacts within each survey sector.

Bleaching was observed in four out of five survey sectors (PL, PS, PT, and PW) as was coral damage (PK, PL, PT, and PW) and Nets (PK, PS, PT, and PW). ‘Other’ damage, which consisted of rope was only observed at survey sector PT. Litter was observed at survey sectors PL, PT and PW.

3.4 Multivariate Analysis and Habitat Definitions

The following section presents the dendrogram produced by agglomerative hierarchical cluster analysis as outlined in the methods section (figure 3.12.). Secondly, using the characteristics of the habitats as defined by SIMPER and univariate analysis; a full and quantitative description of each habitat identified is presented in table 3.1.

It is hoped that this report, which outlines the multivariate defined habitats found in the coral reef communities around Pulau Payar Marine Park, will be used to form a wider resource map of the archipelago. Plans for a collaborative venture between CCC, Marine Parks and Malaysian Centre for Geospatial Data Infrastructure (MaCGDI) are, at the time of the writing of this report, being discussed. Collaboration will allow the overlaying of the field data presented in this report with high-resolution satellite imagery to produce detailed coral reef resource maps.

3.4.1 Habitat Descriptions

In total, seven statistically discreet habitat types or habitats have been defined from data collected around the Pulau Payar Marine Park. A quantitative description of each of these habitats is given in table 3.1. The values shown in parenthesis in these tables indicate the mean percentage cover of the variable recorded in the habitat in question.

Habitat one is characterised as being of high composition of Corallimorphs and anemones. This coverage has developed in this area on bedrock and is interspersed with patchy scleractinian of hard coral cover.

Habitat two is largely dominated by rubble that occupies 45% of the total area surveyed and subsequently classified into this habitat. Despite this, the small areas of bedrock were found to support some live hard coral growth.

Habitats 3, 6 and 7 represent the live hard coral communities. Habitat 3 is a community developed at the mid-reef slope and the communities of hard coral found in these areas coexist with patchy areas of rubble. By contrast, both habitats 6 and 7 are shallow reef crest high live hard coral communities. The average percentage live hard coral cover for these habitats has been calculated as 44% and 36% respectively. Of this coverage, by far the most dominant lifeform is the massive non-Acropora species and in particular members of the Genus Porites.

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 c^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.

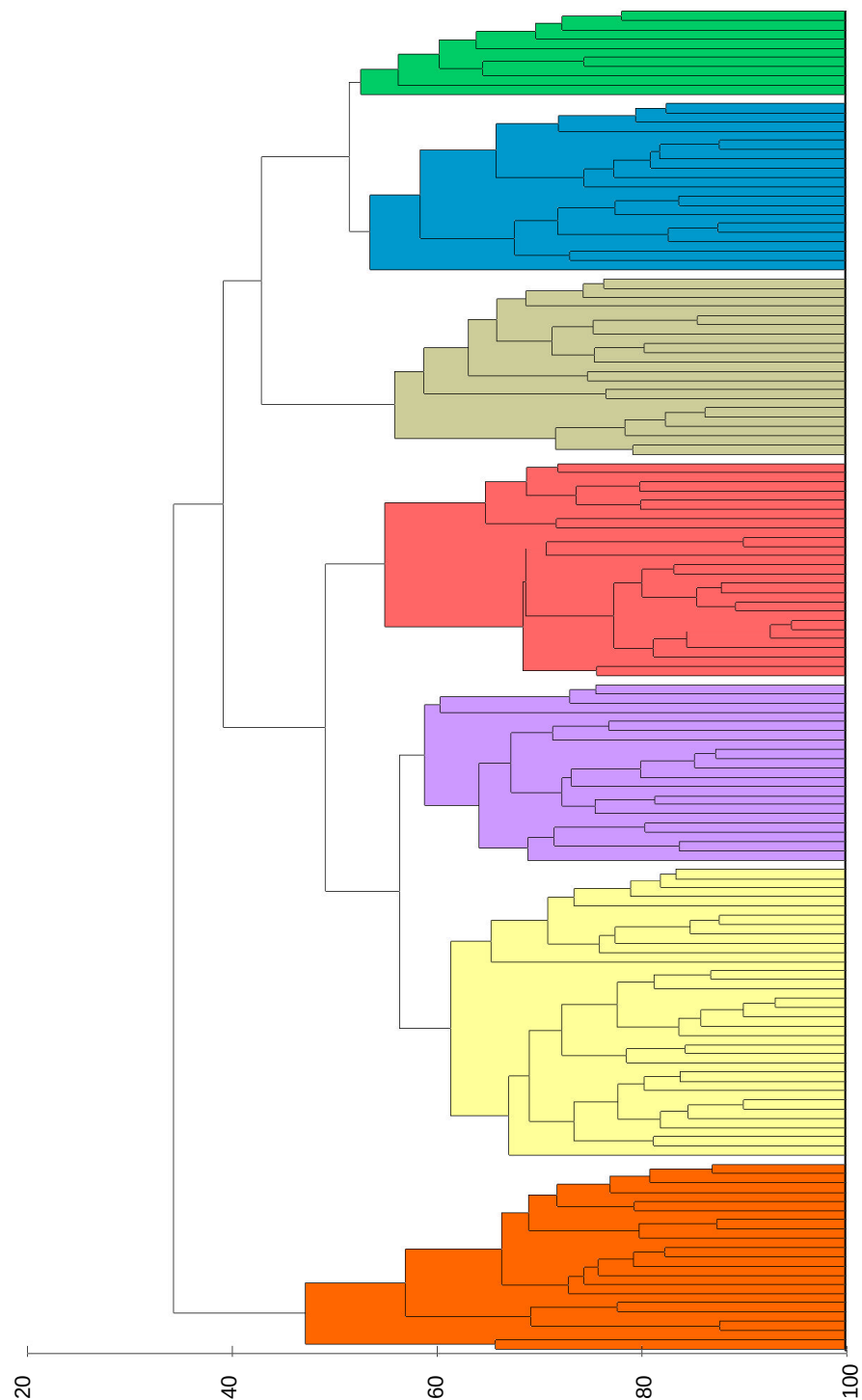


Figure 3.12. Dendrogram derived from cluster analysis of CCC survey data collected during the Pulau Payar Project. Each line represents benthic and substratum data from each Site Record. The different colours highlight the major clusters representing the habitats discriminated. Horizontal axis represents similarity as calculated with the Bray- Curtis coefficient (%).

