

STATUS REPORT ON THE CORAL REEFS OF THE EAST COAST OF PENINSULA MALAYSIA



- Prepared by -

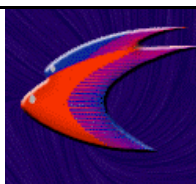
Alastair Harborne, Dr Douglas Fenner, Amy Barnes,
Maria Beger, Dr Simon Harding and Toby Roxburgh

2000



CORAL CAY CONSERVATION LTD
154 Clapham Park Road, London, SW4 7DE, UK
Tel: +44 (0)20 7498 6248
Fax: +44 (0)20 7498 8447
Email: marine@coralcay.org
www: <http://www.coralcay.org/>

- Report prepared in conjunction with -



MARINE PARKS SECTION
DEPARTMENT OF FISHERIES MALAYSIA
Wisma Tani, Jalan Sultan Salahuddin
50628 Kuala Lumpur, Malaysia
Email: mpark@dof.moa.my
www: <http://agrolink.moa.my/dof/>

- Funding provided by -



UNDP-GEF
Wisma UN, Block C, Komplek Pejabat Damansara
Jalan Dungun, Damansara Heights
50490 Kuala Lumpur
Malaysia
www: <http://www.undp.org/gef/>

CONTENTS

BACKGROUND	2
SUMMARY OF KEY FINDINGS	3
OVERVIEW OF SURVEY METHODS	4
REPORT STRUCTURE.....	6
EXTENT OF SURVEY WORK.....	7
SUMMARY OF THE STATUS OF THE REEFS OF PULAU REDANG, PULAU TIOMAN AND PULAU TINGGI MARINE PARKS	11
PARKS SUMMARY: PULAU REDANG MARINE PARKS.....	21
Site 1: Teluk Mat Delah, Pulau Redang.....	23
Site 2: Chagar Hutang, Pulau Redang.....	24
Site 3: Pulau Ling.....	25
Site 4: Pulau Lima.....	26
Site 5: Pulau Lang Tengah.....	27
Site 6: Terumbu Kili.....	28
PARKS SUMMARY: PULAU TIOMAN MARINE PARKS.....	29
Site 7: Batu Malang.....	31
Site 8: Teluk Juara, Pulau Tioman	32
Site 9: Pulau Gut.....	33
Site 10: Pulau Tokong Bahara.....	34
Site 11: Pulau Seri Buat.....	35
Site 12: Kadar Bay, Pulau Tulai.....	36
Site 13: Pulau Renggis.....	37
PARKS SUMMARY: PULAU TINGGI MARINE PARKS.....	38
Site 14: Teluk Jawa, Pulau Dayang.....	40
Site 15: Teluk Pontianak, Pulau Pemanggil.....	41
Site 16: Pulau Simbang.....	42
Site 17: Batu Tikus.....	43
RECOMMENDATIONS	44
ACKNOWLEDGEMENTS	45
REFERENCES	46
APPENDIX 1: SURVEY METHODOLOGIES	48
APPENDIX 1(A): CORAL BIODIVERSITY.....	48
APPENDIX 1(B): FISH BIODIVERSITY.....	51
APPENDIX 1(C): REEF ZONATION.....	52
APPENDIX 1(D): REEF HEALTH.....	54
APPENDIX 2: REEF PROFILE DATA ANALYSIS AND RESULTS	56
APPENDIX 2(A): MULTIVARIATE STATISTICAL ANALYSIS OF REEF PROFILE DATA.....	56
APPENDIX 2(B): RESULTS.....	58
APPENDIX 3: DESCRIPTION OF THE BENTHIC CLASSES FOUND DURING REEF PROFILE TRANSECTS.....	59
APPENDIX 4: CORAL SPECIES LISTS.....	61
APPENDIX 4(A): CORALS RECORDED AT EACH SITE.....	61
APPENDIX 4(B): NEW CORAL RECORDS FOR MALAYSIA.....	67
APPENDIX 4(C): NEW CORAL RECORDS FOR PENINSULA MALAYSIA.....	69
APPENDIX 5: FISH SPECIES LISTS.....	72
APPENDIX 5(A): FISH RECORDED AT EACH SITE.....	72
APPENDIX 5(B): NEW FISH RECORDS FOR MALAYSIA.....	80
APPENDIX 5(C): NEW FISH RECORDS FOR PENINSULA MALAYSIA.....	84

BACKGROUND

During 2000, the Marine Parks Section of the Department of Fisheries Malaysia (DoFM), Ministry of Agriculture, in cooperation with WWF-Malaysia (WWF-M) and the United Nations Development Programme (UNDP), developed a proposal for 'The Conservation of Marine Biodiversity in the Marine Park Islands in Malaysia'. The aim was for the proposal to be funded through UNDP by the Global Environment Facility (GEF). At the time of writing this report, the UNDP-GEF had provided project development funds (PDF-A and PDF-B).

The GEF project proposal encompasses the marine parks in three states, namely Terengganu, Pahang and Johor. Each area encompasses a series of marine parks, but for clarity they are subsequently referred to by the largest island in the group: the 'Pulau Redang Marine Parks' (state of Terengganu), 'Pulau Tioman Marine Parks' (Pahang) and the 'Pulau Tinggi Marine Parks' (Johor). The Establishment of Marine Parks of Malaysia Order 1994, conferred by the Fisheries Act 1985, came into force in December 1994.

Baseline data for the project sites include the DoFM and WWF-M collaborative surveys in 1994 (Aikanathan and Wong, 1994) and surveys undertaken by Lim and Spring (1997). Earlier in 2000, WWF-M undertook a series of surveys to update WWF-Malaysia's Biodiversity Report for the Tioman archipelago (Hendry, 2000). However, very little recent information exists on the status, health and biodiversity of the coral reefs at many proposed project sites. It is, therefore, impossible to determine whether trends indicate biodiversity loss and declining ecosystem health or whether some reefs are in good condition and restoration is occurring in the more impacted areas.

In order to fill the significant gaps in knowledge, a rapid, detailed field survey by Coral Cay Conservation Ltd (CCC) was proposed before the onset of the 2000 north-east monsoon (approximately November to March). The two key aims of the field team¹ were to document the project sites' biodiversity and to provide data on the health of the coral reefs. Surveys and data analysis were also intended to provide information to expand the initial threats analysis completed during the PDF-A phase.

This report documents the results of the CCC field survey.

¹ The CCC field team, assisted by DoFM staff, consisted of: Dr Douglas Fenner (DF, coral specialist), Maria Beger (MB, fish specialist), Dr Simon Harding and Toby Roxburgh (SH and TR, reef health and zonation surveys) and Amy Barnes (AB, logistics and training co-ordinator). DF and MB are affiliated to Australian Institute of Marine Science, PMB No 3, TMC, Townsville, QLD, 4810, Australia. Alastair Harborne (AH) joined the team following the field survey to co-ordinate data analysis and report production.

SUMMARY OF KEY FINDINGS

1. The marine parks of the east coast of Peninsula Malaysia constitute a globally important area of biodiversity, especially when considering the limited number of reef types (dominated by shallow fringing reefs). This is confirmed by a total of 221 coral species being identified during this study. This figure represents approximately 80% of the number of species identified at an equivalent number of sites in the 'Coral Triangle', which is known to have the greatest coral diversity on earth. Sixty seven species from this study had not previously been reported from Malaysia in published studies, giving a total of 323 for the country. One new species of coral (from the genus *Lobophyllia*) was collected for description and seven additional species may also prove to be undescribed. Four species were found which were previously thought to be endemic to other countries. Furthermore, a graph of species identified versus sites surveyed indicates that further survey effort will highlight a significant number of additional species.
2. The fish fauna of the marine parks is also globally important since a total of 298 species were identified during this study. Previous published studies indicated that 158 species found in this study were not previously known to be present in Malaysia and, following this study, approximately 450 species are now known from the country. There is also some evidence that, as for corals, the country has 80% of the number of fish species of the 'Coral Triangle'. Furthermore, a graph of species identified versus sites surveyed indicates that further survey effort will highlight a significant number of additional species, particularly cryptic species which were not recorded in this study.
3. Coral cover is a general indicator of reef health and this study indicates that the selected sites (mean cover of 42.2%) are at least in 'fair' condition, with some sites in 'good' condition (using the criteria of the ASEAN-Australia Living Coastal Resources project). The percentage of recently killed coral was relatively low (5.3%) and most seemed to be caused by corallivore feeding. Total non-coralline algal cover was less than 10% for all sites combined and this is consistent with the reefs being in fair to good condition. *Diadema* urchins were frequently seen but their densities varied dramatically. However, the explanation for this variation, and the effect of *Diadema* on the reefs, is not currently clear. Commercially important edible sea cucumbers and *Tridacna* clams were frequently recorded but few lobsters and no triton shells were seen, suggesting past over-fishing.
4. Although there are many healthy areas, reefs in the marine parks have been impacted by a variety of factors, including the 1998 coral bleaching event. Hence large sections appear to have significantly reduced coral cover. The overall ratio is difficult to estimate and will vary between and within each marine park. However, the presence of 'young' corals and the observation of a coral spawning event indicates that there are areas of reef which are sufficiently healthy, large and frequent to facilitate recovery in the more impacted areas. Increased protection for some of these healthy reefs areas, possibly via designation as 'sanctuary zones', will aid recovery by conserving sources of coral and fish larvae.
5. An obvious current impact to the marine parks is the result of mass coral bleaching in 1998 but the parks facilitate the best possible chance of recovery from this, and future, bleaching events. Nutrient runoff is a significant threat to reefs in the parks, particularly near to large population centres. Similarly, sedimentation from island deforestation would heavily impact the fringing reefs. Fishing appears well controlled and apparently low to moderate in the marine parks but abandoned gear was seen during the surveys. Corallivorous *Acanthaster planci* and *Drupella* were seen during this study but there were no major population outbreaks. Additional threats include mechanical coral damage from anchors, discarded refuse, divers and snorkellers and, while minimal at the study sites, are likely to be significant within the parks and will increase with increased tourism.

OVERVIEW OF SURVEY METHODS

Site selection and data collection

Since the scope of the proposed GEF project area is extensive (approximately 400 km from north to south) and the field work was limited to 21 days, surveys were targeted at a series of individual ‘sites’ at different islands in each group of marine parks. A key aim of the survey work was to document biodiversity and, therefore, the field team attempted to identify the ‘best’ reefs in the area for site locations i.e. areas with high coral cover, low anthropogenic impacts and perceived high species richness. The rationale was that such site selection was likely to document higher diversity than a random sampling regime and extrapolation of the results to the whole area would still be possible. Selections were based on a combination of existing data, local information (e.g. dive shops), local biologists and initial assessments (e.g. snorkelling and manta tows). It should be noted that although the team attempted to select the ‘best’ sites there is little evidence to suggest that they are indeed the healthiest or most diverse in the area and other equally good reefs certainly exist. However, the survey sites do provide a representative sample of the best reef areas in the three systems of marine parks.

Each site took one day’s surveying and generated a standardised data set to facilitate a summary of the overall biodiversity and reef health of the project area. The data set also allows powerful comparisons at a range of spatial scales, including between individual islands and each group of marine parks and with the wider Indo-Pacific region. At each site, data were collected on hard coral and fish diversity, reef zonation and semi-quantitative assessment of the major habitat types and reef health via a quantitative assessment of the benthic community and indicator invertebrate taxa. Full details of the methodologies are given in Appendix 1 but brief synopses are presented here:

Coral and fish biodiversity

DF (coral) and MB (fish) carried out two species counts, listing each species seen, at each site. These biodiversity estimates were conducted along plot-less transects from the base of the coral rich zone to shallow water (<5 m) and standardised to a total dive time of one hour. Using this technique allowed DF to compare the diversity of the area with other countries via previous research. In addition, quantitative counts of each fish species were recorded.

Reef zonation

To provide information on reef zonation, habitat diversity and general reef health, during the first dive at each site SH and TR (assisted by AB) conducted a reef profile assessment. This was achieved via a plot-less transect from just below the coral rich zone to shallow water (<5 m). The surveyors took depth readings every 10 m and, in each major habitat type, recorded the abundance of main components of the sessile benthic community and commercially and ecologically important motile invertebrates. Abundance was assessed using the five point ‘DAFOR’ scale and was complimented by basic oceanographic and anthropogenic impact data. This technique has been shown to be ideally suited for rapidly describing reef habitat types and data can be used to classify remotely sensed imagery when available (Raines et al., 1992; Mumby et al., 1995a; Mumby et al., 1995b).

Reef health

A quantitative assessment of reef health was undertaken by SH and TR (assisted by AB) during the second dive at each site. This assessment was conducted on the shallow forereef and was based on the ‘Reef Check’ protocol, which is a well established and reviewed method for rapidly assessing global reef health². The protocol utilised a 100 m transect, perpendicular to the shore, and one surveyor conducted a point intercept assessment of the

² <http://www.ReefCheck.org/>

benthic community and the second counted important invertebrate indicators of reef health. These data were complemented by an assessment of anthropogenic impacts. Reef Check data can be used in combination with transect information to assess overall reef health and provide a baseline for future comparisons.

Data analysis

Data from the biodiversity and Reef Check surveys were summarised using basic univariate statistics such as mean and standard deviation. Specific data relationships were analysed via regression analysis and expressed using the universally recognised ' R^2 ' coefficient (0= no relationship, 1 = perfect correlation). Analysis of habitat data from the reef profile surveys utilised more sophisticated multivariate statistics which are documented in Appendix 2. Descriptions of the resulting benthic classes are in Appendix 3.

REPORT STRUCTURE

This report is structured into three distinct levels of increasing spatial resolution. Firstly, there is an overall summary of the biodiversity, health and reef zonation of all three marine parks combined. This section also includes an overview of anecdotal, historical and regional evidence of current impacts and potential threats. Secondly, there are sections describing the biodiversity, health and reef zonation of each system of marine parks, along with anecdotal discussions of localised impacts and perceived threats. Finally, following each parks summary there are a series of site reports for each survey location in that particular area (17 in total). Each site report summarises the biodiversity, health and reef zonation of that locale, along with specific impacts and perceived threats.

The following notes are designed to aid interpretation of each section of the report.

Generally

- Coral communities are quantitatively described via percentage cover of ‘*Acropora*’ and ‘non-*Acropora*’. Such a division is often used 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. Total coral cover is a sum of these two parameters.
- Benthic classes discriminated within this study during reef profile surveys are not described in detail within the report because the key characteristics are summarised in Appendix 3. Benthic classes are highlighted throughout by quotation marks e.g. ‘Dense corals’.
- Total algal cover is the sum of ‘Non-coralline algae’ and ‘Dead coral + algae’. The latter category was only used if corallites could clearly be seen but much of the former was also growing on older dead coral.
- To conserve space, *Acanthaster planci* are subsequently referred to as *A. planci*.

Parks summaries

- Biodiversity data are minimal within the parks summaries because the key results are the findings for all three parks combined, which are presented in the overall summary.
- Since numerous fish species were unique to each park, their names are not listed in full in the parks summaries but are highlighted in Appendix 5(a).

Site reports

- The co-ordinates provided for each site are from a Global Positioning System (GPS) and are given using the Universal Transverse Mercator (UTM) system, within which the marine parks are in sector 48. The co-ordinates refer to the Reef Check transect location and were taken using the WGS-84 datum.
- Biodiversity data are minimal within these sections because the key results are the findings for all three parks combined, which are presented in the overall summary.
- Since numerous fish species were unique to each site, their names are not listed in full but are highlighted in Appendix 5(a).

EXTENT OF SURVEY WORK

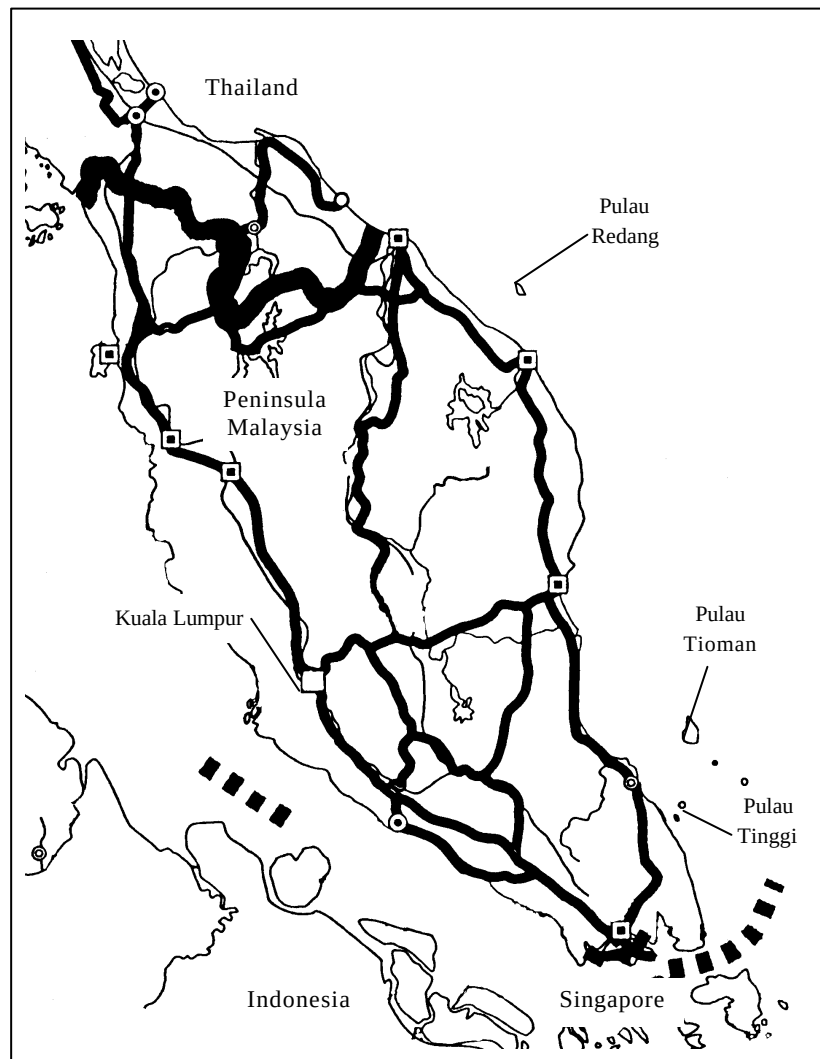
Sites completed and oceanographic and climatic conditions

Between the 9th and 27th September 2000, the field survey team completed a total of 17 sites in the three marine park areas. Of these sites, six were in the P. Redang Marine Parks, seven were in the P. Tioman Marine Parks and four were in the P. Tinggi Marine Parks.