Habitat	# surveys	Mean depth	Substratum	Hard Corals	Octocorals	Invertebrates	Sponges	Algae/ Seagrass
1 Corallimorph dominated cnidaria community developed on bedrock on the mid-reef slope	21	8.2	Bedrock (13.7), Rubble (10.1)	Total cover (10.2), Non-Acropora massive (3.6), Non-Acropora branching (3.0), Non-Acropora encrusting (2.0)	Total cover (0)	Corallimorph (38), Anemone (14)	Total cover (7.1)	Total cover (0.7), Rhodophyta (0.6)
2 Rubble dominated lower reef slope	32	9.1	Rubble (44.8), Sand (25.1), Bedrock (10)	Total cover (12.7), Non-Acropora massive (5.9), Non-Acropora encrusting (2.6)	Total cover (0)	Corallimorph (2.6), Anemone (1.1)	Total cover (0.4)	Total cover (2.1), Rhodophyta (1.2), Chlorophyta (0.9)
3 Mixed community of moderate cover live hard coral and algal assemblage interspersed with rubble patches	20	7.8	Rubble (24.5), Sand (15), Bedrock (14)	Total cover (24.6), Non-Acropora massive (11.1), Non-Acropora encrusting (8.8)	Total cover (0.7), Sinularia (0.4)	Corallimorph (5.3), Anemone (2.3), Mollusc (1.1)	Total cover (1.7)	Total cover (7.6), Chlorophyta (5.6), Green filamentous algae (4.2), Rhodophyta (1.8)
4 Sand dominated lower reef slope with patchy bedrock supporting diffuse live hard coral formation	24	11.0	Sand (58), Bedrock (12.1), Rubble (10.8)	Total cover (11.6), Non-Acropora massive (4.6), Non-Acropora branching (3.2)	Total cover (0.1)	Corallimorph (1.3)	Total cover (1.1)	Total cover (1.8), Rhodophyta (0.9), Chlorophyta (0.5)
5 Shallow, largely bare bedrock substrate with moderate and patchy live coral cover dominated by encrusting coral forms	20	3.2	Bedrock (59), Rubble (7.4)	Total cover (17.9), Non-Acropora encrusting (6.1), Non-Acropora massive (5.5), Non-Acropora branching (2.8)	Total cover (0.7), Sinularia (0.5)	Corallimorph (3.4), Mollusc (0.9)	Total cover (1.8), Lumpy (1.6)	Total cover (5.3), Phaeophyta (3.2), Brown filamentous (2.9), Chlorophyta (1.4)
6 High live hard coral cover upper reef slope community	19	4.4	Bedrock (19.3), Sand (14.1), Rubble (11.8)	Total cover (44.1), Non-Acropora massive (32.5), Porites massive (29.5), Non-Acropora encrusting (3.2), Non-Acropora foliose (3.1)	Total cover (0)	Corallimorph (4.1), Anemone (1.2)	Total cover (1.1)	Total cover (1.3), Chlorophyta (0.9), Green filamentous (0.9)
7 High live hard coral and mixed algae coverage community developed at the reef crest zone	10	4.9	Bedrock (15.8), Rubble (7.0)	Total cover (36.0), Non-Acropora encrusting (14.8), Non-Acropora massive (10.0), Non-Acropora foliose (4.5)	Total cover (0.3)	Corallimorph (6.5), Anemone (4.1)	Total cover (3.4), encrusting (2.5)	Total cover (20), Chlorophyta (7.6), Rhodophyta (7.6), Green filamentous algae (5.1), Red encrusting coralline algae (3.2)

Table 3.1. Quantitative description of the seven habitats defined from the data collected in the Pulau Payar Marine Park. Figures in parenthesis indicate mean percentage cover as assessed using the CCC point intercept transect surveys.

3.4.2 Univariate Measures of Habitat Biodiversity

Table 3.2 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 habitat.

Habitat three stands out as having the highest number of recorded target species present (53). This habitat is the mid reef slope, moderate live hard coral cover community. Habitat one that is the habitat dominated by large, mono-specific stands of Corallimorph is the habitat with the lowest number of target species recorded within sites representative of it.

Despite this, habitat one has a very high cover of live benthic organisms (75%) which is second only to the shallow reef crest community of mixed hard corals and algal assemblage representative of habitat 7 (94% live benthic organism cover).

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. Habitat five has the highest overall Shannon-Weiner diversity rating, with a calculated value of 2.92, this despite having one of the lowest coverage of live benthic organisms. Habitat one has the lowest Log_e Shannon-Weiner statistic as, has been mentioned before, it is dominated by large mono-specific stands of Corallimorph and anemones.

Habitat	Number of Species	Sum percentage cover of sessile benthic organisms	Log _e Shannon-Weiner Diversity	Mean percentage Live Hard Coral cover
1	39	74.57	2.08	10.19
2	49	20.69	2.67	12.69
3	53	52.40	2.71	24.60
4	40	20.33	2.73	11.58
5	49	37.20	2.92	17.90
6	44	55.47	2.13	44.11
7	45	93.60	2.77	36.00

Table 3.2. Univariate biodiversity measures of the fourteen Habitats derived from Cluster Analysis from data collected during the Pulau Payar phase of the MCRCP.

3.5 Fish Populations

The mean number of individuals observed at each transect for the most commonly encountered fish taxa are shown in descending order in table 3.3. The most commonly observed taxa are the fusiliers. These pelagic fish species are found associated though swimming above the reef feeding on planktonic food sources. The high corresponding standard deviation around the mean is as a result of the gregarious and schooling nature of fusiliers where hundreds could be observed in one survey and none in the next.

Damselfish were observed with an average abundance of 58.51 individuals per survey transect area of 200 m³. Whilst Damselfish do not display the same schooling behaviour as the Fusiliers, they do have a specific food source of turf algae, the distribution of which in turn is heterogeneous according to the habitat type. Accordingly, the standard deviation around the mean number of Damselfish individuals is very high.

Wrasse were the third most commonly recorded fish taxa with on average 20.5 individuals per 200 m³ area. However, this time the standard deviation around this calculated mean value is lower which indicates that they have a more ubiquitous distribution and are not confined to geographic areas represented by individuals transects.

Fish Taxa	Latin name	Mean no of individuals per 200 m ³	S.D
Fusilier sp.	Caesionidae	180.14	198.50
Damselfish sp.	Pomacentridae	58.51	134.20
Wrasse sp.	Labridae	20.48	46.69
Filefish sp.	Monacanthidae	12.59	36.48
Butterfly fish sp.	Chaetodontidae	11.59	11.17
Spine cheek sp.	Nemipteridae	7.72	11.20
Angelfish sp.	Pomacanthidae	2.20	20.71
Snapper sp.	Lutjanidae	1.50	3.77
Parrot fish sp.	Scaridae	0.88	1.75
Triggerfish sp.	Balistidae	0.71	1.46
Grouper sp.	Serranidae	0.61	1.34
Rabbit fish sp.	Siganidae	0.44	2.62
Cardinalfish sp.	Apogonidae	0.41	1.87
Anthias sp.	Serranidae	0.40	4.16
Goat fish sp.	Mullidae	0.10	0.41
Goby sp.	Gobiidae	0.04	0.20
Chromis sp.	Pomacentridae	0.00	39.75

Table 3.3. Calculated mean number of individuals observed per 200 m³ survey area assigned to each major fish family (or subfamily for Serranids) during CCC surveys of the MCRCP. Mean values $\pm$ SD given correct to 2 Decimal places (D.P).

3.5.1 Fish Assemblage variation between Survey Sector

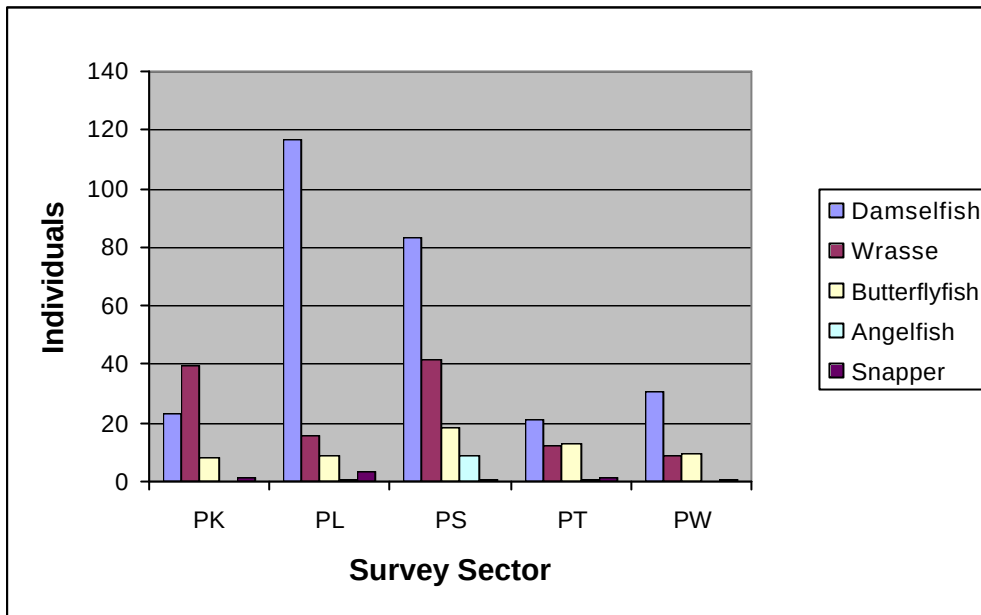


Figure 3.13. Commonly encountered fish families in each survey sector. Calculated mean number of individuals observed per 200 m³ survey area

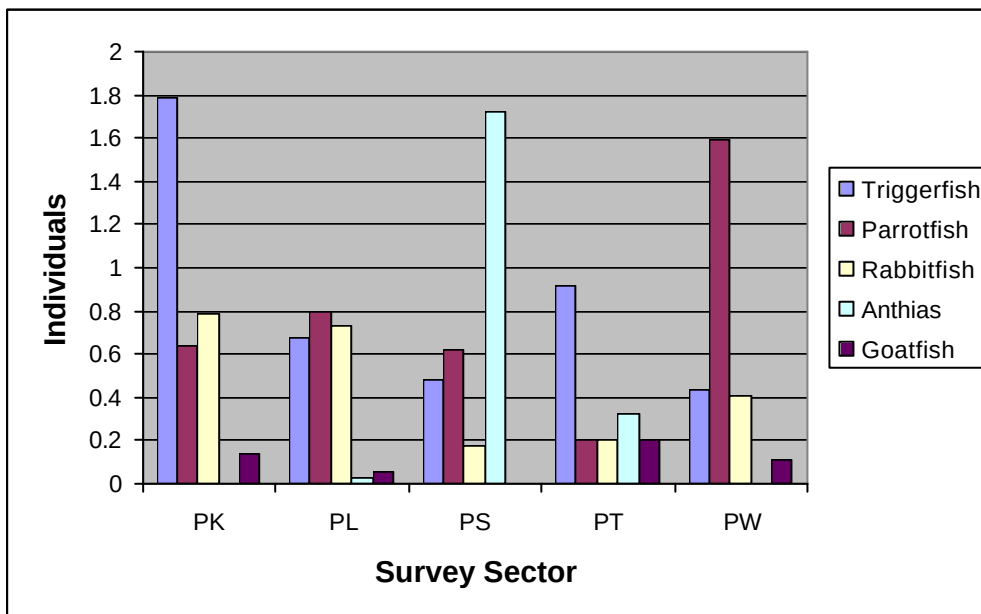


Figure 3.14. Less frequently encountered fish families in each survey sector. Calculated mean number of individuals observed per 200 m³ survey area

The most abundant encountered fish families per survey sector are shown in figure 3.13. The three most common families are Damselfish, Wrasse and Butterfly fish, which were abundant in all survey sectors. Damselfish were particularly abundant around Pulau Lembu, and Pulau Segantang that had high coverage of bare bedrock substrates which support the algal feeding habits of Damselfish. Overall, across all of

the survey sectors, Pulau Segantang had the highest number of fish individuals across all represented taxa.

Of the less frequently encountered fish families per survey sector (figure 3.14), Triggerfish, Anthias and Parrotfish were most commonly seen around Pulau Kaca, Pulau Segantang and the north side of Pulau Payar respectively.

3.5.2 Fish Assemblage variation between habitat types

The abundance of fish families (mean number of individuals per 200m³) found associated with each of the habitats defined by multivariate analysis and outlined in section 3.4.1 are graphically represented in figures 3.15 –3.16.

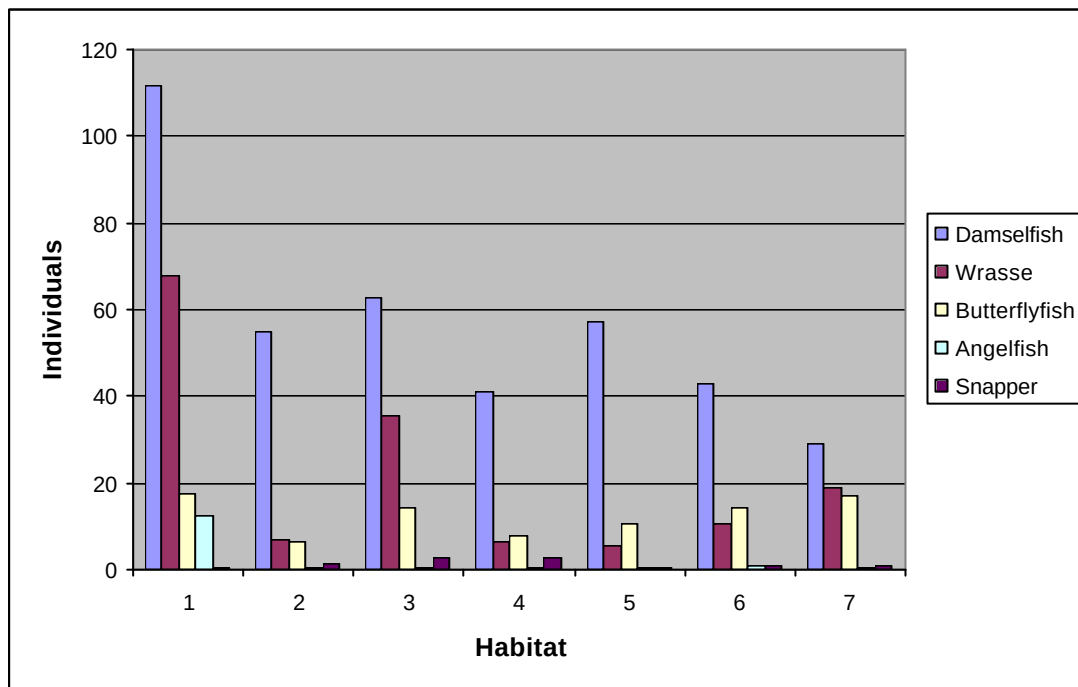


Figure 3.15. Mean abundance (individuals per 200 m³) of more frequently observed fish families found associated with each habitat..

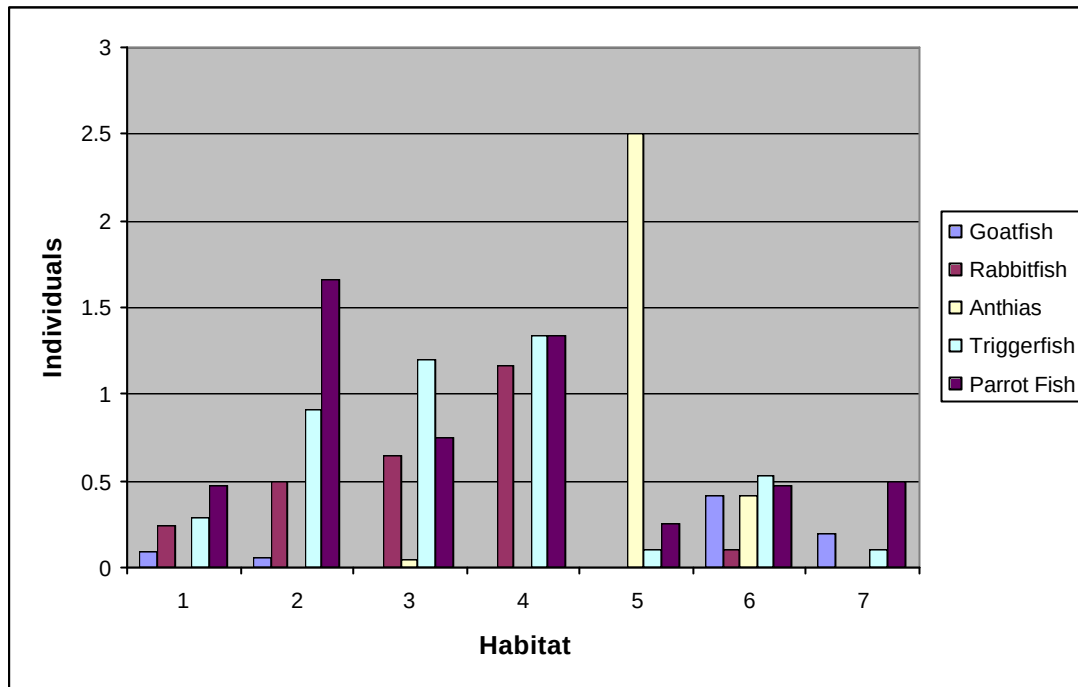


Figure 3.16. Mean abundance (individuals per 200 m³) of less frequently observed fish families found associated with each habitat.