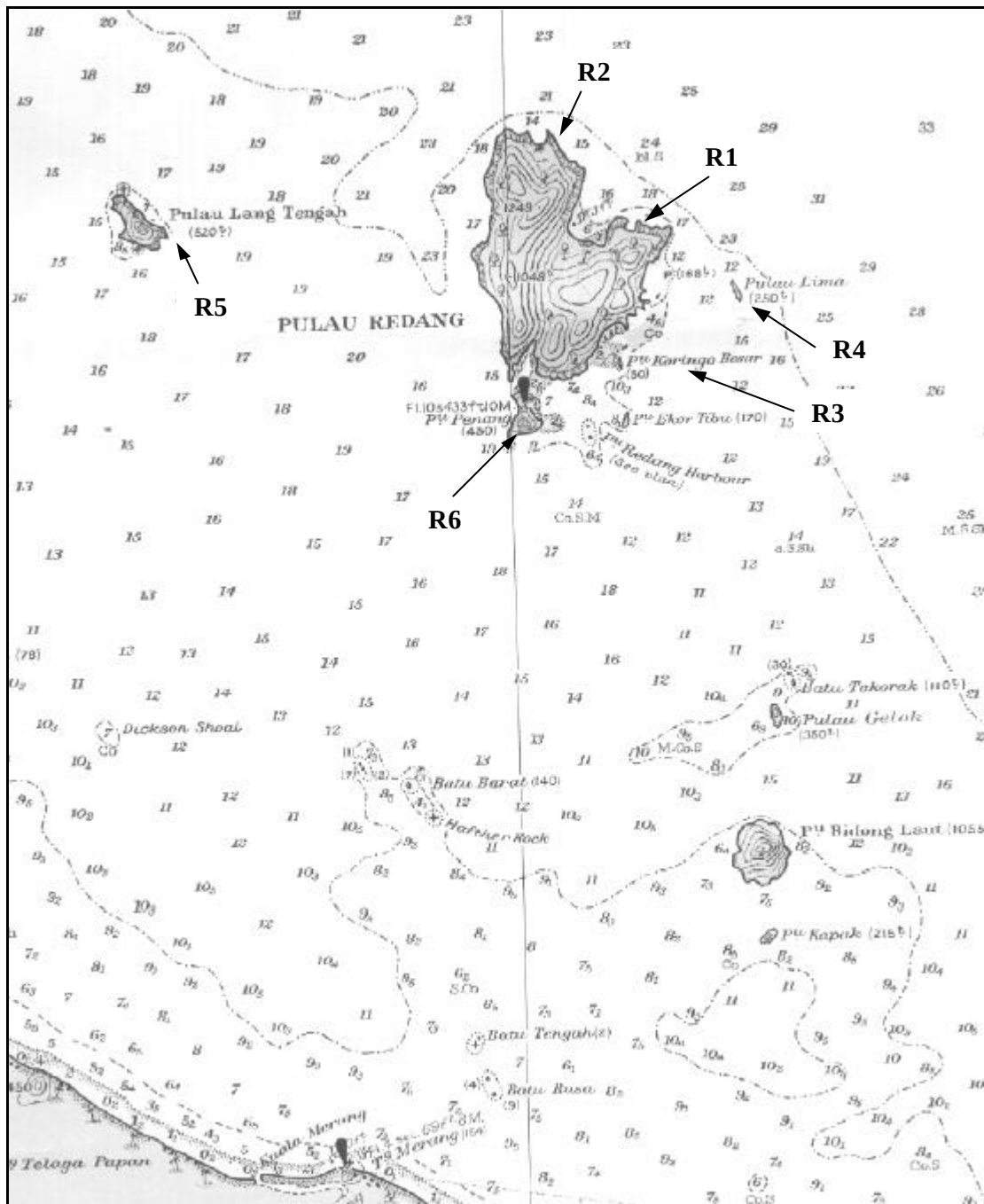
All surveys were carried out between 08.45 and 16.45, under generally sunny conditions (mean air temperature 31.2°C) with light winds, typically from the west. Currents were generally weak or absent. Water temperature was 28.9°C (SD = 1.3°C) with minimal variation throughout the water column. Salinity of the water column was 33.6‰ (SD = 0.6‰).

Site locations

The approximate locations of the 17 survey sites are shown on Maps 2-4. The overall project area is shown in Map 1. Within maps 2-4, site codes reflect those used during the fieldwork and the locations are schematic with more precise GPS co-ordinates given with each site report.



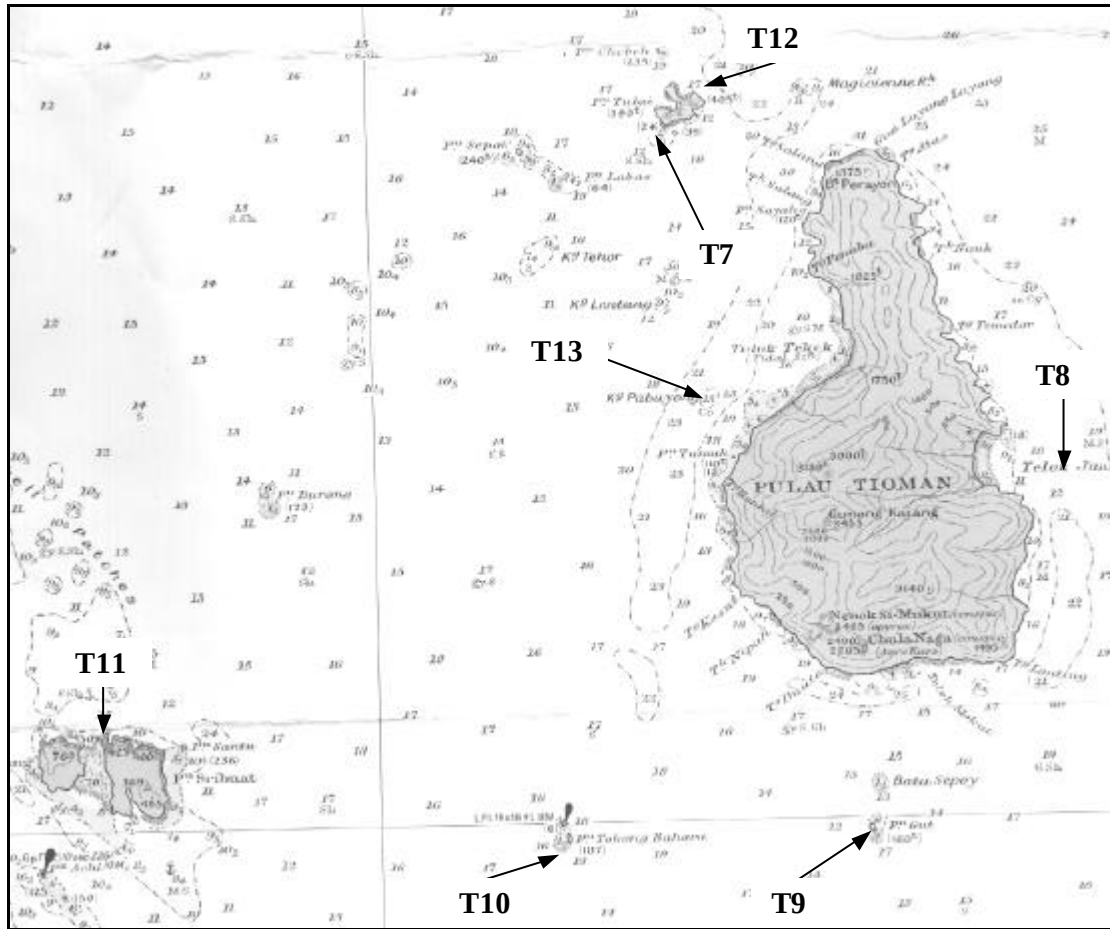
Map 1. Location of the Pulau Redang, Pulau Tioman and Pulau Tinggi Marine Parks.



Map 2. Survey sites within the Pulau Redang Marine Parks.

R1 = Teluk Mat Delah, Pulau Redang; **R2** = Chagar Hutang, Pulau Redang; **R3** = Pulau Ling; **R4** = Pulau Lima; **R5** = Pulau Lang Tengah; **R6** = Terumbu Kili.

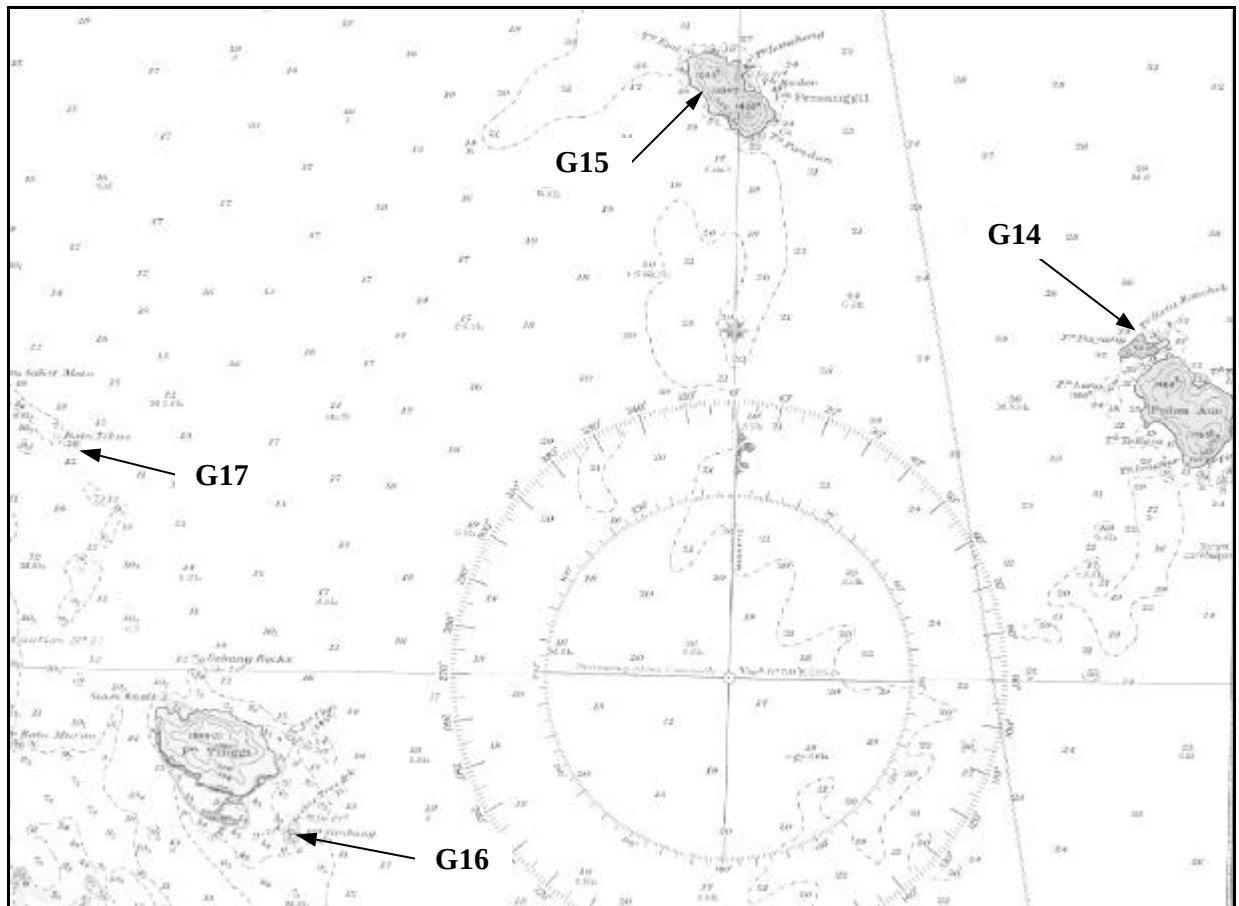
Source: Admiralty Chart 771 (Trengganu to Tumpat). Printed with corrections in 1992. All sounding in fathoms.



Map 3. Survey sites within the Pulau Tioman Marine Parks.

T7 = Batu Malang; **T8** = Teluk Juara, Pulau Tioman; **T9** = Pulau Gut; **T10** = Pulau Tokong Bahara; **T11** = Pulau Seri Buat; **T12** = Kadar Bay, Pulau Tulai; **T13** = Pulau Renggis.

Source: Admiralty Chart 769 (Sungei Sedili Besar to Kuala Pahang). Printed with corrections in 1992. All sounding in fathoms.



Map 4. Survey sites within the Pulau Tinggi Marine Parks.

G14 = Teluk Jawa, Pulau Dayang; **G15** = Teluk Pontianak, Pulau Pemanggil; **G16** = Pulau Simbang; **G17** = Batu Tikus.

Source: Admiralty Chart 769 (Sungei Sedili Besar to Kuala Pahang). Printed with corrections in 1992. All sounding in fathoms.

SUMMARY OF THE STATUS OF THE REEFS OF PULAU REDANG, PULAU TIOMAN AND PULAU TINGGI MARINE PARKS

Coral biodiversity

A total of 221 species from 66 genera of hard corals (215 species from 60 genera of zooxanthellate Scleractinia) were found in the three marine parks (Appendix 4(a)). Of these species, 216 were seen at the 17 sites and an additional five were seen during additional dives or snorkels. Several further 'species' were sighted, but could not be identified without collecting samples. The number of species identified during this study is approximately 80% of the number (and at least 94% of the genera) identified by the same author (DF) using the same method at an equivalent number of sites in the Philippines, Indonesia and Papua New Guinea. In this study, there were a total of 202 species at 17 sites (counting only one dive per site for comparison with the other studies), while there were 249 species in the Philippines, 257 in Papua New Guinea and 250 in Indonesia. These three countries are known as the 'Coral Triangle' since they have the greatest diversity of species. Each has over 400 species of coral reported and a number of additional species yet to be published. Hence the east coast of Peninsular Malaysia has a very high coral species richness and can be considered to be a globally important area of coral biodiversity.

Among the 226 species identified in this study, 67 species had never been reported in previous published studies from anywhere in Malaysia, including Sarawak and Sabah (Searle, 1956; Pillai and Scheer, 1974; de Silva et al., 1980; Betterton, 1981; Veron, 1983; Rahman, 1986; Wood and Tan, 1987) and are listed in Appendix 4(b). However, it would be necessary to collect specimens before this list could be confirmed and formally published. The total number of species now known from published literature for Malaysia is 323, again approximately 80% of the number reported from the 'Coral Triangle' (about 411 species). A total of 346 species for Malaysia is reported by Ridzwan (1994) but its validity is not clear and appears to originate from unpublished studies and anecdotal reports. Only comparisons with published lists are undertaken in this report and it is recommended that the more conservative totals are cited.

Of the 226 coral species identified in this study, a total of 119 species (Appendix 4(c)) had not previously been reported from Peninsular Malaysia (both coasts) by previous published studies (Pillai and Scheer, 1974; de Silva et al., 1980; Betterton, 1981; Rahman, 1986). This indicates that the area has not been well studied in the past but previous publications did report 44 species not found in this study, bringing the total number of species currently known from Peninsular Malaysia to 270, or 84% of those known from the entire country.

Among the species identified in this study, a few are of particular importance. One new species, from the genus *Lobophyllia*, was discovered and a sample taken (from outside the marine parks) to facilitate a full description for publication. Furthermore, four species were found which had each previously been reported from only one country. Three (*Montipora confusa*, *Pachyseris foliosa* and *Oxypora crassispinosa*) had previously been reported only from the Philippines and *Coscinaraea hahazimaensis* had been reported only from Japan. Each of the four species was rare at the study sites.

Figure 1 shows the correlation between the number of survey sites and the cumulative number of species identified. The curve represents a logarithmic relationship since this provides an excellent correlation ($R^2 = 0.98$). Figure 1 shows that the curve is still increasing steadily and supports the view that additional studies of Malaysia's corals will reveal many more species.

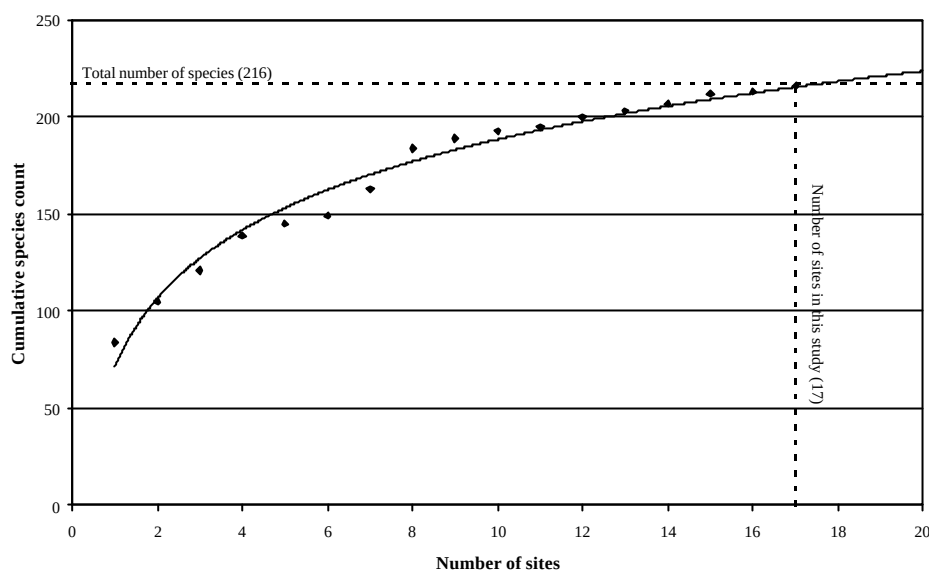


Figure 1. Curve showing the logarithmic relationship between number of sites surveyed and cumulative number of corals species identified in this study.

Table 1 shows the number of hard corals in each group of marine parks and the average number of species per site. To facilitate an accurate comparison between the marine parks, Table 1 also shows the total number of species in the first four sites, since this was the minimum survey effort in any one park (P. Tinggi). Differences between the three marine parks were relatively small and there was no clear pattern of varying biodiversity. However, there is some evidence that P. Redang has the fewest species, even though it had the highest number per site, but this could be a learning effect since P. Redang was surveyed first and the surveyor was still becoming accustomed to the area.

Table 1. Comparison of the number of coral species in each of the three marine parks. Standard deviations in parentheses.

Marine park	Total number of species	Total number of species in first 4 sites	Mean number of species per site
Pulau Redang	149	139	87.2 (6.3)
Pulau Tioman	183	166	82.9 (13.6)
Pulau Tinggi	155	155	81.0 (1.4)

Fish biodiversity

A total of 298 species of fishes from 44 families and 132 genera were found in the coral reefs of the three marine parks (Appendix 5(a)). Previous published studies of Malaysian reef fish reported 171 species for Peninsular Malaysia (Rahman and Ibrahim, 1996; Sin et al., 1994). Additional early studies (e.g. Fowler, 1938) included freshwater and non-reef fish and also used many names which are no longer used by fish taxonomists. Hence, it is currently not possible to determine how many reef fish were included or what area of Malaysia they were recorded from. As shown in Appendix 5(c), 200 of the 298 species recorded in this study were not recorded by Rahman and Ibrahim (1996) and Sin et al. (1994), indicating that the area has been poorly studied. A total of 362 species of fish are now known from Peninsular Malaysia.

In addition to studies of Peninsula Malaysia, Wood and Wood (1987) reported 171 species of fish in Sabah. However, 158 species recorded in this study have never been previously

reported in a published report from anywhere in Malaysia, including Sarawak and Sabah (Appendix 5(b)). When all studies are combined, the total number of coral reef fishes known for the whole of Malaysia is approximately 450. This is significantly higher than the 326 species reported by Ridzwan (1994), although the origin of this total is not clear and appears to originate from unpublished studies and anecdotal reports. Therefore, the east coast of Peninsular Malaysia has approximately 80% of the number of species known from the entire country, significantly higher than the figure of 43.9-55.2% given by Ridzwan (1994). Finding 80% of the fish fauna of the whole country on the east coast of Peninsular Malaysia is a very similar result to that for corals (84%). This concurrence with the better studied coral community supports the conclusion that the east coast of Peninsula Malaysia has approximately 80% of the entire country's reef fish fauna. Indeed the area may have a similar percentage of the fish fauna of countries in the 'Coral Triangle', as is the case with corals. There is also some evidence for this hypothesis from the Pomacentridae (damselfish). This study documented a total of 50 species (17 more than the 33 species previously reported from Peninsular Malaysia; Sin et al., 1994) and 51 additional species have been identified by Rahman and Ibrahim (1996), Wood and Wood (1987) and Sin et al. (1994). A total of 101 species of damselfish from Malaysia is 82% of the total from Indonesia and 86% of the total from the Philippines (Allen, 1991). Hence the east coast of Peninsular Malaysia has a very high fish species richness and is a globally important area of fish biodiversity.

Figure 2 shows the correlation between the number of survey sites and the cumulative number of species identified. The curve represents a logarithmic relationship since this provides an excellent correlation ($R^2 = 0.98$). Figure 2 shows that the curve is still increasing steadily and supports the view that additional studies of Malaysia's fish will reveal many more species. There was no correlation between fish and coral species richness at each site ($R^2 < 0.05$).