The overall most abundant and ubiquitous fish family observed across all habitat types defined were the Damselfish (Pomacentridae). Whilst there was variation observed in the abundance of Pomacentrids between habitat types, their abundance did not fall below 25 individuals per 200m³ in any single habitat. Damselfish populations were found to be most abundant in areas classified as habitat one- the Corallimorph dominated areas in the mid reef slope depth range.

Habitat one had the highest overall abundance of fish individuals per 200m³ survey unit and also had the highest individual abundance of Wrasse, Butterfly fish and Angelfish, the second, third and fourth most commonly encountered fish taxa. However, Snapper were found to be absent from the areas classified as being habitat one.

Amongst the more rare fish taxa encountered, Triggerfish and Parrotfish were seen ubiquitously across all of the habitats. Anthias on the other hand were absent in all but two of the habitats and were found to be particularly abundant in areas classified as being shallow, largely bare bedrock areas at the reef crest- habitat 5. With the feeding behaviour of Anthias being of a pelagic, plankton feeding lifestyle, these areas which are exposed to current and therefore a high abundance of current borne plankton would be able to support a higher Anthia population density.

Table 3.4 shows the statistical relationship between fish assemblages found associated with each of the habitat types identified. The values in the table indicate the results of a multivariate pair-wise analysis between fish assemblages and values in bold marked with an asterisk indicate that there is a significant difference between the composition of these fish assemblages.

	1						
2	0.07 0.042*	2					
3	0.09 0.012*	-0.03 0.768	3				
4	0.08 0.013*	-0.04 0.922	0.02 0.24	4			
5	0.18 0.001*	0.09 0.026*	0.11 0.017*	0.17 0.001*	5		
6	0.13 0.003*	0.07 0.093	0.10 0.015*	0.15 0.005*	0.04 0.113	6	
7	0.14 0.077	0.07 0.23	0.06 0.169	0.16 0.028*	0.02 0.337	0.06 0.218	7

Table 3.4. 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.

Examination of table 3.4 indicates that the fish assemblages found associated with habitat one are very dissimilar to those found associated with all of the other habitats (5 of 6 pairwise comparisons showing significant differences) except for habitat 7 which, as has previously been discussed, is similar in community composition to habitat one as is of very high sessile organism coverage.

Perhaps surprisingly therefore, the fish assemblage found associated with habitat seven is similar in composition to all but one of the remaining habitats. When taken in context with the habitat descriptions however, it is clear that the mixed benthic organism community of habitat seven has components similar to all of the other habitats. This would therefore provide the similar ecological niches as all of the other habitats and therefore would be capable of supporting a similar fish community.

The number of reef fish species recorded and associated biodiversity indices for each habitat are depicted in table 3.5.

The greatest recorded species number was found within the fish assemblage associated with habitat two, though the overall number of individuals across all of the target species encountered was one of the lowest (952). Despite this, the fish assemblage associated with habitat 2 has the highest biodiversity status as calculated using the Shannon-Weiner and Marglef species richness indices.

By contrast, the number of species recorded associated with habitat one was relatively low, though the species that were seen were encountered with a very high abundance of an average of 1742 individuals per 50 meter transect line.

Habitat	Species Number	Sum of abundance ratings	Marglef Index of species richness	Pielous Evenness Index	Loge Shannon-Weiner Index	Simpsons Diversity
1	64	1742	8.44	0.58	2.42	0.86
2	76	952	10.94	0.52	2.26	0.83
3	74	1225	10.27	0.53	2.30	0.82
4	70	1153	9.79	0.51	2.15	0.81
5	62	855	9.04	0.59	2.43	0.86
6	72	1098	10.14	0.57	2.42	0.84
7	55	1072	7.74	0.60	2.42	0.84

Table 3.5. 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.

3.6 Invertebrate Populations

The mean abundance of selected invertebrate target organisms is shown as number of individuals per 250m² in table 3.6. The most commonly observed invertebrate was the Diadema or long-spined Sea Urchin which was seen with an average abundance of 130.4 individuals per 250m². Oysters were also seen with an average abundance of over 100 individuals per 250m² survey area. However, both these calculated mean values have around them a large Standard Deviation which implies that their distribution is heterogeneous.

With an abundance that is ten times lower than the Diadema and Oyster, the next most commonly encountered invertebrate is the non-synaptid Sea Cucumber which was seen with an average abundance of 10 individuals per 250m². Again, this mean calculated abundance has a very high Standard Deviation around it, which implies they were found with patchy distribution. In the case of the Sea Cucumbers, this likely results from their feeding method being dependent on a source of sand and soft sediment from which they extract organic matter; which in turn was only found at key selected survey sites at the base of the reef slope.

Taxa	Mean Abundance	Standard Deviation
Diadema Sea Urchin	130.4	178.40
Oyster	108.2	146.29
Non-Synaptid Sea Cucumber	10.0	41.94
Limpet	7.3	58.28
Giant Clam	7.3	48.28
Short spine urchin	3.8	18.68
Synaptid Sea Cucumber	3.6	26.20
Shrimp	3.0	17.38
Feather Duster	1.0	2.15

Table 3.6. Calculated mean number of individuals of each major invertebrate target species during survey dives during the MCRCP. Mean values given correct to 1.D.P $\pm$ SD given correct to 2 D.P.

4 DISCUSSION

4.1 Training

The training programme used during the MCRCP Pulau Payar Marine Park survey program 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

The prevalent wind direction recorded during the period of the program at Pulau Payar Marine Park was from the North and Northeast. This data was recorded during the period from October to March (2004-2005) during the monsoon period in the South China Sea on the East side of Peninsular Malaysia. Of these recordings, a proportion were assessed to be either moderate, strong or very strong.

Whilst wind speed and direction do not have a direct influence and impact on sub-tidal coral reef communities, they are the main driving influence behind both the direction and magnitude of wind borne waves. The magnitude of waves is proportional to the wind speed, though is also influenced by the distance over which the wind blows across the sea surface; the fetch of the wave. A short fetch leads to the formation of smaller, high frequency waves whilst a long fetch allows larger, oceanic waves with a lower frequency to develop. In turn the impact of these waves has direct influence on the coral reef community both through direct impact on the organisms themselves as well as controlling factors such as the dominant substrate types and geomorphology at sites.

Around Pulau Payar Marine Park, the prevalent wind direction has had a bearing on the type of coral reef formation as well as the deposition of sediments around the archipelago. Beaches that are depositional features are confined largely to the more sheltered south shores of the Islands and contrast the more exposed, rocky shorelines of the northern aspect coasts.

Both water temperature and, albeit to a lesser extent, salinity show variation between the upper two to three meters of water and the rest of the water column. Both water temperature and salinity are higher in this shallow zone. This commonly observed phenomenon in shallow tropical seas is as a result of the heating of the shallow water by the tropical sun and the consequential evaporation of surface water that increases the salinity of this layer.

Both horizontal and vertical visibility through the water column are indicative of the amount of suspended solids in the water column. All of the recordings of visibility made around Pulau Payar are generally low when compared to those taken using same standardised methodology by CCC at the East coast of Peninsular Malaysia Marine Park Islands. It is likely in some part that this presence of suspended solids in the water column comes from the Kedah river which is only 15 nautical miles away from the Marine Park. This river has a high flow rate and agricultural and urban

development along its banks would increase the amount of suspended solids and sediment being washed into the sea. Additionally, the extensive mudflats that today exist at the mouth of Kuala Kedah once supported coastal mangrove development. This mangrove forest would provide a barrier and filter between the riverine system and the neighbouring sea, removing and trapping sediments and nutrients from the river mouth. Today the mangrove has been removed there is little protection afforded to the coastal areas.

The coral reefs around the Pulau Payar Marine Park Islands are subject to a wide and varied degree of anthropogenic impacts.

Boat activity is concentrated in the main to the survey sector surrounding the Marine Park Center that receives in excess of 70,000 visitors per year (Lim, 1998). Of these boats, 45% have been identified as being engaged in the tourism industry and twenty five percent as being dive boats. This indicates a dense concentration of tourist users of the resource and has associated with it the potential to cause damage to the coral reef resource.

Given that Pulau Segantang is encompassed within the two nautical mile boundary of the Payar Marine Park area, it is perhaps suprising to note that of the boat activity observed when undertaking surveys in this area, all of the boats were engaged in fishing activities. Additionally, although only observed once, a boat actively engaged in fishing was also observed around Pulau Lembu. It is interesting to note that the occurrence of these fishing activities which is illegal under the jurisdiction of the laws relating to the management of the Marine Park of Malaysia, have all been noted far away from the Marine Park Centre and the enforcement patrols concentrated on the South shore of Pulau Payar.

By far the most commonly observed surface impact between all survey sectors was the occurrence of litter. It was observed on every survey dive conducted around Pulau Kaca and the north and south sides of Pulau Payar. It is assumed that much of this solid waste is derived from commercial activities in the Straits of Malacca and more locally through the disposal of solid wastes by tourists who visit the Marine Park Centre. This solid waste is not only aesthetically displeasing to the visiting resource users, but also poses a significant risk to the health and ecological function of the coral reef. The study of Lim (1998) found through questionnaires that 71% of reef-users (divers and snorkellers) rated clean beaches as the most important criterion for their continued enjoyment of the Marine Park.

The appropriate disposal of solid waste is therefore a key management objective of the Department of Marine Parks

4.3 Benthic Data

A total of seven benthic habitats have been identified from the data collected in the Pulau Payar Marine Park. This number is somewhat lower than that found from other studies conducted by CCC in the East Malaysian Peninsular Marine Park Islands as well as at other SE Asian coral reef areas. The coral reefs around Pulau Payar develop at depths shallower than those found elsewhere, likely as a result of the lack of availability of light in this semi-turbid environment (Lim 1998).

Of the seven benthic classes, three show moderate to high live hard coral cover and these three classes are found in the mid to upper reef slope. Below this zone are the areas that have mixed bare substrates of bedrock and also the depositional substrates of sand and rubble. Finally, at some of the more exposed sites, in the shallow areas, bare bedrock dominates and is colonised only by encrusting live hard coral forms that are able to withstand the physical disturbance of the prevalent high wave energy environment.

Comparison has been made between the data presented in this report and that collected and presented in the work of Lim (1998). The results of this comparison are illustrated graphically in figures 4.1 and 4.2 which shows the current benthic community composition found in the CCC dataset and that of the former study respectively. Additionally, the values of the main benthic cover categories are presented in table 4.1. The names of the sites refer to those used in Lim (1998) and the CCC data presented represents the average percentage cover values calculated from CCC survey sites that correspond with those in the work of Lim (1998). CCC sites on which this average has been calculated have been chosen to replicate the depth (within two meters) of the original 1998 surveys to minimise the environmental variation and therefore to facilitate a more meaningful comparison.

It appears from the time series of data presented here that there has been a clear decline in the percentage cover of the live hard coral between 1998 and 2005 at the survey sites at Pulau Kaca and the control site at the northern tip of Pulau Payar. The difference between the live hard coral cover in the two datasets at the two sites is 37 and 61% respectively whilst there has been an increase of the abiotic components of the benthic community of 54 and 81% respectively. Of this increase in the cover of the abiotic component of the community, over 90% can be attributed to an increase in the percentage cover of algae; additionally, whilst 67% of the hard coral community at Pulau Kaca was found to be of the branching lifeform in the 1998 study, branching corals were found to be all but absent in the 2005 study. This evidence indicates that some disturbance has affected these sites and has brought about the decline in live hard coral cover. Whilst it is not possible to directly attribute this impact to either an anthropogenic or natural disturbance agent, it seems likely that a natural event such as a storm may have caused the damage as both of these affected sites have a north-facing aspect whilst all of the south facing sites do not exhibit the same decline in live hard coral cover.

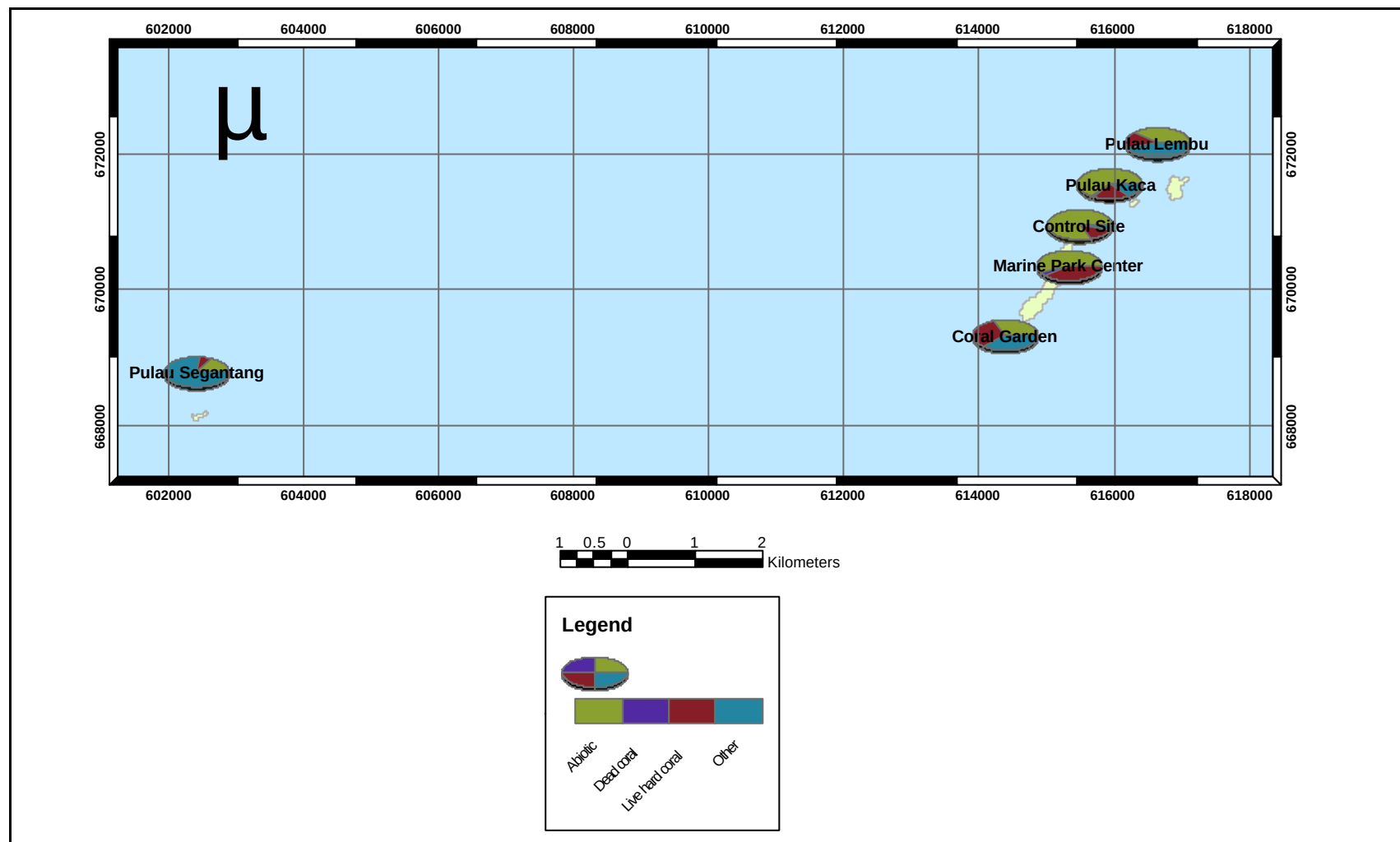


Figure 4.1 Percentage benthic community composition presented in this report and used in comparison with survey sites in Lim, 1998