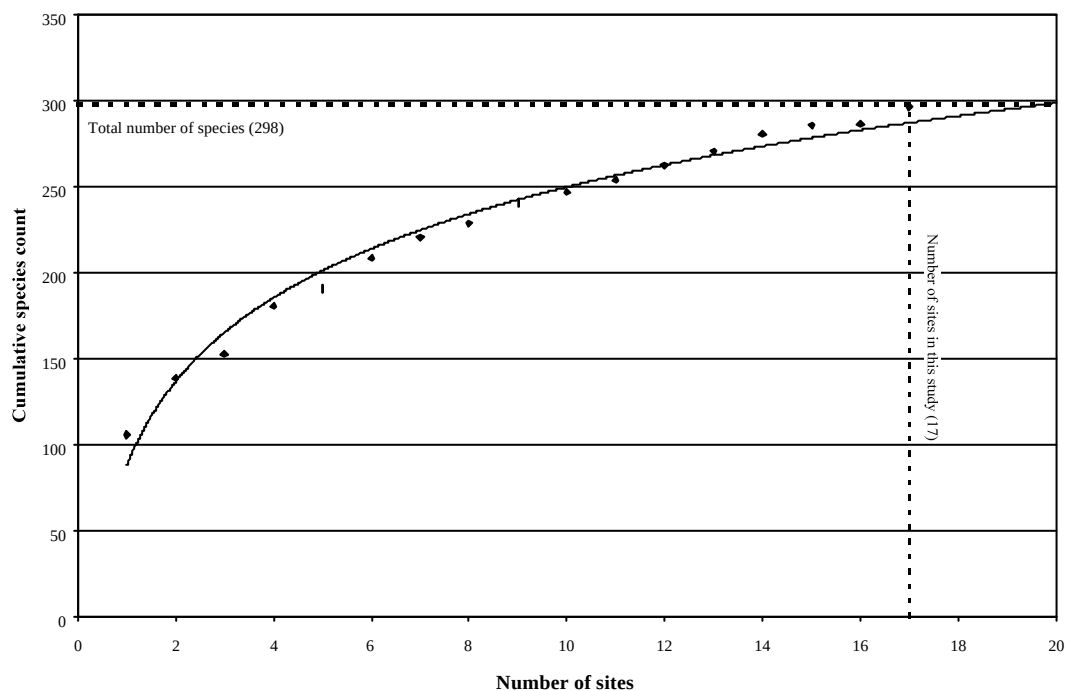


Figure 2. Curve showing the logarithmic relationship between number of sites surveyed and cumulative number of fish species identified in this study.

Since this study used a visual census, large numbers of cryptic species were not surveyed and represent an additional component of the fish fauna of the east coast of Peninsula Malaysia. Families such as Gobiidae (gobies) and Blennidae (blennies) cannot be adequately sampled without using a poison which also affects the benthic community and non-target fish species.

Table 2 shows the number of fish in each group of marine parks and the average number of species per site. Table 2 also shows the total number of species in the first four sites, since this was the minimum survey effort in any one group of parks (P. Tinggi). Differences between the three groups of parks were relatively small and there was no clear pattern of varying biodiversity. However, there is some evidence that P. Redang has the fewest species and that species richness increases from north to south, but this could be a learning effect since P. Redang was surveyed first and P. Tinggi last.

Table 2. Comparison of the number of coral species in each of the three marine parks. Standard deviations in parentheses.

Marine park	Total number of species	Total number of species in first 4 sites	Mean number of species per site
Pulau Redang	209	181	120.0 (16.2)
Pulau Tioman	233	193	132.4 (15.4)
Pulau Tinggi	219	219	130.5 (19.1)

During this study, schools of *Bolbometopon muricatum* (bumphead parrotfish) were sighted, along with some *Carcharhinus melanopterus* (blacktip reef sharks) and occasional adult *Plectropomus* spp. and large *Epinephelus polyphekadion* (marbled grouper). These species are known to be locally extinct or very uncommon in many parts of the Indo-Pacific region and their presence within the marine parks supports the conclusion that fishing pressure is low or moderate. Large fish are very sensitive indicators of fishing pressure, since they are the first to be removed (Jennings et al., 1999). It is possible that populations of the large and long-lived fish will increase further within marine parks in the future.

Reef zonation

The reef profile transects at each site discriminated a total of ten benthic classes, which are shown in Table 3. The full characteristics of each class are described in Appendix 3.

Table 3. Benthic classes found by reef profile transects, their occurrence in each marine park and notes on their distribution.

Benthic class	Occurrences in each marine park			Distribution
	P. Redang (6 profiles)	P. Tioman (7 profiles)	P. Tinggi (4 profiles)	
Bedrock and <i>Acropora</i> rich corals	3	0	0	Restricted to P. Redang, generally in shallow water (<10 m).
Bedrock and mixed corals	1	1	1	Generally in wave exposed shallow water (<7.5 m) except P. Redang.
Bedrock and non- <i>Acropora</i> rich corals and octocorals	1	0	2	Found at a variety of depths, including deep water (>18 m).
Dense corals	4	6	3	Main benthic class in coral rich zone (approximately 5 – 15 m).
Rubble / sand and sparse algae and corals	6	2	2	Main benthic class below coral rich zone (generally >15 m).
Rubble and mixed corals, invertebrates and algae	0	3	0	Generally in deep water below coral zone but once across whole profile.
Rubble and sparse algae and corals	1	0	2	Below coral zone (P. Tinggi) but in shallower water in P. Redang.
Sand / bedrock boulders and scattered corals	0	1	1	Found in very shallow water (< 5 m).
Sand / rubble and scattered corals	0	1	1	Found in very shallow water at P. Tinggi but deeper at P. Tioman.
Sand / silt	0	2	0	Found below coral rich zone in relatively deep water (>14 m).
Total	16	16	12	

With a few exceptions at particular sites, reef zonation is similar in each of the three marine parks. The transects generally began at a depth of greater than 15 m in a habitat dominated by rubble and / or sand with low hard coral cover. Only Batu Tikus (P. Tinggi Marine Parks) had significant reef development at 20 m or deeper but this lack of deep water coral communities is entirely natural because of geo-morphological and oceanographic conditions. At approximately 15 m this habitat merged into the zone of highest coral cover, which usually continued into shallow water at around 5 m. Usually, this area supported the benthic class 'Dense corals', which was a rich coral community of both *Acropora* and non-*Acropora* corals. Occasionally there was a further habitat in shallow water which was either *Acropora* dominated (P. Redang) or characterised by bedrock and relatively sparse hard coral cover at more exposed sites. Note that there is little correlation between the number of occurrences of any particular habitat and its areal extent in each of the marine parks. For example, although there were 13 occurrences of the benthic class 'Dense corals' it covers a much smaller area than 'Rubble / sand and sparse algae and corals' (10 occurrences) which probably covers a large proportion of the deep water between the islands.

The geomorphology of the east coast of Peninsula Malaysia is relatively simple, with only shallow, narrow fringing reefs bordering the islands. This is partly because of the shallow seabed between Peninsula Malaysia, Vietnam and Borneo. Conversely, the presence of at least 10 benthic classes in the area shows that there is a reasonable level of habitat diversity (and hence species diversity), even though many of them have low coral cover. However, the indication that the fringing reefs of the marine parks may include 80% of the corals and fish found in the countries of the 'Coral Triangle', which have a complex series of fringing and barrier reefs and atolls, accentuates their importance as a globally important site of biodiversity.

Reef health

Reef health was assessed via the Reef Check transects which were conducted in the coral rich zone at depths between 7 and 10 m. The results of the quantitative benthic surveys are summarised for each marine park, and all sites overall, in Table 3.

Table 3. Summary of the percentage cover of each benthic category as recorded by the Reef Check transect from each marine park and all sites combined. Standard deviations in parentheses.

Benthic category	% cover							
	P. Redang		P. Tioman		P. Tinggi		All sites	
<i>Acropora</i> corals	14.5	(10.5)	22.8	(17.5)	13.1	(3.1)	17.6	(13.1)
Non- <i>Acropora</i> corals	29.2	(9.1)	22.5	(9.3)	21.4	(12.9)	24.6	(10.1)
Octocorals	2.2	(3.0)	2.4	(4.1)	4.1	(3.2)	2.7	(3.4)
Sponges	2.7	(2.0)	2.9	(2.2)	6.7	(4.8)	3.7	(3.2)
Zoanthids	7.7	(16.5)	0.1	(0.2)	0.0	(0.0)	2.8	(10.0)
Coralline algae	2.6	(1.0)	5.0	(2.6)	6.7	(5.0)	4.6	(3.2)
Non-coralline algae	7.9	(6.9)	7.8	(5.6)	7.0	(6.4)	7.6	(5.8)
Recently killed coral	4.7	(4.2)	6.7	(4.5)	3.8	(2.0)	5.3	(3.9)
Dead coral + algae	2.8	(3.2)	1.8	(2.1)	1.9	(2.1)	2.2	(2.4)
Rubble	7.0	(7.0)	5.7	(3.5)	9.8	(6.8)	7.1	(5.6)
Other substratum	18.8	(6.4)	22.4	(7.8)	25.5	(4.9)	21.8	(6.9)

Mean coral cover was 42.2% for all sites combined. The mean cover was slightly higher at P. Redang and P. Tioman (43.7% and 45.3% respectively) compared to P. Tinggi (34.5%). However, this latter mean included one site (P. Pemanggil) which had particularly low coral cover because the coral rich zone was naturally shallower than the Reef Check transect. When

this site was discounted, mean coral cover was 40.8%. 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). At the site level, five sites could be categorised at 'good', with two in the P. Redang Marine Parks and three in the P. Tioman Marine Parks. None of the sites selected in the P. Tinggi Marine Parks had >50% cover, providing some evidence that the reefs in this area are in the poorest condition. With the exception of P. Pemanggil, only the site on the east coast of P. Tioman could be classified as 'poor' (21.3% cover).

Data from this study are generally consistent with previous research. Chou et al. (1994) reported that 11.4% of Malaysian reefs were in 'excellent' condition, 52.8% are 'good', 27.5% are 'fair' and 8.3% are 'poor'. More detailed site specific data are provided by Ridzwan (1994), who concludes that 64% of the reefs in Malaysia are in 'fair' condition, with P. Perhentian, P. Redang and P. Tenggol having reefs in 'good' condition. Data from Ridzwan (1994) also highlighted low coral cover at P. Tioman (27%), which was supported by results presented here, and poor cover at P. Renggis (13%), which was not. It should be noted that Malaysia, along with the whole ASEAN region, was recently affected by a major coral bleaching event and that coral cover has inevitably been reduced from pre-1998 levels.

Although coral cover is a useful indicator of health, reefs are complex systems and cannot be fully assessed via a single parameter. One key index is the ratio of live to dead coral tissue but these data were not collected by this study because of time constraints and similarly coral diseases could not be identified reliably, although occurrences appeared limited. However, the percentage of recently killed coral was assessed during surveys and was relatively low (5.3%). Most of this recent mortality seemed to be caused by corallivore feeding (particularly *A. planci* and *Drupella* spp.). There was little variation in the amount of recently killed coral between marine parks. Percentage cover of algae is also important as this can indicate impacts such as a significant reduction of fish or invertebrate herbivores and / or increased nutrient levels. Total non-coralline algal cover was less than 10% for all sites combined and this is consistent with the reefs being in fair to good condition. Data are remarkably similar in the three parks, with cover varying between 8.9 and 10.7%. However, in the P. Tinggi Marine Parks, algal cover was lower at sites closer to the mainland than those further offshore (<3.5% compared to >13.5%) and seemingly correlated with urchin density. This may indicate spatial variation in impacts on the area. Octocorals, sponges, zoanthids and coralline algae were seen on most transects but were generally uncommon, except for one site (P. Ling in the P. Redang Marine Parks) where significant numbers of zoanthids were colonising *Acropora* rubble.

Reef Check transects also record the density of a series of invertebrates which are indicators of reef health. Nine taxa were recorded but only five were commonly observed and their densities in each marine park, and for all sites combined, are shown in Table 4.

Table 4. Summary of the density per 100 m² of commonly observed indicator invertebrate taxa as recorded by the Reef Check transect from each marine park and all sites combined. Standard deviations in parentheses.

Taxa	Density / 100 m ²							
	P. Redang		P. Tioman		P. Tinggi		All sites	
<i>Diadema</i>	11.7	(12.1)	54.7	(77.8)	139.5	(163.2)	59.5	(98.9)
Edible sea cucumber	4.7	(4.2)	2.8	(2.6)	11.9	(17.8)	5.6	(9.0)
<i>Tridacna</i>	5.0	(5.6)	2.3	(2.5)	1.3	(1.1)	3.0	(3.9)
<i>A. planci</i>	1.5	(1.0)	0.7	(0.7)	0.1	(0.1)	0.8	(0.9)
<i>Drupella</i>	4.3	(6.7)	11.4	(26.9)	6.6	(6.8)	7.8	(17.5)

Diadema urchins were frequent on most transects but their densities varied dramatically, as shown by the high standard deviations. For example, within the P. Tinggi Marine Parks, no *Diadema* were seen at the site around P. Dayang but 320.8 were seen per 100 m² at Batu Tikus. Given that there is significant local variation in density, there is an apparent pattern of increasing numbers of urchins from north (P. Redang) to south (P. Tinggi). The explanation for this pattern, and the obvious clusters at some sites and not others, is not clear and requires further research. However, the reasons are likely to be complex and a synergy of natural and anthropogenic factors such as nutrient input which increases algal productivity, reduction of triggerfish predators, meta-population dynamics and physical and biological habitat preferences. *Diadema* are an important part of a reef's ecology and are required, along with herbivorous fish, to graze and hence maintain the competitive balance between corals and macro-algae. When insufficient herbivores are present, coral cover is reduced and macro-algae flourish. Grazing also increases the amount of coralline algae present (as was the case at the sites in the P. Tinggi Marine Parks with high *Diadema* densities), which is known to be an important cue for coral settlement (Morse et al., 1988). Conversely, if *Diadema* become over abundant, for instance following removal of predators, grazing can reach such high levels that coral recruits are killed shortly after settlement (McClanahan and Muthiga, 1988).

Commercially important edible sea cucumbers and *Tridacna* clams were frequently seen and suggest that fishing intensity is relatively low. However, it should be noted that most of the *Tridacna* recorded in this study were *T. squamosa*, and *T. gigas* were never seen. *T. gigas* is the largest of all bivalves (Colin and Arneson, 1995) and a highly prized fishery item. It is possible that none of these animals are left in any of the marine parks and they may be ecologically extinct in the area.

In contrast to the abundance of sea cucumbers and *Tridacna*, few edible lobsters (none on the Reef Check transects) and no triton shells (*Charonia tritonis*) were recorded. Lobster populations can sustain a commercially important fishery and their absence indicates significant past fishing pressure. It is possible that insufficient time has elapsed since the establishment of the marine parks for the replenishment of populations of these species. Triton shells are prized by the curios trade and again their absence seems to indicate significant collecting in the past. Such removal may have important ecological effects since *Charonia* are known to feed on *A. planci*. It is possible that there are none of these animals left in any of the marine parks and they may be ecologically extinct in the area.

A. planci were seen on many transects but there was no evidence of large-scale population outbreaks. They were generally more abundant in the P. Redang Marine Parks sites. *Drupella* were more abundant, particularly in the P. Tioman Marine Parks although this density was biased by a cluster of animals at the P. Renggis site. Much of the recently killed coral cover was attributable to these corallivores.

Current impacts and existing threats to reef health

An obvious current impact to the marine parks is the result of mass coral bleaching in 1998, although quantitative mortality data were not available during the preparation of this report. Coral bleaching occurs when water temperatures exceed a critical threshold, typically approximately 1°C degree above the normal annual maximum. During bleaching events, corals expel their symbiotic algae and appear white or 'bleached'. Depending on temperatures reached, the duration of warm water and other oceanographic conditions, corals can either die within days to weeks or recover their algae and survive. Coral bleaching is often most apparent in shallower water, which may be critical in this area because the rich coral communities are all shallower than approximately 15 m. Increasingly frequent bleaching events are linked to global warming but, although this cannot be altered regionally, other synergistic threats can be minimised and hence provide reefs with the best possible chance of post-bleaching recovery. Virtually no bleaching was seen during this study.

Another significant threat to reef health in the marine parks is nutrient runoff from human activities, particularly sewage. Nutrients added to reef systems can result in algal blooms which can consequently out-compete corals for space and light and lead to a reduction in coral cover or retard recovery. The threat is greatest near the largest concentrations of people (and downstream from those areas) but smaller populations can have significant negative effects. However, sufficient water quality data are not currently available to fully assess the current impacts (which appear limited) and future threats. Proper sewage systems and runoff controls are some of the tools that can control this problem.

Sedimentation could also represent a major threat to reef health. Where trees are cut and land cleared for building or agriculture, large quantities of fine soil particles are carried by rainwater into the coastal zone. Runoff is much higher during rainy seasons and the sediment blocks light reaching the benthos and reduces coral growth. Furthermore, sediment settles out of the water column and smothers coral polyps, requiring energy to be expended on cleaning (rather than on growth or reproduction). Sedimentation can kill whole coral colonies at high concentrations and also decreases water visibility and discourages snorkellers and divers. However, turbidity data collected within this study, via secchi disc, showed moderately clear water (mean reading 14.1 m) and there were no significant differences between marine parks (ANOVA analysis, $p > 0.05$). Further studies are required since sample sizes were limited and sites such as P. Simbang had noticeably lower values (secchi disc reading = 9.0 m). The forests on the islands in the area are largely uncut and any clearance would heavily impact the reefs, which are fringing and close to the shore.

Fishing appeared well controlled in the parks since only local fishermen have been given permission to fish and only via traditional techniques. A mean of only 0.6 fishing boats were observed per site but fishing pressure, probably low or moderate, was not fully assessed during this study. Fishing can have major economic and ecological impacts, including the reduction of herbivorous fish which can affect the ability of reefs to regenerate via increased macro-algal biomass and coral exclusion. However, it is possible that at current levels many of the fisheries are sustainable and finfish stocks will increase with time. Large fish, sensitive indicators of fishing pressure, were still observed, even though few lobsters and no triton shells or *Tridacna gigas* were seen. Abandoned fishing gear, which was seen at many sites, is not a major threat to coral health but nets can smother relatively large areas and continue to catch fish through 'ghost fishing'.

Coral eating *A. planci* were seen during this study, especially at P. Redang. These large sea stars eat the living coral tissue and can do severe damage when they occur in large aggregations at high densities. No outbreaks, which are too extensive for control efforts on a large scale, were seen in the marine parks. However, if observed on small reefs that are particularly important (e.g. for tourism) collection efforts and removal to a land site can be successful and worth the expense and effort. *Drupella* spp. is a second, less threatening animal which eats coral. This snail is normally present on healthy reefs, where it does minimal damage and only rarely does it cause significant damage. Similarly to *A. planci*, if they become common enough to do visible damage to valuable reefs, a removal campaign can be undertaken.

Additional anthropogenic threats to the marine parks included mechanical damage from boat anchors, discarded refuse, divers and snorkellers. Specific projects, such as the construction of a submarine freshwater pipeline to P. Redang, have also been shown to cause significant impacts on coral communities (Hamid Rezai et al., 1999). Some discarded refuse was observed at a few sites but two of the island groups have well-organized discarded refuse remove services and visible discarded refuse on the reefs was insignificant. Very little coral breakage was observed from anchors, divers, or snorkellers and there was no damage from blast fishing. However, this study's sites were generally away from population centres (mean distance of 1.8 km from communities averaging 600 people) and these threats are likely to be

significantly higher elsewhere within the area and will increase with increased tourism. World class systems for controlling mechanical damage exist within the parks, such as the restrictions on snorkellers swimming over the *Acropora* rich shallows close to the P. Redang Marine Parks Centre (P. Pinang). Furthermore, dive operators seem conscientious in promoting environmental education and highlighting the consequences of contacting coral during dives.

Summary of previous literature and temporal comparisons

Although excellent summaries are available for the status of the reefs throughout Malaysia (see Ridzwan, 1994 and Chou, 2000), quantitative data for the parks of the east coast of Peninsula Malaysia are limited. This lack of data inhibits analysis of temporal change of reef health and a monitoring programme in the parks is urgently required. Existing studies include Green (1978), which provides only qualitative descriptions of the reefs of P. Redang. More detailed information is contained in Aikanathan and Wong (1994) but actual percentage cover data, although shown schematically in figures, are generally absent. However, it is possible to establish that coral cover in the parks was at least equivalent to that documented by this study (approximately 30-60%). Site selection was not limited to the 'best' sites and, therefore, the range of coral cover was inevitably larger than the present study. For example, cover ranged from less than 10% to approximately 70% at P. Tioman and P. Tulai. Since the Aikanathan and Wong study was carried out before the 1998 bleaching event, it also provides some evidence that there was higher coral cover in selected areas than currently present. For example, the southern coast of P. Sembilang and P. Seri Buat appeared to have greater than 75% cover and coral cover of 56% was recorded for P. Lang Tengah, compared to the 41.3% recorded in this study. Aikanathan and Wong (1994) also indicates excellent coral cover at sites not selected by this study, such as P. Rawa and P. Goal (P. Tinggi Marine Parks). However, the authors refer to unquantified deterioration of coral cover over preceding years because of pollution and sedimentation. Finally, Aikanathan and Wong (1994) also include sections of Landsat TM and SPOT satellite imagery to illustrate the project area but no attempt was made to generate habitat maps. Such work is urgently required to map the marine resources of the marine parks.