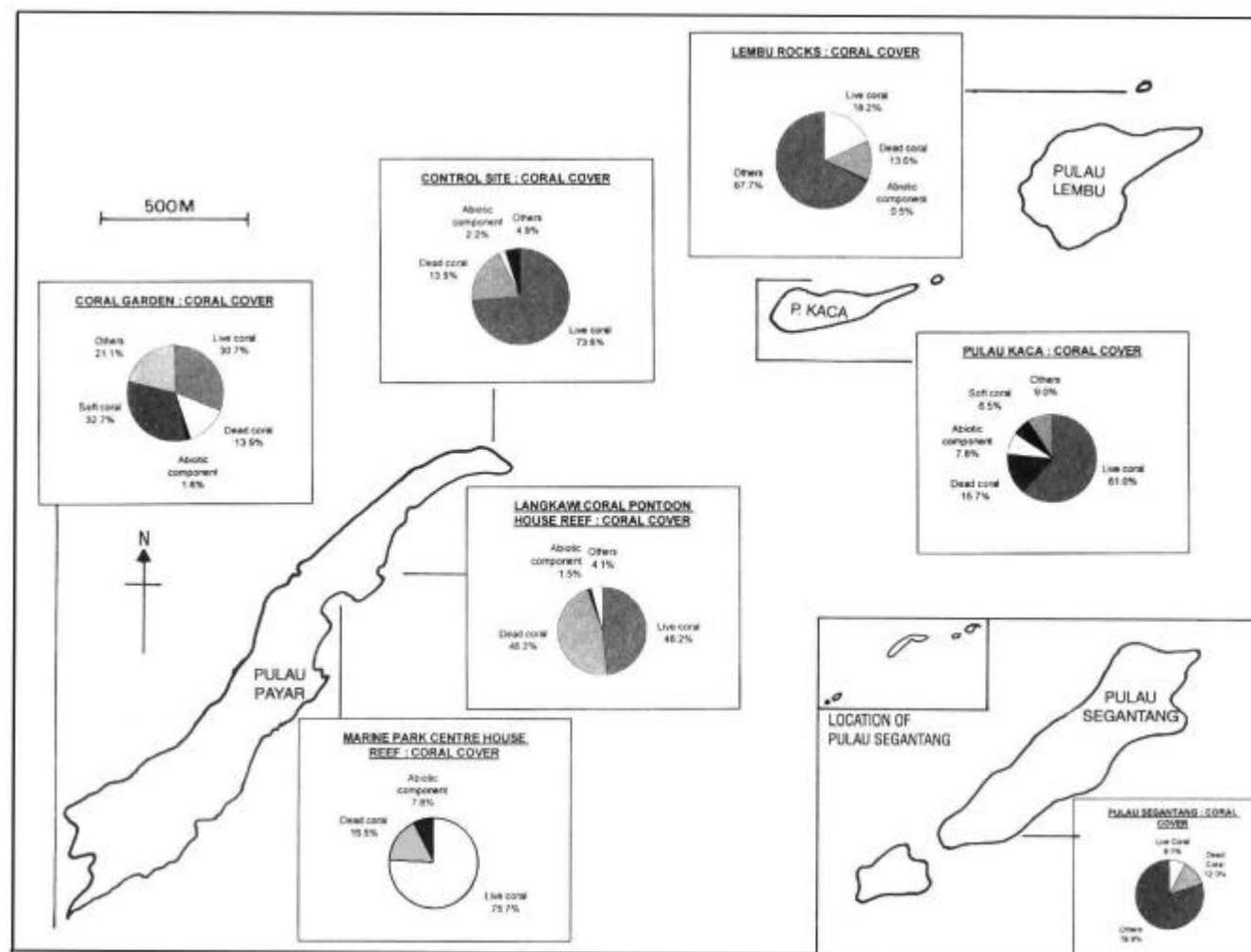


Figure 4.2 Percentage benthic community composition taken from Lim, 1998 and used in comparison with data presented in this report.

	Live Hard Coral		Dead Coral		Abiotic		Other	
	Lim	CCC	Lim	CCC	Lim	CCC	Lim	CCC
Pulau Kaca	61	24	16	2	8	62	15***	12
Pulau Lembu	18	14	14	0	1	40	67	46
Pulau Segantang	8	8	12	0	N/a	15	80	76
Marine Park Center	59*	42	32*	2	5*	56	2*	0
Coral Garden	31	27	14	0	2	33	52**	40
Control site	74	13	19	0	2	83	5	4

Table 4.1. Comparison statistics of percentage benthic community composition between Lim, 1998 and CCC, 2004-2005. *value calculated as mean value between two study sites in Lim 1998 (Langkawi Coral Pontoon and Marine Park Centre house reef), ** including 33% soft coral, ***including 7% soft coral,

4.4 Fish Data

Although it appears that fish populations in the Pulau Payar Marine Park Islands are fairly low in their abundance, there is a good representation of all of the major families. Particularly abundant were the Damselfish and Wrasse. Patchy distributions of taxa such as Anthias and Parrotfish indicate the link between the fish population dynamics and composition and the spatially distinct benthic communities.

The pairwise analysis of the interaction between fish assemblages in relationship to the habitat types they were found associated with indicates that around the Pulau Payar Marine Park, there is a close relationship between the two. Of particular note was the dissimilarity between the fish assemblages found associated with habitat one and those found associated with all of the other habitats. Additionally, when the univariate summary statistics of the fish assemblage associated with habitat one are examined, it is found to have the highest species number and, on average, the highest number of individuals. This is perhaps surprising given that habitat one has overall a low live hard coral cover and is instead dominated by Corallimorphs. Therefore it appears that from this data the Corallimorph dominated areas support a diverse and high-abundance fish community and therefore has importance for the management of the fish populations of Pulau Payar Marine Park.

4.5 Invertebrate Data

Invertebrate populations throughout the Pulau Payar Marine Park 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.

Crown of Thorns starfish (*Acanathaster plancii*) were not recorded on any of the to be low throughout all areas surveyed. 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 Redang Islands 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 lack of observations made in this study indicate that at present at least, COTs do not pose a threat to the coral reef resources of the Marine Park.

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 one of 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 Pulau Payar Marine Park. In addition, the large numbers of *Tridacna spp.* clams, which are also commercially viable species, indicates that the invertebrate population is well protected in the Pulau Payar Marine Park.

4.6 Indian Ocean tsunami

The December 2004 tsunami that originated from a sub-marine earthquake off the coast of Sumatra caused an enormous humanitarian tragedy in the wider Indian Ocean region and also specifically in the area of Northern Malaysia close to the Pulau Payar Marine Park. In the aftermath of the humanitarian disaster, it was also thought that there would have been serious damage done to the natural resources represented by the coral reefs of the region.

CCCs field personnel conducted a series of reconnaissance dives and recorded any signs of tsunami impact on the reefs of Pulau Payar. The outcome of this work is presented in the report Allen (2005), although no impacts that could be specifically attributed to the tsunami were recorded.

4.7 Management findings

Despite the fact that the apparent decline in live hard coral cover at selected sites between 1998 and this study cannot be attributed directly to either anthropogenic or natural disturbance, such a decline in live hard coral cover indicates that action is needed to ensure that these sites are efficiently managed. Additionally, it is a recommendation that use of monitoring techniques is made to assess the recovery process which is in turn an essential step towards ensuring this management strategy is of maximum benefit.

Based on visitor data up to 1997 Lim (1998) calculated there to have been a 5000% increase in visitor numbers to Pulau Payar Marine Park in the preceding seven years. This represents an intensive and concentrated use of what is a geographically limited resource base in the Marine Park. Of these visitors, all are day-trip visitors as there is no accommodation within the boundaries of the Park. Day-trippers in turn present their own unique range of management issues in contrast compared to more conventional tourism users. Whilst this predominance of day-trippers ensures that there are fewer problems in terms of development on the near shore, it brings with it the increased risk of solid waste disposal problems as characteristically, day-trippers leave their waste behind when departing.

There are a number of simple steps that can be taken to mitigate many of the impacts associated with such intense use of a natural resource. These can be divided into the following categories;

- Mitigation of direct impacts on the reef system

Effective and efficient zoning schemes where areas of coral reef that are most susceptible to impact are afforded extra protection is a successful mechanism for the conservation of the wider natural system. However, the implementation of such a zoning scheme needs, as it base a sound scientific understanding of the ecological and conservation importance of geographic areas. It is an aim following the assimilation of the data presented in this report to use it as a base of Geographic Information System one purpose of which will be the identification of these key sites

Additional mitigation activities include the installation of mooring systems to prevent direct impact of boat anchors on the coral reef system and the regulation of resource use activities.

- Increased public awareness

One of the most pro-active steps that can be taken towards the mitigation of tourism impact on reefs is the raising awareness of resource users. These initiatives include best practice guidelines involving pre-dive or pre-snorkel briefings and the provision of displays and videos that outline the impact that resource users can have.

All of the actions that can be taken to reduce the impact of such intensive tourism use should however be done in a participatory manner involving all resource users and conservation bodies so that the popularity and accessibility of sites such as Pulau

Payar can continue to be enjoyed and can continue to provide financial benefit to the local region and Malaysia as a Nation.

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APPENDIX I
CCC SURVEY RECORDING FORMS

BACKGROUND INFORMATION

Data Identifier _____	Start Easting _____
Survey code _____	Start Northing _____
Survey Date _____	End Easting _____
Start Time _____	End Northing _____
End Time _____	Wind Strength (1-6) _____
Marshall _____	Wind Direction (from) _____
Fish Recorder _____	Current Strength none / weak / mod / strong
Invertebrate Recorder _____	Current Direction (towards) _____
Point data Recorder _____	Horizontal vis _____
max depth _____	surface temp _____
min depth _____	surface salinity _____
	subsurface temp _____
	subsurface salinity _____
	Secchi disc _____

SURFACE IMPACTS

Algae ☐	Litter ☐
Driftwood ☐	Nets ☐
Surface sewage ☐	Other impacts _____

UNDERWATER IMPACTS

Bleaching ☐	Coral disease ☐
Coral Damage ☐	Litter ☐
Other impacts _____	

ACTIVITIES

Net Fishing ☐	Line Fishing ☐
Boating ☐	Snorkelling ☐
Diving ☐	Swimming ☐
	Other activities _____

SUBSTRATES		TARGET INVERTEBRATES		Target species	
Bedrock	1	<u>Porifera : Sponges</u>	13	<u>Pocilloporidae</u>	Merulin
Sand	2	Tube	13 27	Pocillopora: Small	Hydnop
Mud	3	Barrel	13 28	Medium	51
Dead Coral & Algae	4	Elephant Ear	13 29	Large	52
Dead Coral	5	Branching	13 30	<i>Seriatopora hystrix</i>	53
Rubble	6	Encrusting	13 31	<i>Stylophora pistillata</i>	54
		Lumpy	13 32		
		Rope	13 33	<u>Acroporidae</u>	
		Vase	13 34	Bottlebrush Acropora	55
				"Foliose" Montipora spp.	56
<u>MICRO-ALGAE</u>		<u>Octocorallia: Soft Coral Forms</u>	14	<u>Pontidae</u>	
<u>Cyano-Bacteria: Blue-Green</u>	7	Deadman's Fingers	14 35	Massive Porites	57
		Leather	14 36	<i>Porites cylindrica</i>	58
<u>MACRO-ALGAE</u>		Tree	14 37	<i>Porites nigrescens</i>	59
<u>Chlorophyta : Green</u>	8	Pulsing	14 38	<i>Porites rus</i>	60
Green Filamentous	8 1	Sea Fan	14 39	<i>Goniopora / Alveopora</i>	61
<i>Chaetomorpha</i> sp.	8 2	Sea Whip	14 40		
Marble (<i>Valonia ventricosa</i>)	8 3	Bamboo	14 41	<u>Agaricidae</u>	
<i>Bometella</i> sp.	8 4	Flower	14 42	<i>Pavona clavus</i>	62
Finger - <i>Neomeris</i> sp.	8 5	Sea pen	14 43	<i>Pavona decussata</i>	63
Grape - <i>Caulerpa</i> sp.	8 6			<i>Pachyseris speciosa</i>	64
Calcified - <i>Halimeda</i> sp.	8 7	<u>Other Cnidarians</u>	15	<i>Pachyseris rugosa</i>	65
- <i>Tydemania</i> sp.	8 8	Black Coral	15 44	<u>Fungidae</u>	
		Anemone (Sea and tube)	15 45	<i>Ctenactis echinata</i>	66
<u>Phaeophyta : Brown</u>	9	Zoanthid	15 46	<i>Herpolitha limax</i>	67
<i>Dictyota</i> sp. (Flat-Branching)	9 9	Jellyfish (Medusa)	15 47	<i>Polyphyllia talpina</i>	68
<i>Padina</i> sp. (Fan Blade)	9 10	Hydroid	15 48	Upsidedown bowl	69
<i>Lobophora</i> sp. (Blade/Ruffle)	9 11	Coralimorph	15 49		
<i>Hydroclathrus</i> sp.	9 12	<u>HARD CORAL</u>			
<i>Turbinaria</i> sp. (Pyramid)	9 13	<u>Life Forms</u>		<u>Oculinidae</u>	
Brown Filamentous	9 14	ACROPORA:	16	<i>Galaxea</i>	70
<i>Sargassum</i> sp. (Bladder)	9 15	BRANCHING	17	<u>Pectinidae</u>	
		ENCrustING	18	<i>Pectinia lecluca</i>	71
<u>Rhodophyta : Red</u>	10	SUBMASSIVE	19	<i>Mycidium elephantotus</i>	72
Encrusting coralline algae	10 16	DIGITATE	20	<u>Mussidae</u>	
<i>Galaxaura</i> sp.	10 17	TABULATE	21	<i>Lobophyllia</i>	73
<i>Amphiroa</i> sp.	10 18			<u>Favidae</u>	
<i>Jania</i> sp.	10 19	NOV-ACROPORA:	22	<i>Favia</i>	74
Red Filamentous	10 20	BRANCHING	23	<i>Favites</i>	75
Sheet	10 21	ENCrustING	24	<i>Diploastrea heliopora</i>	76
<i>Actinotrichia</i> - spikeweed	10 22	FOLIOSE	25	<i>Echinopora</i> spp.	77
Wiry branched	10 23	MASSIVE	26	<u>Euphyllidae</u>	
Fine branched - <i>Laurencia</i> spp	10 24	SUB-MASSIVE	27	<i>Euphyllia</i>	78
		MUSHROOM		<i>Plerogyra</i>	79
<u>MARINE PLANTS</u>		OTHER:	28	<i>Physogyra</i>	80
Sea Grass	11	FIRE (<i>Millepora</i>)	29	<u>Milleporidae</u>	
<i>Thalassia</i> sp.	11 25	BLUE (<i>Helopora</i>)	30	<i>Millepora platyphylla</i>	81
<i>Halophila</i> sp.	11 26	ORGAN PIPE (<i>Tubipora</i>)		<i>Millepora intricata</i>	82
Mangroves	12			<u>Dendrogyllidae</u>	
Molluscs	31			<i>Tubastrea micrantha</i>	83
Clams	31 89			<i>Turbinaria</i> sp.	84
Oyster	31 90				
Other bivalves	31 91				
Tunicates	32				
Bryozoans	33				