Quantitative data are presented by Ching and Spring (1995) at sites around P. Tioman and P. Tulai. Although the aim of their research was to assess reef carrying capacities, which is beyond the scope of this study, the results can be compared to the data presented here. Ching and Spring (1995) recorded a much lower coral cover than documented in this report (22.9% versus 42.2%). Furthermore, coral cover at the five sites which were surveyed by both studies (P. Tulai, Batu Malang, P. Renggis, P. Tokong Bahara and P. Gut) also appeared to have less coral cover in 1995 (28.9% versus 49.5%). However, these differences seem unlikely to reflect true increases in reef health in the last five years and are more likely to be a function of the methodological differences (surface manta tows in 1995 and more accurate point intercept transects with SCUBA in 2000).

Many of the sites surveyed by Ching and Spring (1995) were recently re-surveyed by Hendry (2000) using line intercept transects, generating data more directly comparable to this study. Hendry (2000) found higher coral cover at 64% of the sites compared to 1995, although the conclusion was that reef health had decreased because there was an increase in dead coral cover and decrease in octocoral cover. It seems likely that the variation in coral cover was again caused by different methodologies and that the dead coral was a result of the 1998 bleaching event. Hendry (2000) only surveyed three of the sites used by this study but the limited sample size provides some evidence of improving coral cover (36.2% in Hendry versus 48.2% in this study). However, this variation is almost certainly caused by the patchiness of coral cover in the parks rather than any significant change in reef health during the time between the two studies.

Estimated condition of reefs not surveyed

In addition to the 17 survey sites, a series of manta tows and exploratory dives were conducted. This work was mainly to aid site selection within the three group of parks but the qualitative observations do facilitate a gross assessment of reefs which were not surveyed. However, many more surveys, combined with remote sensing, are required to accurately assess the true status of the marine parks.

There are unequivocally good reefs within each of the marine parks and qualitative observations indicate that these are certainly not limited to the survey sites covered by this study. However, these reefs and sections of reef are separated by areas that have been impacted by a variety of factors. Clearly the 1998 coral bleaching event significantly affected all three marine parks. For example, there was evidence that areas of shallow reef, thought to previously support high *Acropora* cover, were dominated by dead corals which were either still standing or had been reduced to rubble by storms and bioerosion. *Acropora* is particularly susceptible to coral bleaching (Marshall and Baird, 2000) and much of the dead coral had been overgrown by macro-algae. *A posteriori* assessment of the extent of bleaching related mortality is virtually impossible but it seems to have caused much of the dead coral. However, there is also anecdotal evidence that several of the sites themselves had been almost completely bleached but are now in good condition with numerous mature colonies that appear to have survived the warm water. Furthermore, although some areas were thought to be in relatively poor condition, natural coral cover was unlikely to be high because of natural levels of exposure to storm damage during monsoon conditions.

Bleaching effects have also occurred synergistically with impacts caused by over-fishing, sedimentation, nutrient enrichment, corallivores, anchoring and diving and snorkelling. Therefore, the overall conclusion was that, although there are excellent areas, the reefs in the marine parks have been impacted and many areas currently have significantly reduced coral cover. The overall ratio is difficult to estimate and will vary between and within marine parks.

Probability of recovery of damaged reef

Recovery of coral communities on reefal areas following major impacts, such as coral bleaching, requires the settlement and growth of new larvae and asexual reproduction of remaining colonies. Estimating coral settlement rates requires specialised research but this study was able to estimate the density of 'young' corals by recording the numbers of colonies between 1 and 5cm in diameter. These data showed that all sites combined, already with good coral cover, had a mean of 4.2 young corals (SD = 2.7) directly under each section of the Reef Check transect line (20 m long). Although these were relatively healthy areas, it seems reasonable to conclude that there are viable coral larvae in the water column and that they will also settle on damaged reefs. Furthermore, coralline algae are known to be an important cue for settlement (Morse et al., 1988) and this was found at all locations. In addition to the presence of young corals, the vitality of the area was demonstrated by the observation of a mass coral spawning event close to P. Redang (initially discovered by Ab. Rahim Gor Yaman), which was almost certainly also occurring in the other parks.

The conclusion of this study, therefore, would be that there are areas of reef that are sufficiently healthy, large and frequent to provide recruits for the more impacted areas and hence facilitate recovery. Such recovery will obviously rely on minimising additional impacts, but this seems likely given the protection afforded by the marine parks system. However, it is possible that mitigation measures may need to be increased, particularly in the P. Tioman and P. Tinggi Marine Parks. Furthermore, increased protection for some of these areas, perhaps via designation as 'sanctuary zones', will aid reef recovery by conserving sources of coral and fish larvae. Management of tourism at all healthy areas will be critical since divers and snorkellers inevitably favour reefs with high coral cover and abundant fish.

PARKS SUMMARY: PULAU REDANG MARINE PARKS

Background

Pulau Redang Marine Parks consists of nine islands in the state of Terengganu and P. Redang, approximately 22 km from Peninsular Malaysia, is the largest. Little native forest has been cut, agriculture has been abandoned and one of the main occupations is traditional fishing. Marine tourism is a new and rapidly growing industry.

Coral biodiversity

These parks contained 149 species and was the only group in which *Montipora millepora*, *Acropora elseyi* and *valenciennesi*, *Psammocora haimeana*, *Pavona frondifera*, *Echinophyllia orpheensis*, *Platygyra* sp. 1', *Catalaphyllia jardini* and possibly *Turbinaria frondens* *Leptoseris incrustans* and *Favites pentagona* were found. For unknown reasons, *A. valenciennesi* was found at every site, but no sites in the other two parks.

Fish biodiversity

A total of 209 species of fish were found in the marine parks. This was the only group of parks in which 31 species of fish were found.

Reef zonation

All the sites in the marine parks had coral rich forereefs which stopped at a mean depth of 14.8 m and merged into the deeper benthic class 'Rubble / sand and sparse algae and corals'. The coral rich areas were generally characterised by the benthic class 'Dense corals' but the coral community was slightly different at P. Ling ('Bedrock and mixed corals') and Terumbu Kili ('Bedrock and non-*Acropora* rich corals and octocorals'). The two sites on P. Redang itself (Teluk Mat Delah and Chagar Hutang) and the site at P. Ling also had a shallow water habitat of 'Bedrock and *Acropora* rich corals', starting at a mean depth of 7.3 m.

Reef health

Benthic category	% cover*	
<i>Acropora</i> corals	14.5	(10.5)
Non- <i>Acropora</i> corals	29.2	(9.1)
Octocorals	2.2	(3.0)
Sponges	2.7	(2.0)
Zoanthids	7.7	(16.5)
Coralline algae	2.6	(1.0)
Non-coralline algae	7.9	(6.9)
Recently killed coral	4.7	(4.2)
Dead coral + algae	2.8	(3.2)
Rubble	7.0	(7.0)
Other substratum	18.8	(6.4)

Taxa	Density / 100 m ² *	
<i>Diadema</i>	11.7	(12.1)
Sea cucumber	4.7	(4.2)
<i>Tridacna</i>	5.0	(5.6)
<i>A. planci</i>	1.5	(1.0)
<i>Drupella</i>	4.3	(6.7)

* Means for all six sites combined. Standard deviation in parentheses.

The sites surveyed in the marine parks generally had good coral cover (mean 43.7%) at depths of 7 to 10 m, where the Reef Check transect was conducted. Non-*Acropora* corals were generally more abundant than *Acropora*. There was little apparent pattern of variation in coral cover between the sites, although P. Ling had slightly lower coral cover because of the location of the transect line. Octocorals, sponges, zoanthids (except at P. Ling) and coralline algae were generally uncommon. Recently killed coral cover was high at Terumbu Kili (11.9%) but was usually less than 5% and mostly caused by *A. planci* and *Drupella*. Non-coralline algae were present but not abundant (10.7%) except at Teluk Mat Delah (20.0%) and P. Lima (17.5%), possibly highlighting some reef stress on the east coast of side of P. Redang. *Diadema* were frequent and densities varied from 2.3 (Terumbu Kili) to 31.3 / 100 m² at P. Ling. Edible sea cucumbers and *Tridacna* were also seen regularly and there were aggregations of the latter at Teluk Mat Delah and P. Lang Tengah (approximately 12 / 100 m²). *A. planci* were uncommon in the marine parks but *Drupella* were more common, especially at P. Lang Tengah.

Estimated condition of reefs not surveyed

In addition to the six survey sites, two extensive manta tows to assess general reef condition were conducted along the south and south-east sides of P. Lang Tengah (approximately 2 km) and the west coast of P. Redang (approximately 1 km). Both tows showed that reef zonation was very similar to the survey sites, with coral cover to approximately 15 m and rubble / sand areas in deeper water.

Along the south side of P. Lang Tengah much of the coral rich habitat was covered with long dead *Acropora* colonies which were either still standing or had been reduced to rubble. Much of this dead coral had been overgrown by macro-algae and there were frequent clusters of *Diadema* in the depth zone between approximately 7 and 11 m. The south-eastern side of the island showed similar characteristics, with the exception of the sheltered bay selected as the survey site.

The reefs on the west coast of P. Redang were similar to those at P. Lang Tengah, with large areas of *Acropora* rubble overgrown by macro-algae. Similarly, high numbers of *Diadema* were noted. However, there were several small areas of better coral cover, including a section of reef just to the north of Turtle Bay. These areas had occasional large *Porites* colonies, between which branching corals were still healthy. Furthermore, although the whole east coast was thought to be in relatively poor condition overall, natural coral cover is unlikely to be high because of its exposure to storm damage during monsoon conditions.

In addition to these manta tows, observations around P. Lima indicated many sections were in good condition but a second reef profile transect, close to the actual survey site, indicated there were also heavily impacted reefs. Therefore, the overall conclusion was that, with the exception of P. Lang Tengah, the reefs in the marine parks generally had good coral cover and high biodiversity, particularly around the small islands and islets away from P. Redang. However, there is also evidence that many areas have been impacted by a variety of factors and currently have significantly lower coral cover than normal.

Current impacts and existing threats

Much of the dead coral seen at both the survey sites and surrounding reefs may be attributable to the 1998 bleaching event, which obviously had a significant effect on the marine parks. Further coral mortality has been caused, and continues to be caused, by the corallivorous *A. planci* and *Drupella*. However, assuming there is not a population outbreak of *A. planci*, this mortality is relatively minor and will not inhibit either coral recovery or general reef integrity.

Human population pressure is relatively low in the marine parks and the largest community close to any of the survey sites is approximately 1300 people, 1km from Teluk Mat Delah and Chagar Hutang on P. Redang. Water quality, therefore, is likely to be good and furthermore only limited litter was recorded. Local fishermen have been given permission to fish within the marine parks via traditional techniques but fishing pressure appears to be low or moderate. However, snagged lines were seen at many sites, along with some traps and nets. Although abandoned gear is not a major threat to coral health, nets can smother relatively large areas and continue to 'ghost fish'. Fishing itself can have major economic and ecological impacts, including the reduction of herbivorous fish which can affect the ability of reefs to regenerate. Finally, there are numerous dive and snorkelling sites within the marine parks but there was no evidence of significant anchor damage or broken corals caused by divers.

SITE 1: TELUK MAT DELAH, PULAU REDANG

Overview

Teluk Mat Delah was selected as one of two representative sites for Pulau Redang and is a moderately exposed small bay on the north-east coast. The site was selected following a recommendation by marine park officials. Teluk Mat Delah was surveyed on 9th September and was located at 640710 N, 281948 E.

Coral biodiversity

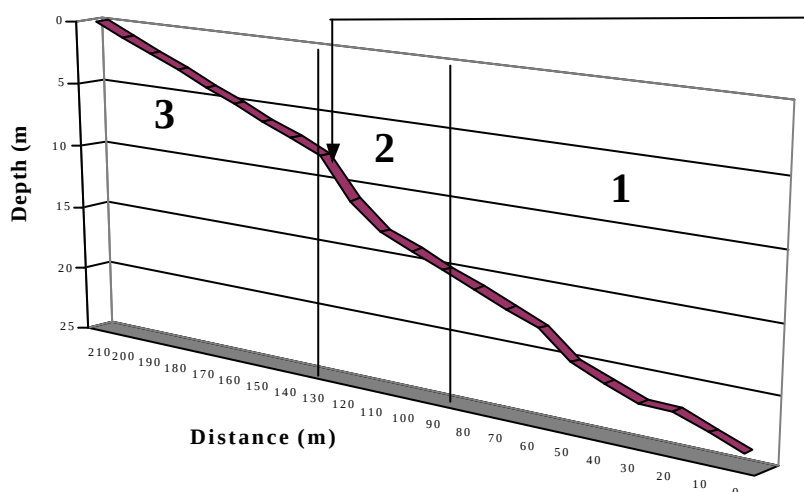
A total of 84 species of coral were found at this site. This was the only site at which *Pavona frondifera* and *Psammocora haimeana* were found.

Fish biodiversity

A total of 106 species of fish were found at this site. This was the only site at which *Plectorhinchus vittatus* was found.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
Acropora corals	1.9
Non-Acropora corals	36.9
Octocorals	7.5
Sponges	3.1
Zoanthids	0.0
Coralline algae	2.5
Non-coralline algae	20.0
Recently killed coral	0.6
Dead coral + algae	0.0
Rubble	3.8
Other substratum	23.8

The reef profile at Teluk Mat Delah consisted of a forereef, surveyed from 23 m, which began with habitat 1: 'Rubble / sand and sparse algae and corals'. This habitat also had an unusually high abundance of anemones, possibly *Aiptasia* sp. Benthic class 'Dense corals' was found in habitat 2 which started at 15 m. The Reef Check transect was laid within this habitat and recorded coral cover of 38.8%, dominated by non-Acropora. Massive and encrusting life forms were most common (17.5 and 11.3% respectively). The transect concluded with habitat 3, a reef crest (from a depth of 8 m) supporting 'Bedrock and Acropora rich corals'. On the Reef Check transect, *Diadema* and edible sea cucumber densities were 4.5 and 2.8 per 100 m² respectively but there were numerous *Tridacna* (12.8 per 100 m²).

Impacts

A total of seven *A. planci* and 10 *Drupella* were seen on the Reef Check transect at Teluk Mat Delah, but were associated with a low level of coral damage. Generally the site was healthy with few obvious impacts.

SITE 2: CHAGAR HUTANG, PULAU REDANG

Overview

Chagar Hutang was selected as one of two representative sites for Pulau Redang and is a sheltered bay on the northern coast. It has one of the two beaches on P. Redang where turtles lay their eggs and consequently is a designated a turtle sanctuary with restricted access and no activity allowed after 15:00 hours. The site was selected because of its increased protection and following a recommendation by marine park officials and a subsequent snorkel. Chagar Hutang was surveyed on 10th September and was located at 643084 N, 279325 E.

Coral biodiversity

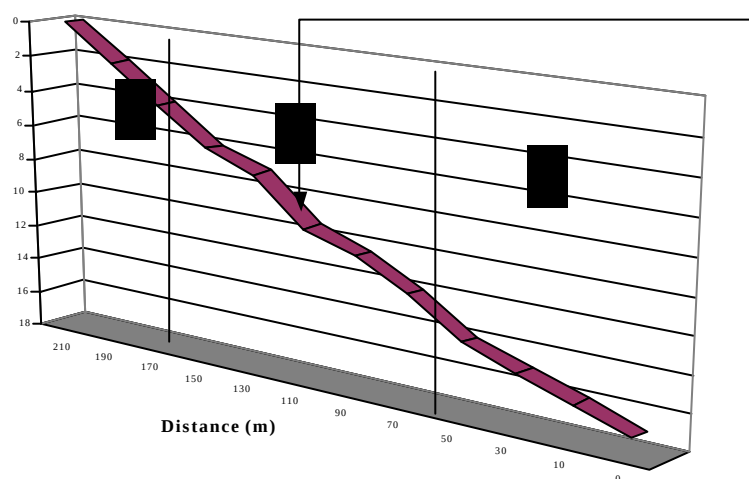
A total of 87 species of coral were found at this site. No species was unique to this site.

Fish biodiversity

A total of 114 species of fish were found at this site. This was the only site at which five species of fish were found. A school of 15 mature *Bolbometopon muricatum* (bumphead parrotfish) were observed grazing coral in shallow water.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
Acropora corals	19.4
Non-Acropora corals	35.0
Octocorals	1.3
Sponges	3.1
Zoanthids	0.0
Coralline algae	1.9
Non-coralline algae	1.9
Recently killed coral	1.3
Dead coral + algae	6.3
Rubble	11.3
Other substratum	18.8

The forereef profile at Chagar Hutang was on the west side of the bay and began at 12.5 m. Habitat 1 consisted of 'Rubble / sand and sparse algae and corals' which then merged into habitat 2 with benthic class 'Dense corals'. The Reef Check transect was within this habitat and highlighted the high coral cover (54.6%), dominated by non-Acropora colonies. The main non-Acropora life forms were massive (particularly *Porites* and *Diploastrea*) and submassive (11.9 and 10.6% respectively) but branching *Acropora* was the most abundant life form (15% cover). *Acropora* increased in dominance above a depth of 4m (habitat 3), along with large colonies of *Millepora*, and the benthic class was 'Bedrock and *Acropora* rich corals'. On the Reef Check transect, *Diadema* and edible sea cucumber densities were 2.8 and 4.3 per 100 m² respectively and 11 *Tridacna* were recorded.

Impacts

Chagar Hutang was an exceptional site with little evidence of anthropogenic impacts, apart from a little litter. There were no *Drupella* on the Reef Check transect and only one *A. planci*.

SITE 3: PULAU LING

Overview

Pulau Ling is a small, exposed rocky island to the south-east of Pulau Redang and the site selected was to the south-west, following a recommendation by marine park officials. The site was surveyed on 11th September and was located at 634463 N, 280569 E.

Coral biodiversity

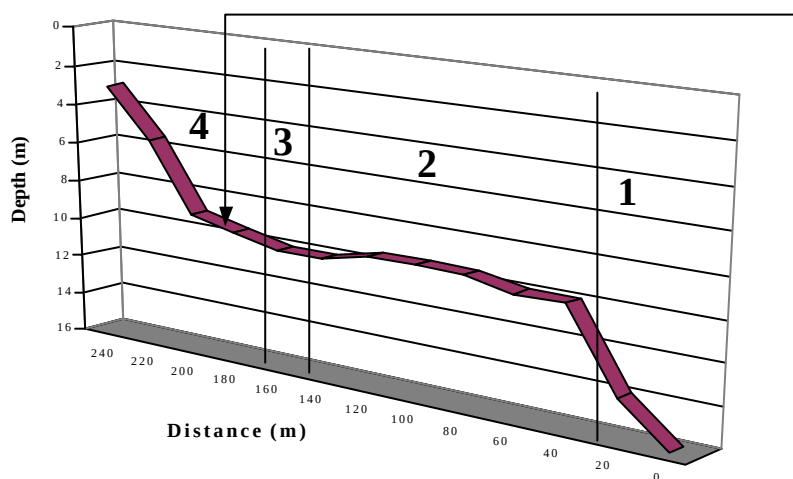
A total of 92 species of coral were found at this site. This was the only site at which *Echinophyllia orpheensis* was found.

Fish biodiversity

A total of 105 species of fish were found at this site, the lowest in any survey. No species was unique to this site and one *Porites* mounds with a large hole and a boat mooring buoy tied to it accounted for approximately a third of all fish species observed on the dive.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
<i>Acropora</i> corals	3.1
Non- <i>Acropora</i> corals	24.4
Octocorals	0.0
Sponges	4.4
Zoanthids	41.3
Coralline algae	2.5
Non-coralline algae	3.1
Recently killed coral	5.0
Dead coral + algae	1.3
Rubble	3.8
Other substratum	11.3

The forereef profile at Pulau Ling was surveyed from 16 m and began with 'Rubble / sand and sparse algae and corals' in habitat 1. At approximately 14 m this habitat changed to habitat 2, which supported benthic class 'Bedrock and mixed corals', with much higher coral cover. This habitat was then separated from a second area of high coral cover (habitat 4: 'Bedrock and *Acropora* rich corals') by a narrow area of 'Rubble and sparse algae and corals' (habitat 3). The Reef Check transect was laid in habitat 4 but was located in an area of relatively low coral cover (27.5%) and few *Acropora* colonies for this benthic class. However, it was obvious from the rubble that *Acropora* had been present but had been killed and then broken down by storms. This rubble was heavily colonised by zoanthids (41.3%). A subsequent second survey showed more a typical coral cover of 38.2% (*Acropora* 26.3%). On the Reef Check transect, there were 31.3 *Diadema* and 2.0 *Tridacna* per 100 m². However, there was only one edible sea cucumber recorded.