POINT	LIFEFORM	TARGET SPECIES
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POINT	LIFEFORM	TARGET SPECIES
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POINT	LIFEFORM	TARGET SPECIES
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<u>TARGET FISH</u>		SECTION A	SECTION B		SECTION A	SECTION B
<u>Butterflyfish</u>	1			<u>Wrasse</u>	56	
(Big) Long-Nosed	2			Diana's hogfish	57	
Klein's	3			Mesothorax hogfish	58	
Vagabond	4			Other hogfish	59	
Pyramid	5			Humphead	60	
Eastern Triangle	6			Red-banded	61	
Latticed	7			Checkerboard	62	
Redfin	8			Twotone	63	
Chevroned	9			Crescent	64	
Orange-banded Coral fish	10			Sixbar	65	
Copper-banded	11			Jansen's	66	
Eight-banded	12			Cigar	67	
Humphead Bannerfish	13			Bird	68	
Pennant Bannerfish	14			Cleaner	69	
Collared Butterfly	15			Sling-jaw	70	
Longfin Bannerfish	16					
<u>Angelfish</u>	17			<u>Goatfish</u>	71	
Regal	18			Half-and-half	72	
Bicolour	19			Two-barred	73	
Pearlscale	20			Dash-and-dot	74	
Emperor	21			Multibarred	75	
Blue-girdled	22			Blackstriped	76	
Vermiculated	23					
Blue-ringed	24			<u>Triggerfish</u>	77	
<u>Surgeonfish</u>	25			Redtooth	78	
Convict	26			Orangestriped	79	
Ringtail' spp.	27			Clown	80	
Brushtail tang	28			Blackbelly Picassofish	81	
Other tang	29			Pinktail	82	
Thompson's	30			Scythe	83	
Mimic	31			Halfmoon	84	
Eyestripe	32			Bluethroat	85	
Unicorn spp.	33			Picasso	86	
Yellowfin	34			Moustache / Titan	87	
<u>Tuna/ Mackerel</u>	35			<u>Groupers (not Anthias/Soapfish)</u>	88	
Narrow-banded king mackerel	36			Flagtail	89	
<u>Fusilier</u>	37			Peacock	90	
"Blue and yellow" sp.	38			Humpback	91	
Bluestreak	39			"Honeycomb" sp.	92	
				Lyretail	93	
				Blue lined	94	
				All groupers >30cm	95	
<u>Damselfish</u>	40			Anthias	96	
Blue-Green Chromis	41			Soapfish	97	
Black Bar Chromis	42					
Other "Chromis" sp.	43			<u>Parrot Fish</u>	98	
Blue devil	44			Bumphead	99	
Threespot dascyllus	45					
Humpbug dascyllus	46			<u>Spinecheek</u>	100	
Reticulated dascyllus	47			Twoline	101	
Whitebelly	48			Pearly	102	
Staghorn	49					
Behn's	50			<u>Snapper</u>	103	
Honeyhead	51			Two-spot	104	
Alexanders	52			Black-and-white	105	
Blackspot	53			Bluelined	106	
"Anemone fish" sp.	54			Spanish Flag	107	
"Sergeant" sp.	55			Chequered	108	
				Blackspot	109	

<u>TARGET FISH (CONT)</u>		SECTION A	SECTION B	<u>TARGET INVERTS</u>		SECTION A	SECTION B
<u>Rabbitfish</u>	110	☐	☐	<u>Annelid Worms</u>		☐	☐
Foxface	111	☐	☐	Segmented Worms	200	☐	☐
Virgate	112	☐	☐	Feather Duster	201	☐	☐
Golden	113	☐	☐	Christmas Tree	202	☐	☐
Starry One	114	☐	☐	Flatworms	203	☐	☐
<u>Dartfish</u>	115	☐	☐	<u>Anthropoda : Crustacea</u>		☐	☐
Blackfin	116	☐	☐	Banded coral shrimp	204	☐	☐
<u>Cardinalfish</u>	117	☐	☐	Other Shrimps	205	☐	☐
Pajama	118	☐	☐	Lobster	206	☐	☐
Blackstriped	119	☐	☐	Crab	207	☐	☐
<u>Puffer</u>	120	☐	☐	<u>Mollusca :</u>		☐	☐
Blackspotted	121	☐	☐	Gastropods:		☐	☐
<u>Goby</u>	122	☐	☐	Abalone	208	☐	☐
Sphinx	123	☐	☐	<i>Murex</i> sp.	209	☐	☐
Brownbarred	124	☐	☐	Conch	210	☐	☐
<u>Dottyback</u>	125	☐	☐	Cowrie	211	☐	☐
Darkstriped	126	☐	☐	Triton	212	☐	☐
OTHER MAJOR FAMILIES		☐	☐	Cone Shell	213	☐	☐
Jack / Trevally	127	☐	☐	<i>Drupella</i> sp.	214	☐	☐
Sweetlips	128	☐	☐	Limpet	215	☐	☐
Barracuda	129	☐	☐	Topshell	216	☐	☐
Moorish Idol	130	☐	☐	Nudibranch	217	☐	☐
Emperor	131	☐	☐	Other	218	☐	☐
Spadefish / Batfish	132	☐	☐	Bi-Valves:		☐	☐
Porcupine	133	☐	☐	"large" Oyster	219	☐	☐
Toby	134	☐	☐	Giant Clam	220	☐	☐
Trunk / Box / Cowfish	135	☐	☐	Chiton:	221	☐	☐
Blenny	136	☐	☐			☐	☐
Sweeper	137	☐	☐	Cephalopods:		☐	☐
Squirrelfish / Soldierfish	138	☐	☐	Cuttlefish	222	☐	☐
Filefish	139	☐	☐	Squid	223	☐	☐
Lionfish	140	☐	☐	Octopus	224	☐	☐
Scorpionfish / Stonefish	141	☐	☐	<u>Echinodermata:</u>		☐	☐
Lizardfish	142	☐	☐	Sea Stars:		☐	☐
Hawkfish	143	☐	☐	<i>Acanthaster planci</i> (COT)	225	☐	☐
Sandperch	144	☐	☐	<i>Linkia laevigata</i> (Blue)	226	☐	☐
Sharksucker	145	☐	☐	<i>Nardoa</i> sp. (Brown)	227	☐	☐
Needlefish	146	☐	☐	<i>Calappa novaeguineae</i>	228	☐	☐
Pipefish	147	☐	☐	<i>Protoreaster nodosus</i>	229	☐	☐
Shrimp fish	148	☐	☐	<i>Choriaster granulatus</i>	230	☐	☐
Trumpetfish	149	☐	☐	Other	231	☐	☐
Moray Eel	150	☐	☐	Brittle Star	232	☐	☐
Mullet	151	☐	☐	Feather Star	233	☐	☐
Rudderfish	152	☐	☐	Basket Star	234	☐	☐
FURTHER SPECIES		☐	☐	Sea		☐	☐
		☐	☐	Urchin:		☐	☐
		☐	☐	Short Spine	236	☐	☐
		☐	☐	Long Spine	237	☐	☐
		☐	☐	Pencil	238	☐	☐
		☐	☐	Sea		☐	☐
		☐	☐	Synaptid	239	☐	☐
		☐	☐	Cucumber:		☐	☐
		☐	☐	Edible	240	☐	☐
		☐	☐	Other	241	☐	☐