Impacts

Fisheries department staff indicated that this site is known to be highly impacted by *A. planci* and, where there was still good *Acropora* cover on the second Reef Check transect, 16 individuals, along with 56 *Drupella*, were recorded. Many *Acropora* colonies may have been killed by coral bleaching in 1998. Snagged fishing lines and nets were also seen at this site.

SITE 4: PULAU LIMA

Overview

Pulau Lima is a relatively large island to the south-east of Pulau Redang and the site selected was at the southern end. This area was chosen following a recommendation by marine park officials and reference to previously published work. The site was surveyed on 12th September and was located at 638342 N, 285089 E.

Coral biodiversity

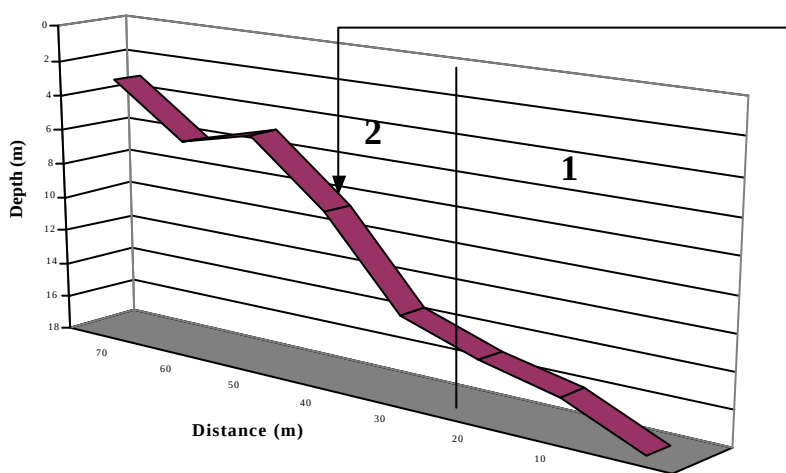
A total of 96 species of coral were found at this site. This was the only site at which *Catalaphyllia jardini* and *Turbinaria frondens* were found.

Fish biodiversity

A total of 131 species of fish were found at this site. This was the only site at which seven species of fish were found. The fish community was abundant and seemed distinct from many sites with many pelagic species. Two nurse sharks (*Nebrius ferrugineus*) were seen in caves.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
Acropora corals	29.4
Non-Acropora corals	16.9
Octocorals	3.8
Sponges	0.6
Zoanthids	1.3
Coralline algae	3.8
Non-coralline algae	10.0
Recently killed coral	6.9
Dead coral + algae	7.5
Rubble	0.6
Other substratum	19.4

The forereef profile at Pulau Lima was surveyed from 18 m and habitat 1 (benthic class 'Rubble / sand and sparse algae and corals') continued to 13.5 m. Sandy areas in habitat 1 were rich in sea cucumbers, with *Holothuria edulis* most abundant. Habitat 2 was then found shallower than 13.5 m and was characterised by the benthic class 'Dense corals'. The Reef Check transect was laid within habitat 2 and highlighted the high coral cover (46.3%). The coral was dominated by *Acropora*, mainly the branching life form (29.4% cover) but non-*Acropora* colonies were common and massive was most frequent (6.9%). Similarly to most Redang sites, the upper 4 m of the reef was characterised by a zone of heavily grazed bedrock with low coral cover. On the Reef Check transect, there were 7.3 *Diadema*, 1.3 edible sea cucumbers and 0.5 *Tridacna* per 100 m².

Impacts

Few impacts were seen at the site for Pulau Lima, with the exception of a limited number of snagged fishing lines. Only three *A. planci* and no *Drupella* were recorded on the Reef Check transect.

SITE 5: PULAU LANG TENGAH

Overview

Pulau Lang Tengah is a large island to the west of Pulau Redang and the site selected was in a bay on the south-eastern corner of the island. This area was chosen following manta towing which showed poorer reefs on the southern side. The site was surveyed on 13th September and was located at 640408 N, 267827 E.

Coral biodiversity

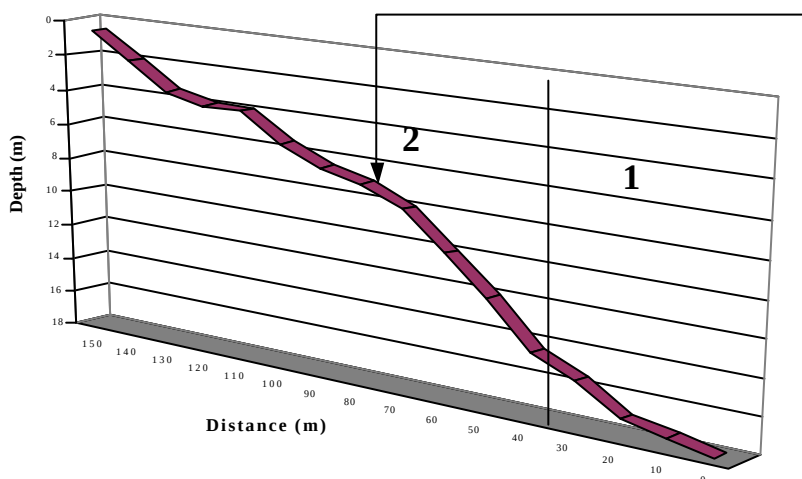
A total of 86 species of coral were found at this site. This was the only site at which *Playgyra* 'sp. 1' was found.

Fish biodiversity

A total of 117 species of fish were found at this site. This was the only site at which *Chromis lepidolepsis* was found.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
<i>Acropora</i> corals	18.8
Non- <i>Acropora</i> corals	22.5
Octocorals	0.6
Sponges	0.0
Zoanthids	3.1
Coralline algae	1.3
Non-coralline algae	3.1
Recently killed coral	2.5
Dead coral + algae	1.3
Rubble	19.4
Other substratum	27.5

The survey transect at Pulau Lang Tengah began on the forereef at 18 m where the benthic class was 'Rubble / sand and sparse algae and corals' (habitat 1). At a depth of 15.5 m this changes to habitat 2 supporting the benthic class 'Dense corals'. The Reef Check transect was laid within habitat 2 and highlighted the high coral cover (41.3%). This coral cover had roughly even proportions of *Acropora* and non-*Acropora* corals but the main life forms were *Acropora* branching and tabulate and non-*Acropora* massive and submassive (11.9, 6.3, 6.3 and 6.3% respectively). Shallow areas (<6 m), exposed to swell and wave action, consisted of bare bedrock, encrusting corals and sponges. *Diadema*, edible sea cucumbers and *Tridacna* were all common on the Reef Check transect (22.0, 9.3 and 11.5 per 100 m² respectively).

Impacts

Although the site for Pulau Lang Tengah had high coral cover, between 10 and 6m there were also extensive patches of damaged or dead branching *Acropora*, colonised by zoanthids and small anemones. This may be evidence of damage caused by *A. planci* or *Drupella*, which were recorded at densities of 3.0 and 17.8 per 100 m² on the Reef Check transect. At least some of the mortality is also likely to be attributable to the 1998 coral bleaching event.

SITE 6: TERUMBU KILI

Overview

Terumbu Kili is an exposed pinnacle separated from a rocky peninsula of Pulau Penang (found south-west of P. Redang) by a narrow channel approximately 10 m deep. This site was chosen on the recommendation of marine park staff and two other dive boats were seen. Terumbu Kili was surveyed on 14th September and was located at 633857 N, 278941 E.

Coral biodiversity

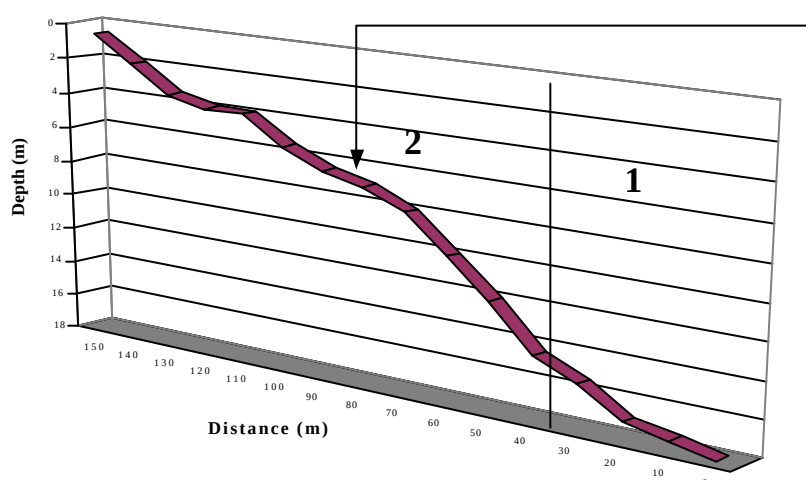
A total of 78 species of coral were found at this site. This was the only site at which *Montipora millepora* and possibly *Favites pentagona* were found.

Fish biodiversity

A total of 147 species of fish were found at this site. This was the only site at which five species of fish were found. Three black tip reef sharks (*Carcharhinus melanopterus*) and several turtles were also seen.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
Acropora corals	14.4
Non-Acropora corals	39.4
Octocorals	0.0
Sponges	5.0
Zoanthids	0.6
Coralline algae	3.8
Non-coralline algae	9.4
Recently killed coral	11.9
Dead coral + algae	0.6
Rubble	3.1
Other substratum	11.9

The transect at Terumbu Kili began at 22 m and at this depth the benthic class 'Rubble / sand and sparse algae and corals' was present (habitat 1). There were numerous clams (*Hyotissa* spp.) in habitat 1. Habitat 2 began at 18.5 m and consisted of the benthic class 'Bedrock and non-Acropora rich corals and octocorals'. The Reef Check transect was laid within habitat 2 and documented excellent coral cover (53.8%). Non-Acropora corals were obviously dominant and the most abundant life forms were branching, foliose and massive (21.3, 6.9 and 6.3% cover respectively). *Acropora* branching was also abundant (13.8% cover). To the south and east of the pinnacle, the reef sloped steeply to sand at a depth of approximately 22 m but the slope was more gentle to the west. On the east side there was an extensive field of *Pocillopora damicornis*. Only nine *Diadema* and one *Tridacna* were seen on the Reef Check transect but edible sea cucumbers were relatively common (10.3 per 100 m²).

Impacts

There was little evidence of impacts at the site for Terumbu Kili except for a piece of net and several snagged fishing lines. There were only isolated areas of coral damage and much of it was recently killed (11.9%), possibly caused by corallivores, as eight *A. planci* and 14 *Drupella* were counted on the Reef Check transect.

PARKS SUMMARY: PULAU TIOMAN MARINE PARKS

Background

Pulau Tioman Marine Parks consists of nine islands in the state of Pahang and P. Tioman is the largest. An airport facilitates tourism to P. Tioman and there are around 1500 guest rooms.

Coral biodiversity

These parks contained 183 species and was the only group in which *Pocillopora eydouxi* and *meandrina*, *Stylophora pistillata*, *Montipora confusa* and 'sp. 2', *Astreopora gracilis*, *Psammocora nierstraszi*, *Coscinaraea hahazimaensis*, *Pavona clavus*, *Leptoseris papyracea*, *Diaseris distorta*, *Heliofungia actiniformis*, *Oxyphora crassispinosa*, *Pectinia alcornicornis*, *Favia maxima*, 'sp. 1', *veroni* and 'sp. 2', *Goniastrea retiformis*, *Montastrea* 'sp. 1', *Trachyphyllia geoffroyi*, *Euphyllia yaeyamaensis*, *Rhizopsammia verrilli*, *Millepora tenera* and possibly *Goniopora planulata*, *Leptoseris scabra* and *Acropora austera* were found.

Fish biodiversity

A total of 233 species of fish were found in the marine parks. This was the only group of parks in which 23 species of fish were found.

Reef zonation

All sites in the marine parks had coral rich forereefs which stopped at a mean depth of 14.6 m and merged into deeper, sparser coral areas. Closer to the mainland, these deeper areas were characterised by the benthic class 'Sand / silt' (P. Tokong Bahara and P. Seri Buat) but at the other sites they were characterised by 'Rubble and mixed corals, invertebrates and algae', 'Sand / bedrock boulders and scattered corals' or 'Rubble / sand and sparse algae and corals'. The coral rich areas were generally characterised by the benthic class 'Dense corals', with the exception of P. Tokong Bahara ('Rubble and mixed corals, invertebrates and algae'). P. Seri Buat and Kadar Bay also had bedrock rich areas in shallow water (<4 m).

Reef health

Benthic category	% cover *	
<i>Acropora</i> corals	22.8	(17.5)
Non- <i>Acropora</i> corals	22.5	(9.3)
Octocorals	2.4	(4.1)
Sponges	2.9	(2.2)
Zoanthids	0.1	(0.2)
Coralline algae	5.0	(2.6)
Non-coralline algae	7.8	(5.6)
Recently killed coral	6.7	(4.5)
Dead coral + algae	1.8	(2.1)
Rubble	5.7	(3.5)
Other substratum	22.4	(7.8)

Taxa	Density / 100m ² *	
<i>Diadema</i>	54.7	(77.8)
Sea cucumber	2.8	(2.6)
<i>Tridacna</i>	2.3	(2.5)
<i>A. planci</i>	0.7	(0.7)
<i>Drupella</i>	11.4	(26.9)

* Means for all seven sites combined. Standard deviation in parentheses.

The survey sites generally had good coral cover (mean 45.3%) at the Reef Check transect depths (7 to 10 m). There was little apparent pattern of coral cover variation between sites, although there was some evidence that reefs around P. Tioman itself were less healthy than the other islands since coral cover was only 21.3% (less than half of most other sites). Octocorals, sponges, zoanthids and coralline algae were generally uncommon. Recently killed coral cover was less than 7% overall but was high at P. Tokong Bahara (12.5%) and P. Renggis (13.1%), mostly from *A. planci* and particularly *Drupella* feeding. Non-coralline algae was present but, although not abundant overall (9.6%), there was variation between three sites with low cover (<5%) and the remainder with cover up to 21.9% (Teluk Juara, P. Gut, P. Seri Buat and Kadar Bay), possibly indicating stress at the latter sites. *Diadema* densities varied dramatically from 0.8 (P. Seri Buat) to 207.5 / 100 m² (P. Renggis). Edible sea cucumbers and *Tridacna* were seen on most surveys. *A. planci* were rare in the parks but *Drupella* were more common, although the mean was biased by 48 animals at P. Renggis.

Estimated condition of reefs not surveyed

In addition to seven survey sites, a series of manta tows and exploratory dives were conducted in the P. Tioman Marine Parks to select locations for data collection. These manta tows did not provide general information on the condition of large sections of reef but the observations provide some evidence of the status of other areas of the marine parks. For example, a manta tow along several areas of the east coast of P. Tioman (north of the survey site) found predominantly poor reefs with a sandy substratum and only occasional coral heads. In contrast, the western side of P. Gut was dominated by an extensive field of healthy *Acropora*.

Further tows and dives showed that P. Labas and P. Sepoi, a pair of islands north-west of P. Tioman, had relatively low coral cover and there were signs of significant impacts from the 1998 coral bleaching event (dead standing and rubble coral). The highest coral cover was seen on the north-eastern side of P. Sepoi but it was a narrow section and did not extend far enough along the 10 m depth contour to facilitate a Reef Check survey (i.e. less than 100 m). Hence these islands did not appear to have any reefs which could qualify as a survey site.

Similarly, Magicienne Rock (north of P. Tioman) was explored and did have several massive boulders starting at a depth of approximately 25 m and extending up to a depth of approximately 14 m. The base of rocks had coral cover of about 20% but, although there were also abundant sea fans, soft corals, and black corals, hard coral cover was generally too low and insufficiently diverse to be selected as a survey site. Therefore, the overall conclusion was that, although there are excellent areas (coral cover was over 60% at Batu Malang and P. Tokong Bahara), the reefs in the marine parks, especially around P. Tioman itself, have been impacted by a variety of factors and many areas currently have significantly reduced coral cover.

Current impacts and existing threats

Much of the dead coral at both the survey sites and surrounding reefs may be attributable to the 1998 bleaching event, which obviously had a significant effect on the marine parks. Further coral mortality has been caused, and continues to be caused, by the corallivores *A. planci* and *Drupella*. However, assuming there is not a population outbreak of *A. planci*, this mortality is relatively minor and will not inhibit either coral recovery or general reef integrity.

Pulau Seri Buat is relatively close to Peninsula Malaysia itself and a higher sedimentation regime was expected than for sites further offshore, partly for natural reasons but also because of coastal development. Siltation indeed seemed higher and there was a layer of silt, which became thicker with increasing depth, on many parts of the benthos. Hence the best corals appeared to be in shallow water. However, high sediment loads also appeared to be present at Teluk Juara and in Kadar Bay (P. Tulai), possibly related to anthropogenic influences such as forest removal and land development. However, while sediment can affect reef health and cause coral mortality, it should be noted that Teluk Juara, and possibly other places on the east coast, had the highest species richness of any site. Hence the link between reef health and biodiversity is complex.

Human populations are relatively low in the marine parks (P. Tioman supports approximately 2200 people) and water quality, therefore, is likely to be good but with some significant point sources of pollution. Local fishermen have been given permission to fish within the marine parks via traditional techniques but fishing pressure appears low to moderate. However, snagged lines were seen at many sites, along with some traps and nets. Although abandoned gear is not a major threat to coral health, nets can smother relatively large areas and there was some evidence of net dragging at P. Tokong Bahara. Fishing itself can have major economic and ecological impacts, including the reduction of herbivorous fish which can affect the ability of reefs to regenerate. Finally, there are numerous dive and snorkelling sites within the marine parks and coral damage may be a significant threat in many areas. Since P. Tioman is particularly popular with tourists, this threats seems likely to increase in the future.

SITE 7: BATU MALANG

Overview

Batu Malang is a small rocky islet, close to Pulau Malang and north-west of P. Tioman, which is sheltered but with considerable current. This site was chosen on the recommendation of marine park staff and after manta towing. Batu Malang was surveyed on 17th September and was located at 321076 N, 400187 E.

Coral biodiversity

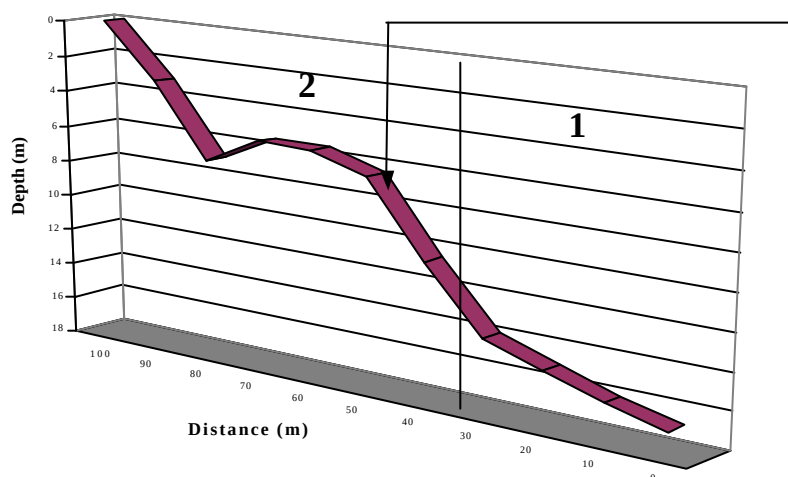
A total of 96 species of coral were found at this site. This was the only site at which *Stylophora pistillata*, *Psammocora nierstraszi*, *Pavona clavus* and *Leptoseris papyracea* were found. *Pavona clavus* was very common.

Fish biodiversity

A total of 123 species of fish were found at this site. This was the only site at which two species of fish were found.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
Acropora corals	26.3
Non-Acropora corals	36.3
Octocorals	0.0
Sponges	1.3
Zoanthids	0.0
Coralline algae	1.9
Non-coralline algae	3.8
Recently killed coral	6.3
Dead coral + algae	1.3
Rubble	4.4
Other substratum	18.8

The forereef transect at Batu Malang was started at 16.8 m and habitat 1 was found between this depth and 14 m, characterised by the benthic class 'Rubble / sand and sparse algae and corals'. This area then changed into habitat 2, supporting benthic class 'Dense corals', at a depth of approximately 14 m. The Reef Check transect was laid within habitat 2 and highlighted very high coral cover (62.6%). The coral community was dominated by branching *Acropora* (26.3%) and non-*Acropora* submassive and foliose (18.1 and 10.0% respectively). The non-*Acropora* corals were dominated by *Pavona clavus*, *P. cactus* and *Montipora* spp.. Coral cover decreased to approximately 30% around the surge channels in depths less than 5 m. *Diadema* were very common on the Reef Check transect (99.8 per 100 m²) and edible sea cucumbers and *Tridacna* were also seen (7.0 and 1.5 per 100 m² respectively).

Impacts

Batu Malang had excellent coral cover but, although only two were seen on the Reef Check transect, there were frequent *A. planci* feeding scars. No *Drupella* were seen. Some coral damage from anchors and mooring ropes was observed and the site appears to be heavily used for snorkelling and diving. For example, during the survey at this site, 12 snorkelling boats and one dive boat were observed.

SITE 8: TELUK JUARA, PULAU TIOMAN

Overview

Teluk Juara is a bay on the eastern side of Pulau Tioman and the site was on the sheltered side of a small rocky islet approximately 50 m from shore. This site was chosen on the recommendation of marine park staff and after manta towing. Teluk Juara was surveyed on 18th September and was located at 309047 N, 412515 E.

Coral biodiversity

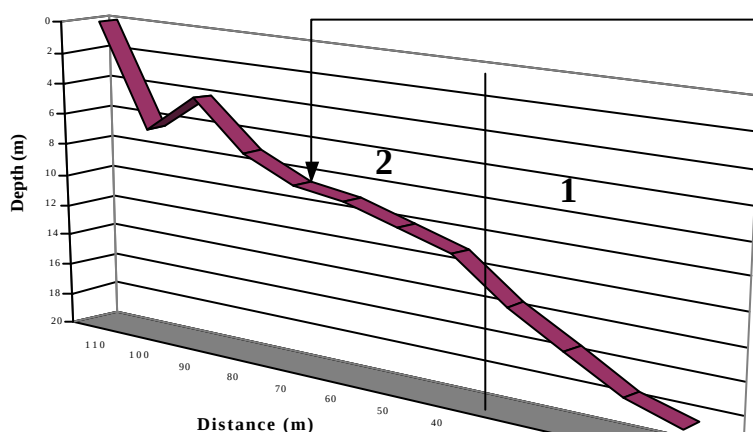
A total of 105 species of coral were found at this site, the highest for all sites. This was the only site at which *Montipora confusa*, *Goniopora planulata*, *Coscinaraea hahazimaensis*, *Favia* 'sp. 1', *Favia veroni*, *Goniastrea retiformis*, *Montastrea* 'sp. 1', *Euphyllia yaeyamaensis* and possibly *Acropora austera* and *Leptoseris scabra* were found.

Fish biodiversity

A total of 120 species of fish were found at this site. No species was unique to the site but a barramundi cod (*Cromileptes altivelis*) was observed.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
Acropora corals	1.3
Non-Acropora corals	20.0
Octocorals	10.0
Sponges	7.5
Zoanthids	0.0
Coralline algae	8.1
Non-coralline algae	12.5
Recently killed coral	3.1
Dead coral + algae	0.0
Rubble	4.4
Other substratum	33.1

The forereef transect at Teluk Juara was conducted from 18.5 m where habitat 1, with benthic class 'Rubble / sand and sparse algae and corals', was present. Habitat 1 then changed into habitat 2 at a depth of 14 m and the latter was characterised by the benthic class 'Dense corals'. However, the Reef Check transect showed that this area had a relatively low coral cover (21.3%) compared to most other reefs with the 'Dense corals' benthic class. The coral community was mainly non-*Acropora*, with the most common life forms being massive and encrusting (13.8 and 5.6% cover respectively). Invertebrates such as tunicates, sponges and bryozoans were abundant. *Diadema*, edible sea cucumbers and *Tridacna* were all seen on the Reef Check transect but were relatively infrequent (1.8, 3.3 and 1.3 per 100 m² respectively).

Impacts

Teluk Juara was a site with a high sedimentation load site and this was reflected in the coral assemblage, which had a low percentage cover but was very diverse. Furthermore, there was frequent evidence of coral mortality and all abiotic areas were covered in a layer of silt. No *A. planci* or *Drupella* were recorded, possibly because of the low coral cover.

SITE 9: PULAU GUT

Overview

Pulau Gut is a small rocky island, south of P. Tioman, and the site was on the southern side. This site was chosen on the recommendation of marine park staff and after manta towing. Pulau Gut was surveyed on 19th September and was located at 294262 N, 407374 E.

Coral biodiversity

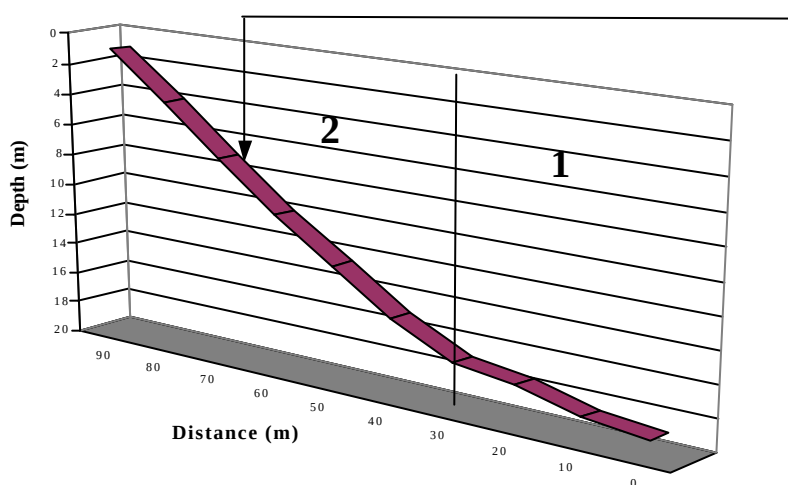
A total of 84 species of coral were found at this site. This was the only site at which *Favia maxima* and possibly *Millepora tenera* were found.

Fish biodiversity

The fish community was particularly abundant at P. Gut and a total of 152 species were found at this site. This was the only site at which four species of fish were found.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
<i>Acropora</i> corals	30.0
Non- <i>Acropora</i> corals	10.6
Octocorals	0.6
Sponges	3.1
Zoanthids	0.6
Coralline algae	8.1
Non-coralline algae	9.4
Recently killed coral	3.8
Dead coral + algae	1.9
Rubble	5.0
Other substratum	26.9

The forereef transect at Pulau Gut began at 19 m (habitat 1) and there was a higher hard coral cover than in deep water (> 18 m) at all other sites, reflected by the benthic class 'Rubble and mixed corals, invertebrates and algae'. Habitat 2, with the benthic class 'Dense corals', began at 17 m and was also the location for the Reef Check transect. Coral cover was high (40.6%) but was over 50% in many areas. The main life form was *Acropora* branching (28.8% cover). There was also a diverse invertebrate fauna, especially in the microhabitats offered by large boulders and caves between 4 and 8m deep. Bedrock on the reefs at less than 4m deep appeared cleanly grazed. *Diadema* were abundant on the Reef Check transect (65.0 per 100 m²) but no edible sea cucumbers and only one *Tridacna* were seen.

Impacts

The site for Pulau Gut had good coral cover and clear water but there were many patches of badly damaged *Acropora* in shallow water. This may be caused by *A. planci* and *Drupella* (four and 16 seen on the Reef Check transect respectively). There was significant evidence of fishing damage with 10 snagged sections of net and numerous lines in the vicinity of the Reef Check survey.

SITE 10: PULAU TOKONG BAHARA

Overview

Pulau Tokong Bahara is a small islet south-west of P. Tioman and the site was on the southern side. This site was chosen on the recommendation of marine park staff and after manta towing. Pulau Tokong Bahara was surveyed on 20th September and was located at 294260 N, 395686 E.

Coral biodiversity

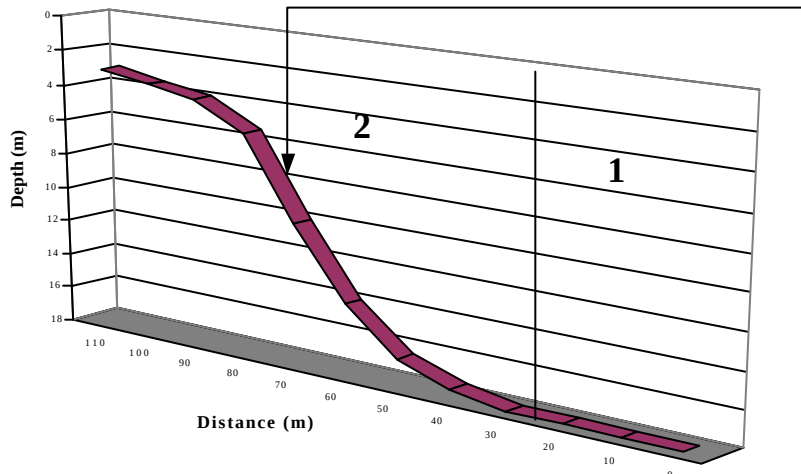
A total of 70 species of coral were found at this site. This was the only site at which *Heliofungia actiniformis* was found.

Fish biodiversity

A total of 131 species of fish were found at this site. This was the only site at which three species of fish were found. A barramundi cod (*Cromileptes altivelis*) was observed.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
Acropora corals	50.6
Non-Acropora corals	11.9
Octocorals	0.0
Sponges	1.9
Zoanthids	0.0
Coralline algae	2.5
Non-coralline algae	1.3
Recently killed coral	12.5
Dead coral + algae	1.9
Rubble	5.0
Other substratum	12.5

The forereef transect at Pulau Tokong Bahara began on a level area at 18 m which was characterised by benthic class 'Sand / silt' (habitat 1). This habitat then merged into habitat 2 which supported the benthic class 'Rubble and mixed corals, invertebrates and algae'. Although this habitat had a relatively low coral cover compared to many reefal sites, there was a narrow area of very high coral cover at a depth of between 10 and 5 m. This area was too small to be highlighted by the transect survey but was surveyed during the Reef Check transect. Hence these data show a very high coral cover (62.5%), dominated by branching *Acropora* (50.0%). The remainder of this habitat was mainly a mix of foliose and massive non-*Acropora* corals and branching *Acropora*. The final 20 m section of reef, to the base of a low cliff wall, was dominated by rubble covered in coralline and filamentous algae. No edible sea cucumbers or *Tridacna* were seen on the Reef Check transect but the *Diadema* density was 6.5 per 100 m². There were also numerous *Echinothrix calomaris*.

Impacts

The site at Pulau Tokong Bahara was not exceptional with a relatively poor coral community overall, possibly because of limited habitat complexity, but the shallow *Acropora* area was healthy. No *A. planci* were seen on the Reef Check transect but 11 *Drupella* were recorded.

SITE 11: PULAU SERI BUAT

Overview

Pulau Seri Buat is located west of P. Tioman and the site was in the centre of a rocky bay, exposed to the north-east monsoon, on the north coast of the island. This site was chosen after manta towing. Unusually for sites in this study, there was a mangrove forest in the intertidal. Pulau Seri Buat was surveyed on 21st September and was located at 298266 N, 378977 E.

Coral biodiversity

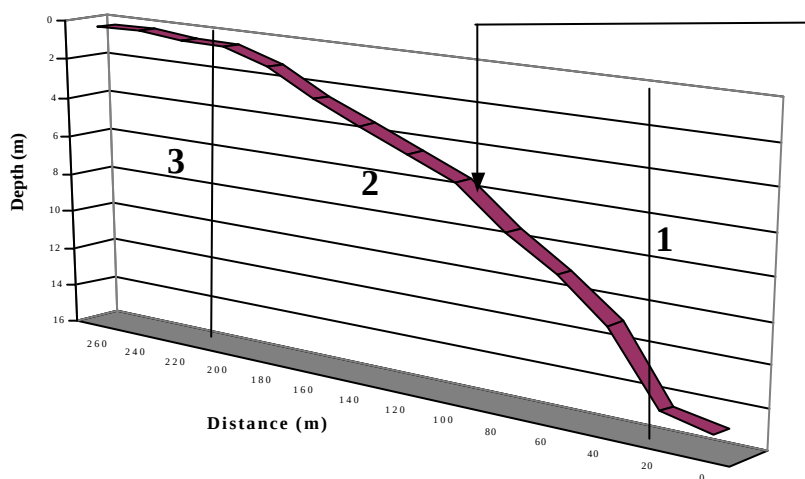
A total of 68 species were recorded, the lowest of all sites, and the only one at which *Oxypora crassispinosa* was found. This species was previously reported only from the Philippines.

Fish biodiversity

A total of 111 species of fish were found at this site. This was the only site at which two species of fish were found.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
Acropora corals	21.3
Non-Acropora corals	26.9
Octocorals	0.0
Sponges	3.1
Zoanthids	0.0
Coralline algae	5.6
Non-coralline algae	15.6
Recently killed coral	1.9
Dead coral + algae	6.3
Rubble	1.9
Other substratum	17.5

The forereef transect at Pulau Seri Buat started at a depth of 15 m in habitat 1, with benthic class 'Sand / silt', which was relatively level and continued to 14.5 m. Habitat 2 began at 14.5 m and was characterised by the benthic class 'Dense corals'. In very shallow water (<0.5 m) the corals became sparser and there was a third habitat, with benthic class 'Bedrock and mixed corals'. The Reef Check transect was laid within habitat 2 and highlighted the high coral cover (48.2%). This coral community consisted of both *Acropora* and non-*Acropora* colonies and the dominant life forms were non-*Acropora* massive and *Acropora* tabulate and branching (15.0, 11.9 and 9.4% respectively). The latter were more frequent between 8 and 2 m than in deeper water and *Heliopora* became abundant between 3 and 1m. Limited numbers of *Diadema*, edible sea cucumbers and *Tridacna* were seen on the Reef Check transect (3, 4 and 4 respectively) but a rock lobster (*Panilurus versicolor*) was seen.

Impacts

The site at Pulau Seri Buat appeared to be subjected to a high sediment load and on areas deeper than 3m there was a fine layer of silt on the substratum which became thicker with increasing depth. However, only one *A. planci* and no *Drupella* were seen on the Reef Check transect.

SITE 12: KADAR BAY, PULAU TULAI

Overview

Kadar Bay is a rocky bay on the north coast of Pulau Tulai (north-east of P. Tioman) and the survey site was on the eastern side with some shelter from the north-east monsoon. This site was chosen on the recommendation of marine park staff and after manta towing. Kadar Bay was surveyed on 22st September and was located at 322240 N, 400739 E.

Coral biodiversity

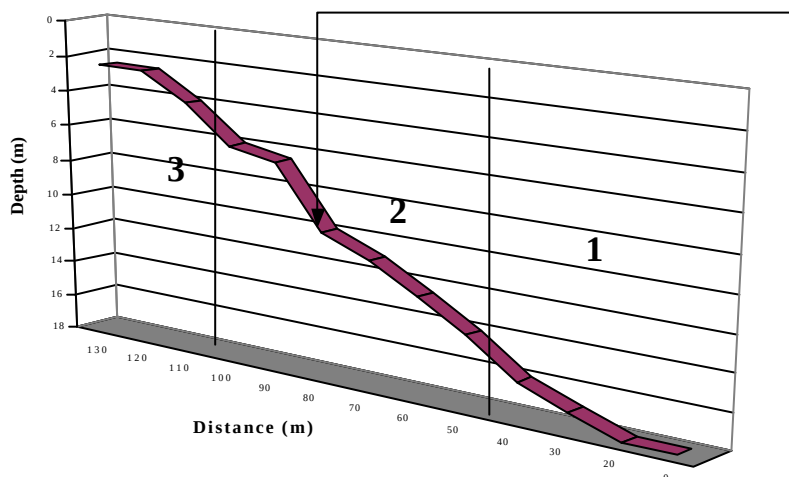
A total of 75 species of coral were found at this site. This was the only site at which *Montipora* 'sp. 2' was found.

Fish biodiversity

A total of 142 species of fish were found at this site. This was the only site at which four species of fish were found.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
<i>Acropora</i> corals	0.6
Non- <i>Acropora</i> corals	29.4
Octocorals	6.3
Sponges	0.6
Zoanthids	0.0
Coralline algae	3.1
Non-coralline algae	10.0
Recently killed coral	6.3
Dead coral + algae	0.0
Rubble	13.1
Other substratum	30.6

The transect at Kadar Bay was started at 18 m and the forereef was characterised by the benthic class 'Rubble and mixed corals, invertebrates and algae' (habitat 1). Hence this site had a more abundant benthic community below the true reef slope than many others. Habitat 2 began at 14 m and supported the benthic class 'Dense corals'. Finally, habitat 3 was found in shallow water (<4 m) with benthic class 'Sand / bedrock boulders and scattered corals'. The Reef Check survey was conducted in habitat 2 and highlighted a coral cover of 30.0%. The coral community was dominated by non-*Acropora* colonies, particularly the life forms submassive and massive (13.8 and 11.8% cover respectively). Only six *Diadema* were seen on the Reef Check transect but edible sea cucumbers and *Tridacna* were relatively abundant (3.0 and 6.3 per 100 m² respectively). *Tridacna* were also common in shallower water (<8 m).

Impacts

The site in Kadar Bay appeared to have suffered from moderate siltation and, in shallow water (<5 m), there were also high levels of filamentous blue-green algae on old dead coral skeletons and bedrock. Both *A. planci* and *Drupella* were recorded at low levels on the Reef Check transect (four and two individuals respectively) but obvious feeding scars were present.

SITE 13: PULAU RENGGIS

Overview

Pulau Renggis is a small rocky island on the west coast of P. Tioman and is close to a number of tourist resorts who utilise it as a diving and snorkelling site. The site was on the southern side and was chosen on the recommendation of marine park staff and local dive operators. Pulau Renggis was surveyed on 23rd September and was located at 310689 N, 403658 E.

Coral biodiversity

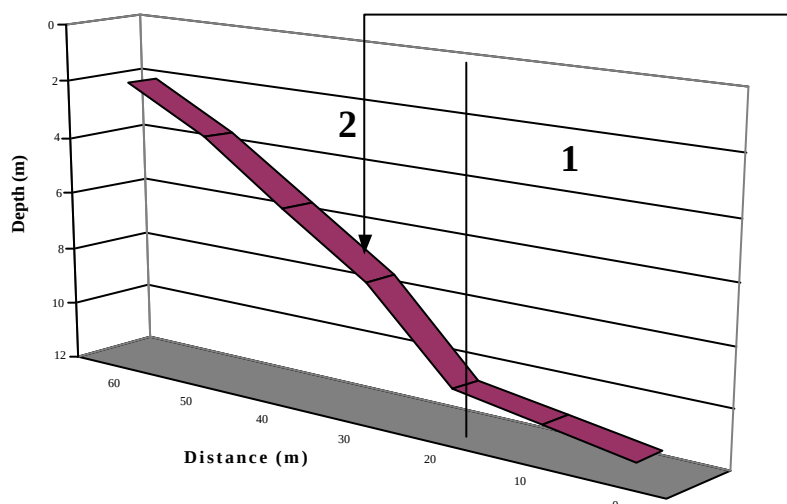
A total of 82 species of coral were found at this site. This was the only site at which *Diaseris distorta*, *Galaxea* 'sp. 1' and *Trachyphyllia geoffroyi* were found.

Fish biodiversity

A total of 148 species of fish were found at this site. This was the only site at which five species of fish were found. A resident school of barracuda (*Sphyrna* sp.) was observed.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
<i>Acropora</i> corals	29.4
Non- <i>Acropora</i> corals	22.5
Octocorals	0.0
Sponges	2.5
Zoanthids	0.0
Coralline algae	5.6
Non-coralline algae	1.9
Recently killed coral	13.1
Dead coral + algae	1.3
Rubble	6.3
Other substratum	17.5

The forereef transect at Pulau Renggis was started at 11.5 m and was characterised by the benthic class 'Sand / rubble and scattered corals' (habitat 1). At 10.5 m this habitat merged into habitat 2, which supported the benthic class 'Dense corals'. The lower reef slope had a diverse coral cover but branching *Acropora* became more common between 6 and 8 m. The Reef Check transect was placed in this area and hence highlighted a very high coral cover (51.9% cover) with a higher proportion of *Acropora*. The dominant life form was branching *Acropora* (28.1%) but branching non-*Acropora* (mainly *Echinopora horrida* and *Hydnophora grandis*) were also common (10.0%). The upper reef had many large bedrock boulders. The urchins *Diadema*, *Echinometra* and *Echinothrix* were present in very high numbers at this site (*Diadema* abundance was 207.5 per 100 m² on the Reef Check transect). A total of 20 edible sea cucumbers and 22 *Tridacna* were also recorded.

Impacts

The site at Pulau Renggis had a generally good reef but appeared under some stress, particularly from *Drupella* which were extremely abundant (72.3 per 100 m² on the Reef Check transect). However, only eight *A. planici* were recorded. This reef also had large patches of dead branching corals overgrown with macro-algae or encrusting sponge.

PARKS SUMMARY: PULAU TINGGI MARINE PARKS

Background

Pulau Tinggi Marine Parks consists of 13 widely scattered islands in the state of Johor and P. Tinggi is the largest and is relatively close to the shoreline of Peninsular Malaysia. Services such as discarded refuse removal and sewage treatment are not as advanced as in the other states. The proximity of the parks to Singapore facilitates revenue from tourism.

Coral biodiversity

These parks contained 155 species and was the only group in which *Montipora cebuensis* and 'sp. 1', *Acropora hoeksemai*, *vermiculata* and *yongei*, *Psammocora explanulata*, *Acanthastrea echinata*, *Lobophyllia corymbosa*, 'sp. 2' and 'sp. 3', *Lobophyllia* 'undescribed', *Favites* 'sp. 2' and possibly *Acropora stoddarti* were found.

Fish biodiversity

A total of 219 species of fish were found in the marine parks. This was the only group of parks in which 26 species of fish were found.

Reef zonation

All sites in the marine parks had coral rich forereefs but there was variation in the depth reached by this zone at different sites. At P. Dayang and Batu Tikus, high coral cover continued to at least 15 m but at P. Pemanggil and P. Simbang rich coral was much shallower (<8 m). High coral cover habitats were generally characterised by the benthic class 'Dense corals' but 'Bedrock and non-*Acropora* rich corals and octocorals' was present at Batu Tikus, changing to 'Bedrock and mixed corals' in shallow water. Below the coral habitats were the benthic classes 'Rubble / sand and sparse algae and corals' and 'Rubble and sparse algae and corals'. Batu Tikus had a further coral rich habitat in deeper water (18 m) and P. Pemanggil had a habitat with benthic class 'Sand / rubble and scattered corals' in very shallow water.

Reef health

Benthic category	% cover *	
<i>Acropora</i> corals	13.1	(3.1)
Non- <i>Acropora</i> corals	21.4	(12.9)
Octocorals	4.1	(3.2)
Sponges	6.7	(4.8)
Zoanthids	0.0	(0.0)
Coralline algae	6.7	(5.0)
Non-coralline algae	7.0	(6.4)
Recently killed coral	3.8	(2.0)
Dead coral + algae	1.9	(2.1)
Rubble	9.8	(6.8)
Other substratum	25.5	(4.9)

Taxa	Density / 100m ² *	
<i>Diadema</i>	139.5	(163.2)
Sea cucumber	11.9	(17.8)
<i>Tridacna</i>	1.3	(1.1)
<i>A. planci</i>	0.1	(0.1)
<i>Drupella</i>	6.6	(6.8)

* Means for all four sites combined. Standard deviation in parentheses.

The survey sites generally had good coral cover (mean 34.5%) on the Reef Check transects. However, this mean was reduced by the low value at P. Pemanggil (15.7%), where the high coral cover habitat was located in shallower water. Octocorals, sponges and zoanthids were generally uncommon. Recently killed coral cover, mostly from *A. planci* and *Drupella* feeding, was less than 4% overall. Non-coralline algae was present, although not abundant overall (8.9%). However, there was a clear distinction between the sites close to the mainland (P. Simbang and Batu Tikus) with low algal cover (<3.5%) and the sites further offshore (P. Dayang and P. Pemanggil) with high algal cover (>13.5%). Non-coralline algae cover was strongly correlated with *Diadema* densities ($R^2 = 0.95$) which varied dramatically from <3.5 ('offshore' sites) to >230 / 100 m² ('mainland' sites). Although the causes of variation in urchin populations are not clear it may be related to high nutrient input which increases algal productivity and hence supports larger populations. Edible sea cucumbers and *Tridacna* were seen on most surveys. *A. planci* were rare in the marine parks but *Drupella* were more common.

Estimated condition of reefs not surveyed

In addition the four survey sites, a series of manta tows were conducted in the P. Tinggi Marine Parks to select appropriate locations for data collection. These manta tows did not provide general information on the condition of large sections of reef but the observations generate some evidence of the status of other areas of the marine parks. For example, a tow on the north-east side of P. Aur and P. Dayang documented impressive topography but little biotic cover. Similarly to north-eastern sections of other islands, the high percentage cover of bedrock and low coral cover is likely to be partly caused by exposure to storm damage during monsoon conditions. However, the survey site at P. Simbang was found after only a brief tow and the surrounding areas seemed in equally good condition, possibly indicating generally good reefs around the island.

All the reefs in the marine parks have been affected by the 1998 coral bleaching event as there was evidence of dead coral, usually overgrown with macro-algae. Therefore, the overall conclusion was that, although there are areas of good coral cover and high biodiversity, the reefs in the marine parks have been impacted by a variety of factors and many areas currently have significantly reduced coral cover. A key example of an excellent area was Batu Tikus which had high coral cover, especially on the north-west side where there was nearly 100% cover of tabulate *Acropora* and encrusting *Pachyseris* colonies. This site was among the best surveyed in terms of diversity, rugosity and live coral cover and since it is currently on the edge of the park boundary in urgent need of increased protection.

Current impacts and existing threats

Much of the dead coral at both the survey sites and surrounding reefs may be attributable to the 1998 bleaching event, which obviously had a significant effect on the marine parks. Further coral mortality has been caused, and continues to be caused, by the corallivores *A. planci* and *Drupella*. However, assuming there is not a population outbreak of *A. planci*, this mortality is relatively minor and will not inhibit either coral recovery or general reef integrity.

Pulau Simbang and Batu Tikus are relatively close to Peninsula Malaysia itself and a higher sedimentation regime was expected than for sites further offshore, partly for natural reasons but also because of coastal development. Siltation was indeed higher at P. Simbang and there was a layer of silt on many parts of the benthos. However, while such sediment loads certainly affect reef health, it should be noted that both sites had good coral cover (47.5% on P. Simbang) and Batu Tikus was one of the best sites surveyed.

Human population pressure is relatively low in the marine parks and is primarily centred on P. Tinggi, with smaller communities on P. Aur and P. Pemanggil. The closest communities to the study sites consisted of a maximum of only approximately 200 people. Water quality in the parks is, therefore, likely to be good but with some significant point sources of pollution. Local fishermen have been given permission to fish within the marine parks via traditional techniques but fishing pressure appears low to moderate. However, snagged lines were seen at many sites, along with some traps and nets. Although abandoned gear is not a major threat to coral health, nets can smother relatively large areas and a large drift net was seen at Batu Tikus. However, corals were growing through it and indeed it had been fused into the skeletons of many *Acropora* colonies. Fishing itself can have major economic and ecological impacts, including the reduction of herbivorous fish which can affect the ability of reefs to regenerate. Finally, there are numerous dive and snorkelling sites within the marine parks but, although there was evidence of coral damage from anchor damage, this does not seem a significant threat.

SITE 14: TELUK JAWA, PULAU DAYANG

Overview

Teluk Jawa was selected as the best site at P. Dayang, a small island close to P. Aur. The site was selected following a manta tow and recommendation by marine park officials and dive shops. Teluk Jawa is a moderately steep slope on the north-western side of the island and, although not as exposed as the north-eastern side, it is still subject to heavy swell conditions. The site was surveyed on 24th September and was located at 273840 N, 443840 E.

Coral biodiversity

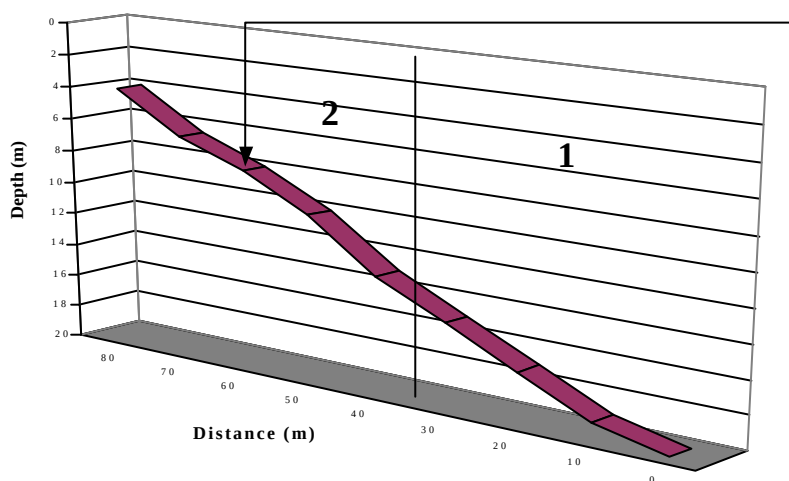
A total of 81 species of coral were found at this site. This was the only site at which *Psammocora explanulata*, *Lobophyllia corymbosa*, 'sp. 1' and 'sp. 2' were found.

Fish biodiversity

A total of 156 species of fish were found at this site, the most on any survey. This was the only site at which nine species of fish were found.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
Acropora corals	9.4
Non-Acropora corals	29.4
Octocorals	3.1
Sponges	5.6
Zoanthids	0.0
Coralline algae	3.1
Non-coralline algae	11.9
Recently killed coral	1.3
Dead coral + algae	5.0
Rubble	7.5
Other substratum	23.8

The reef profile at Teluk Jawa consisted of forereef which was surveyed from 20 m and began with habitat 1: 'Rubble and sparse algae and corals'. At 15 m the benthos changed to habitat 2: 'Dense corals'. Mean total coral cover in this zone was recorded as 38.4% and was mainly Non-Acropora, with massive and encrusting life forms most common (10 and 8.8% respectively). In addition, 11 recruits were recorded by the Reef Check survey and many live coral fragments (branching and foliose life forms) were seen to have reattached to the bedrock and were starting new colonies. Branching *Acropora* stands occurred at depths of between 4 and 6 m, close to large bedrock boulders which were extensively covered on the shaded sides with encrusting sponges, ascidians and hydroids. The shallows (<4m) were comprised entirely of large boulders. On the Reef Check transect, no urchins were seen but there was a mean of 2.8 *Tridacna* and 8.3 edible cucumbers per 100 m².

Impacts

A high level of discarded refuse was recorded at Teluk Jawa. A mean of 12.0 *Drupella* were per 100 m² on the Reef Check transect and there were also eight large (approximately 40 cm) *A. planci* and frequent feeding scars close to this transect.

SITE 15: TELUK PONTIANAK, PULAU PEMANGGIL

Overview

Teluk Pontianak was selected as the best site at Pulau Pemanggil following a recommendation by marine park officials and exploratory snorkelling. Teluk Pontianak is a shallow gently sloping reef on the north-western part of the island, sheltered from the north-eastern monsoon. The site was surveyed on 25th September and was located at 286315 N, 423009 E.

Coral biodiversity

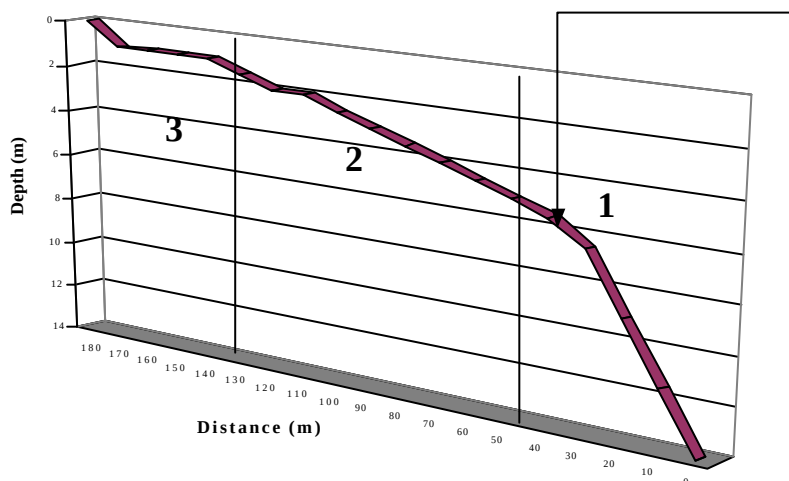
A total of 82 species were found at this site. This was the only site at which *Montipora cebuensis* and 'sp. 1' and *Acropora hoeksemai*, *vermiculata* and *yongei* were found.

Fish biodiversity

A total of 121 species of fish were found at this site. This was the only site at which three species of fish were found. A barramundi cod (*Chromileptes altivelis*) was observed.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
<i>Acropora</i> corals	11.9
Non- <i>Acropora</i> corals	3.8
Octocorals	6.9
Sponges	3.8
Zoanthids	0.0
Coralline algae	1.9
Non-coralline algae	13.1
Recently killed coral	5.6
Dead coral + algae	0.6
Rubble	20.0
Other substratum	32.5

The reef profile at Teluk Pontianak consisted of forereef which was surveyed from 14 m and began with habitat 1: 'Rubble / sand and sparse algae and corals'. Between approximately 6 and 1 m there was a shallow area of 'Dense corals' (habitat 2) which then merged into habitat 3, a shallow lagoon area supporting benthic class 'Sand / rubble and scattered corals'. The Reef Check transect was located on the border of habitats 1 and 2 and hence shows a relatively low coral cover (15.7%) and high abiotic component (52.5%). *Acropora* corals were more common than non-*Acropora* and between 6 and 3m they dominate the reef (mainly branching and tabulate life forms). *Heliopora* was abundant at <4 m and the transition to habitat 3 was characterised by a stubby branching *Acropora* and *Halimeda*. On the Reef Check transect, edible holothurians were common (38 / 100 m²) but only 12 *Diademas* and one *Tridacna* was seen. A number of large gastropods (*Lambis chiragra* and *Chicoreus ramosus*) were noted.

Impacts

Coral damage through lost fishing nets and line was observed at Teluk Pontianak. Large areas of branching *Acropora* were dead but still intact and overgrown with filamentous algae and small anemones, possibly indicating effects from the 1998 bleaching event. Only one *Drupella* was seen but there were some *A. planici* feeding scars.

SITE 16: PULAU SIMBANG

Overview

Pulau Simbang is a small forested island just south of Pulau Tinggi and the selected site was to the north-west of the island. The site was selected following a recommendation by marine park officials and manta towing. Pulau Simbang was surveyed on 26th September and was located at 250817 N, 404923 E.

Coral biodiversity

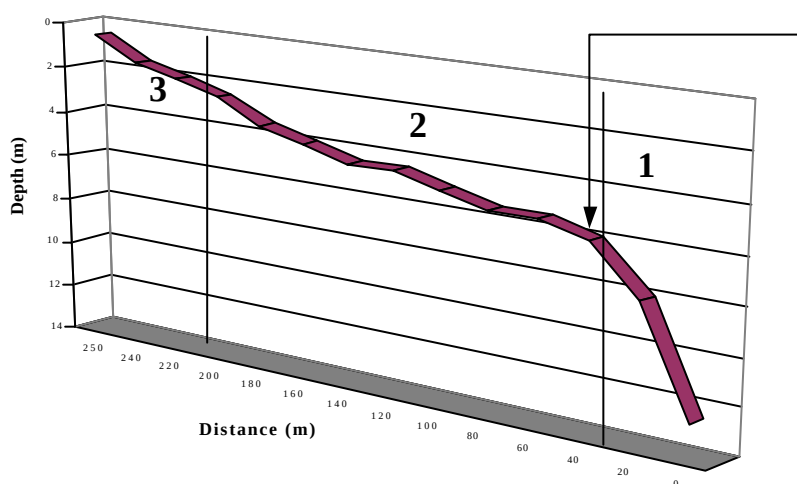
A total of 82 species of coral were found at this site. No species were unique to this site.

Fish biodiversity

A total of 112 species of fish were found at this site. This was the only site at which *Dischistodus prosopotaenia* was found.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
<i>Acropora</i> corals	15.0
Non- <i>Acropora</i> corals	32.5
Octocorals	0.0
Sponges	3.8
Zoanthids	0.0
Coralline algae	11.9
Non-coralline algae	2.5
Recently killed coral	3.1
Dead coral + algae	0.6
Rubble	6.3
Other substratum	24.4

The reef profile at Pulau Simbang consisted of forereef which was surveyed from 12.5 m and began with habitat 1: 'Rubble and sparse algae and corals'. Between approximately 8 and 1.5 m there was an area of 'Dense corals' (habitat 2) which then adjoined habitat 3, a reef flat area with benthic class 'Sand / bedrock boulders and scattered corals'. The dense coral area, where the Reef Check transect was laid, had high coral cover (47.5%) and associated rugosity. Non-*Acropora* corals were more abundant than *Acropora*, and foliose, massive and encrusting were the main life forms (9.4, 6.1 and 5.8% cover respectively). On the Reef Check transect, *Diadema* were very abundant with a density of 234.2 / 100 m². However, only two edible holothurians and three *Tridacna* were seen.

Impacts

The site for Pulau Simbang appeared relatively highly impacted with many branching corals reduced to rubble, presumably following the 1998 bleaching event. Similarly, in shallow water an extensive area of *Pachyseris* was completely dead (but still standing) and other areas had numerous collapsed tabulate *Acropora* colonies. The site also a high sediment regime and a layer of fine silt covered the substratum and dead corals. There were several *A. planci* feeding scars and 13.0 *Drupella* per 100 m² on the Reef Check transect.

SITE 17: BATU TIKUS

Overview

Batu Tikus is a small rocky islet north-west of Pulau Tinggi and the selected site was to the south-east. Batu Tikus, although on the boundary of the marine protected area was selected following a recommendation by marine park officials and the site was chosen after manta towing. The site was surveyed on 27th September and was located at 268790 N, 394278 E.

Coral biodiversity

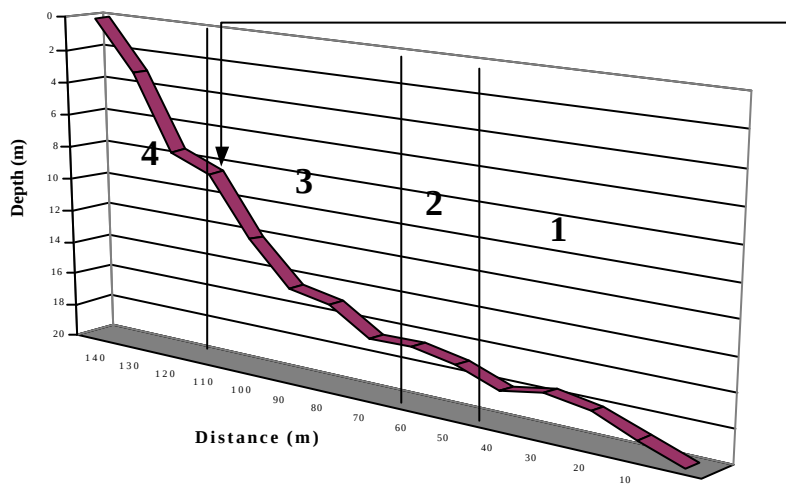
A total of 79 species of coral were found at this site. This was the only site at which *Lobophyllia* 'undescribed', *Favites* 'sp. 2' and possibly *Acropora stoddarti* were found. The undescribed species of *Lobophyllia* was most common here and collected from this location.

Fish biodiversity

A total of 133 species of fish were found at this site. This was the only site at which ten species of fish were found. Fish life was recorded as abundant.

Reef health and zonation

Transect survey



Reef Check survey

Benthic category	% cover
<i>Acropora</i> corals	16.3
Non- <i>Acropora</i> corals	20.0
Octocorals	6.3
Sponges	13.8
Zoanthids	0.0
Coralline algae	10.0
Non-coralline algae	0.6
Recently killed coral	5.0
Dead coral + algae	1.3
Rubble	5.6
Other substratum	21.3

The reef profile at Batu Tikus was relatively complex and began at a depth of 20 m on a patch reef approximately 60m from the reef slope (habitat 1). The patch reef supported the benthic class 'Bedrock and non-*Acropora* rich corals and octocorals' which then became 'Rubble / sand and sparse algae and corals' (habitat 2). At 16.5 m the forereef began with the benthic class 'Bedrock and non-*Acropora* rich corals and octocorals' (habitat 3). Finally, the reef increased in slope to an escarpment with 'Bedrock and mixed corals' (habitat 4). The Reef Check transect was in habitat 3 and highlighted relatively high coral cover (36.3%), with non-*Acropora* corals the most abundant. Non-*Acropora* massive was by far the most dominant life form (16.3%). Coral cover was estimated at being over 50% deeper on the forereef and on the patch reef. On the Reef Check transect, *Diadema* were very abundant with a density of 320.8 / 100 m². In addition, three edible holothurians and five *Tridacna* were seen.

Impacts

Five *Drupella* and some *A. planci* feeding scars were seen at the site for Batu Tikus but the main impact noted was approximately 150 m of snagged drift net draped over areas of excellent coral cover. According to marine park staff, this net had been present for at least six months but the coral appears relatively unaffected. However, it continues to 'ghost fish' for fish, including small sharks.

RECOMMENDATIONS

The aim of this study was to document the biodiversity and health of the reefs in three groups of marine parks. However, during this work it was apparent that there are additional data collection programmes, training opportunities and educational requirements that would aid the management of the marine parks. Hence, the following recommendations are presented but they are relatively *ad hoc* and should not be viewed as either comprehensive or ranked in order of importance.

- Establishing the current status of reef health is limited by a lack of existing quantitative spatial and temporal data in the marine parks. A monitoring programme would provide standardised and consistent data on changes to reef health. Data on water quality would also assist assessment of threats, for example from nutrient enrichment, and help establish mitigation measures.
- Additional training for marine park staff would allow them to undertake monitoring programmes and rapidly respond to dynamic data collection requirements during coral bleaching events, *A. planci* outbreaks, changing *Drupella* populations or increases in the presence of coral diseases.
- Management of the marine parks would be assisted by a thorough assessment of the status of all reefs within the marine parks. Such an assessment can be assisted by the use of non-specialist divers to collect baseline data and should incorporate remotely sensed imagery and the mapping capabilities of Geographic Information Systems. This research could result in a marine resource atlas of the parks.
- The coral and fish biodiversity assessments generated by this study could be extended by additional survey effort by specialist researchers. Additional biodiversity assessments are possible for other taxa, particularly marine plants and invertebrates.
- Managing tourist use of the marine parks (particularly diving, snorkelling and boat anchoring) appears to be important for maintaining reef health. Excellent programmes for controlling tourist impacts to the reef exist within the parks and could be extended throughout the whole system. Such management requirements will increase with increasing tourism.
- Additional environmental education for both communities within the parks and tourists will assist management of the parks via greater awareness of threats to reef health, implications of decreased coral cover, fish populations and biodiversity and the interactions between marine and terrestrial systems.
- Since the reefs within the marine parks are a network of healthy and impacted reefs, the ‘good’ areas will be important in facilitating recovery of the ‘poor’ areas via production of coral and fish larvae. Increased protection for some of these healthy reefs areas, possibly via designation as ‘sanctuary zones’, may aid this process.

ACKNOWLEDGEMENTS

This study would not have been possible without the support of numerous organisations and individuals, only some of whom can be listed here. We gratefully acknowledge all the support given to the fieldwork and report preparation.

This study was funded by the UNDP-GEF and the authors would like to thank all the staff at the office in Malaysia who co-ordinated the work. Particular thanks are due to Tim Clairs (GEF Regional Advisor – Biodiversity Asia and the Pacific), Dr Martin Abraham (National Co-ordinator UNDP-GEF Small Grants Programme) and Norzilla Mohamed.

Logistical support during the fieldwork and report writing phases of this study was provided by the Department of Fisheries, who are gratefully acknowledged. The authors would also like to thank the following individuals, without whose help this study would not have been possible:

Department of Fisheries

Kevin Hiew Wai Phang (Head, Marine Parks Branch); Mohd Najib Ramli, Ahmad Azahari Ahmad, Hamidon Ahmad and Zabawi Saat (Marine Parks Branch); Ab. Rahim Gor Yaman (Head of Unit, Marine Parks of Terengganu); Abd. Khalil Abd. Karim, (Head of Unit, Marine Parks of Johor); Noorazizah Kemat (Head of Unit, Marine Parks of Pahang); Choong Kah Tung (Head, Marine Parks Centre of P. Tioman); Pauzi Abdullah and Zaidnuddin Ilias (Fisheries Research Institute); Dr Khusairi Rajuddin (Marine Fisheries Resources Development and Management Department); Zakariya Tayib, Sabri Jaafar and Mazlan Wahab (Marine Parks Unit of Kedah) and Radzuan Razak (Marine Parks Unit of Johor).

We are grateful to all the ground staff of the Marine Parks Units of Terengganu, Pahang and Johor: Azman Md. Dahan, Osman Ahmad and Mohd Nor Ismail (Pahang); Ahmad Jefri Saidin, Ahmad Faizal Abdullah, Mohamad Abd. Rahman, Mohd Azizul Khan Hashim, Jaafar Din, Naseri Noramat, Zawawi Ismail, Roslee Abdullah, Fadzil Jais, Murad Khamis and Azlan Ismail (Johor); Sharif Saad, Manas Haron, Nor Azman Che Din, Yusri Mohd Daud, Moha Rashib Darus, Johari Hussin, Sidek Mohammad, Razali Abu Bakar, Ismadi Endut, Zulkifli Hussin and Rosdi Ambok (Terengganu).

Volunteers

Liew Hock Chark, Baharin Mustapa, Yab hae jae, Chiew Sau San and Helen Wong Chin Chiew (University College Terengganu, Kuala Terengganu); Yusri Yusof, P. Shamala Shubashini and Syaripah Nora Ibrahim (University Science of Malaysia, Penang); Yuen Yeong Shyan (University Malaya, Kuala Lumpur) and Hashimi Ismail (WWF-Malaysia, Kuala Lumpur).

The authors are grateful to the staff of WWF-Malaysia for their continual advice and access to previously published literature. Particular thanks are due to Jeet Sukumaran and Dr Vidhisha Samarasekara.

Finally, this study would not have been possible with the help of the staff at Coral Cay Conservation, particularly Jonathon Ridley who established the opportunity to conduct the fieldwork. Jean-Luc Solandt significantly improved an earlier version of the manuscript and advice and comments were gratefully received from Peter Raines and Alex Page. Dr David Vousden (UNDP-GEF) is also thanked for additional comments.

REFERENCES

- Aikanathan, S. and Wong, E.F.H. 1994. Marine park management conceptual plan for Peninsula Malaysia. Department of Fisheries Malaysia and WWF-Malaysia.
- Allen, G.R. 1991. Damselfishes of the world. Aquarium Systems, Mentor, Ohio, USA.
- Betterton, C. 1981. A guide to the hard corals of Peninsular Malaysia (excluding the genus *Acropora*). *Malayan Nature Journal* **34**: 171-336.
- Ching, L.L. and Spring, N. 1995. The concepts and analysis of carrying capacity: A management tool for effective planning. Part III Case Study: Pulau Tioman. Unpublished WWF-Malaysia report.
- Chou, L.M. and 9 other authors. 1994. Status of coral reefs in the ASEAN region. Pages: 1-10. In: Wilkinson, C.R., Suraphol Sudara and Chou, L.M (Eds). *Proceedings of the Third ASEAN-Australia Symposium on Living Coastal Resources. Volume 1: Status reviews*. Australian Institute of Marine Science.
- Chou, L.M. 2000. Southeast Asian reefs – status update: Cambodia, Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. Pages: 117-129. In: Wilkinson, C.R. (Ed.). *Status of coral reefs of the world: 2000*. Australian Institute of Marine Science.
- Colin, P.L. and Arneson, C. 1995. Tropical Pacific Invertebrates. Coral Reef Press, Beverly Hills.
- De Silva, M.W.R.N., Betterton, C. and Smith, R.A. 1980. Coral reef resources of the east coast of Peninsular Malaysia. In: Coastal Resources of East Coast Peninsular Malaysia (Eds: Chua, T.E. and Charles, J.K.). Universiti Sains Malaysia, Penang.
- Fowler, H. 1938 A list of the fishes from Malaysia. *Fisheries Bulletin, Singapore*. Published by authority WWF-Malaysia.
- Green, J.P. 1978. A survey and proposal for the establishment of the Pulau Redang Archipelago National Park. Unpublished WWF-Malaysia report.
- Hamid Rezai, Ibrahim, H.M., Idris, B.A.G. and Kushairi, M.R.M. 1999. Some effects of submarine pipeline construction on the sessile zoobenthic community of Redang Island. *Hydrobiologia* **405**: 163-167.
- Hendry, H.J. 2000. Update on the status of the coral reef ecosystems and management of the Pulau Tioman Marine Park, Peninsular Malaysia. Unpublished report to WWF-Malaysia.
- Jennings, S., Reynolds, J.D. and Polunin, N.V.C. 1999. Predicting the vulnerability of tropical reef fishes to exploitation with phylogenies and life histories. *Conservation Biology* **13**: 1466-1475.
- Marshall, P.A. and Baird, A.H. 2000. Bleaching of corals on the Great Barrier Reef: differential susceptibilities among taxa. *Coral Reefs* **19**: 155-163.
- McClanahan, T.R. and Muthiga, N.A. 1988. Changes in Kenyan coral reef community structure and function due to exploitation. *Hydrobiologia* **166**: 269-276.

- Morse, D.E., Hooker, N., More, A.N.C. and Jensen, R.A. 1988. Control of larval metamorphosis and recruitment in sympatric agariciid corals. *Journal of Experimental Marine Biology and Ecology* **116**: 193-217.
- Mumby, P.J., Gray, D.A., Gibson, J.P. and Raines, P.S. 1995a. Geographic Information Systems: A tool for integrated coastal zone management in Belize. *Coastal Management* **23**: 111-121.
- Mumby, P.J., Harborne, A.R., Raines, P.S. and Ridley, J.M. 1995b. A critical assessment of data derived from Coral Cay Conservation volunteers. *Bulletin of Marine Science*. **56**: 737-751.
- Pillai, C.S.G. and G. Scheer. 1974. On a collection of scleractinia from the Strait of Malacca. *Proceedings of the 2nd International Coral Reef Symposium* **1**: 445-464.
- Rahman, R.B.A. 1986. Palau Redang Marine Park, Resource Study. Universiti Pertanian Malaysia, Serdang, Selangor.
- Rahman, R.A. and Ibrahim, S.N.S. 1996. Pulau Redang Marine Park Malaysia. The Department of Fisheries Malaysia and Design Dimensions Sdn Bhd.
- Raines, P.S., Ridley, J.M., McCorry, D. and Mumby, P.J., 1992. Coral Cay Conservation - survey techniques and their application in Belize. *Proceedings of the 7th International Coral Reef Symposium*, Guam. **1**: 122-126.
- Ridzwan, A.R. 1994. Status of coral reefs in Malaysia. Pages: 49-56. In: Wilkinson, C.R., Suraphol Sudara and Chou, L.M (Eds). *Proceedings of the Third ASEAN-Australia Symposium on Living Coastal Resources. Volume 1: Status reviews*. Australian Institute of Marine Science.
- Searle, A.G. 1956. An illustrated key to Malayan hard corals. *Malayan Nature Journal* **11**: 1-26.
- Sin, T.M., Teo, M.M., Ng, P.K.L., Chou, L.M. and Khoo, H.W. 1994. The damselfishes (Pisces: Osteichthyes: Pomacentridae) of Peninsular Malaysia and Singapore: systematics, ecology and conservation. *Hydrobiologia* **285**: 49-58.
- Veron, J.E.N. 1993. A biogeographic database of hermatypic corals. *AIMS Monograph* **10**: 1-433.
- Veron, J.E.N. 2000. Corals of the World. 3 Vols. M. Stafford-Smith (Ed.). Australian Institute of Marine Science Monograph Series.
- Wood, E.M. and Tan, B.S. 1987. The coral reefs of the Bodgaya Islands (Sabah: Malaysia) and Pulau Sipadan. 3. Hard corals. *Malayan Nature Journal* **40**: 189-224.
- Wood, C.R. and Wood, E.M. 1987. The coral reefs of the Bodgaya Islands (Sabah: Malaysia) and Pulau Sipadan. 3. Fishes. *Malayan Nature Journal* **40**: 285-310.

APPENDIX 1: SURVEY METHODOLOGIES

At each of the 17 selected survey sites, four major data types were collected to generate a standardised data set for each location:

APPENDIX 1(A): CORAL BIODIVERSITY

A list of coral species was recorded at each site via underwater observations during two, 60-minute dives. The name of each species identified was marked on a plastic sheet on which species names were printed. A initial descent was generally made to the base of the reef but occasionally the surveys started beyond the maximum depth of abundant coral growth (approximately 20 m). The majority of the dive consisted of a slow ascent in a 'zigzag' path to the shallowest point of the reef or until further swimming was not possible. Sample areas of all habitats encountered were surveyed, including sandy areas, walls, overhangs, slopes and shallow reef. Many corals could be identified to species with certainty in the water and a few must be identified alive since they cannot be identified without living tissues.

Field guides assisted identification (Nishihira and Veron, 1995; Wallace and Wolstenholme, 1998). However, a number of species were sighted which could not be identified (without collection) so it is clear that the total coral fauna exceeds that identified in this study. Some species can be tentatively identified in the field, but are best confirmed by the collection of a sample. No samples were collected and hence these species are indicated by a '?' following the species name in Appendix 4. Additional references that provided background material for the identification of species were Best and Hoeksema (1987); Best and Suharsono (1991); Boschma (1959); Claereboudt (1990); Dai (1989); Dai and Lin (1992); Dineson (1980); Hodgson and Ross (1981); Hoeksema (1989); Hoeksema and Best (1991); Hoeksema and Dai (1992); Moll and Best (1984); Nemenzo (1986); Ogawa and Takamashi (1993, 1995); Randall and Cheng (1984); Sheppard (1998); Sheppard and Sheppard (1991); Veron (1985, 1990, 2000); Veron and Pichon (1976, 1980, 1982); Veron, Pichon and Wijman-Best (1977); Veron and Wallace (1984); Wallace (1994, 1997a, 1999) and Wallace and Dai (1997).

The primary survey group was the hard corals (zooxanthellate scleractinians) that contain single-cell algae and which contribute to reef building. However, this study also included a small number of zooxanthellate non-scleractinian corals which also produce large skeletons (e.g. *Heliopora* and *Millepora*), a small number of azooxanthellate scleractinian corals (*Tubastrea* and *Rhizopsammia*) and one azooxanthellate non-scleractinian coral (*Distichopora*). All produce calcium carbonate skeletons which contribute to reef building.

References

- Best, M.B. and Hoeksema, B.W. 1987. New observations on Scleractinian corals from Indonesia: 1. Free-living species belonging to the Faviina. *Zoologische Mededelingen Leiden*. **61**: 387-403.
- Best, M. B. and Suharsono. 1991. New observations on Scleractinian corals from Indonesia: 3. Species belonging to the Merulinidae with new records of *Merulina* and *Boninastrea*. *Zoologische Mededelingen Leiden* **65**: 333-342.
- Boschma, H. 1959. Revision of the Indo-Pacific species of the genus *Distichopora*. *Bijdragen tot de Dierkunde* **29**: 121-171.
- Claereboudt, M. 1990. *Galaxea paucisepta* nom. nov. (for *G. pauciradiata*), rediscovery and redescription of a poorly known scleractinian species (Oculinidae). *Galaxea* **9**: 1-8.

- Dai, C-F. 1989. Scleractinia of Taiwan. I. Families Astrocoeniidae and Pocilloporiidae. *Acta Oceanographica Taiwanica* **22**: 83-101.
- Dai, C-F. and Lin, C-H. 1992. Scleractinia of Taiwan III. Family Agariciidae. *Acta Oceanographica Taiwanica* **28**: 80-101.
- Dineson, Z. D. 1980. A revision of the coral genus *Leptoseris* (Scleractinia: Fungiina: Agariciidae). *Memoires of the Queensland Museum* **20**: 181-235.
- Hodgson, G. and Ross, M.A.. 1981. Unreported scleractinian corals from the Philippines. *Proceedings of the Fourth International Coral Reef Symposium*, **2**: 171-175.
- Hoeksema, B.W. 1989. Taxonomy, phylogeny and biogeography of mushroom corals (Scleractinia: Fungiidae). *Zoologische Verhandelingen* **254**: 1-295.
- Hoeksema, B.W. and Best, M.B. 1991. New observations on scleractinian corals from Indonesia: 2. Sipunculan-associated species belonging to the genera *Heterocyathus* and *Heteropsammia*. *Zoologische Mededelingen* **65**: 221-245.
- Hoeksema, B. and Dai, C-F. 1992. Scleractinia of Taiwan. II. Family Fungiidae (including a new species). *Bulletin of the Institute of Zoology Academia Sinica* **30**: 201-226.
- Moll, H. and Best, M.B. 1984. New scleractinian corals (Anthozoa: Scleractinia) from the Spermonde Archipelago, south Sulawesi, Indonesia. *Zoologische Mededelingen* **58**: 47-58.
- Nemenzo, F. Sr. 1986. Guide to Philippine Flora and Fauna: Corals. Natural Resources Management Center and the University of the Philippines.
- Nishihira, M. 1991. Field Guide to Hermatypic Corals of Japan. Tokai University Press, Tokyo. (in Japanese).
- Nishihira, M. and Veron, J.E.N. 1995. Corals of Japan. Kaiyusha Publishers Co., Ltd, Tokyo. (in Japanese).
- Ogawa, K. and Takamashi, K. 1993. A revision of Japanese ahermatypic corals around the coastal region with guide to identification- I. Genus *Tubastraea*. *Nankiseibutu: The Nanki Biological Society* **35**: 95-109. (in Japanese)
- Ogawa, K. and Takamashi, K. 1995. A revision of Japanese ahermatypic corals around the coastal region with guide to identification- II. Genus *Dendrophyllia*. *Nankiseibutu: The Nanki Biological Society* **37**: 15-33. (in Japanese)
- Randall, R. H. and Cheng, Y-M. 1984. Recent corals of Taiwan. Part III. Shallow water Hydrozoan Corals. *Acta Geologica Taiwanica* **22**: 35-99.
- Sheppard, C.R.C. 1998. Corals of the Indian Ocean. CD-ROM. Sida, Stockholm.
- Sheppard, C.R.C. and Sheppard, A.L.S. 1991. Corals and coral communities of Arabia. *Fauna of Saudi Arabia* **12**: 3-170.
- Veron, J.E.N. 1985. New scleractinia from Australian reefs. *Records of the Western Australian Museum* **12**: 147-183.
- Veron, J.E.N. 1986. Corals of Australia and the Indo-Pacific. Univ. Hawaii Press.

- Veron, J.E.N. 1990. New scleractinia from Japan and other Indo-West Pacific countries. *Galaxea* **9**: 95-173.
- Veron, J.E.N. 1993. A Biogeographic Database of Hermatypic Corals. *AIMS Monograph* **10**: 1-433.
- Veron, J.E.N. 1998. Corals of the Milne Bay Region of Papua New Guinea. Pages 26-34 In: Werner, T.A. and Allen, G.R. (Eds). A rapid biodiversity assessment of the coral reefs of the Milne Bay Province, Papua New Guinea. Washington D.C., Conservation International.
- Veron, J.E.N. 2000. Corals of the World. 3 Vols. M. Stafford-Smith (Ed.). Australian Institute of Marine Science Monograph Series.
- Veron, J.E.N., Fenner, D. and Stafford-Smith, M. In press. CoralID. CD-ROM.
- Veron, J. E. N. and Hodgson, G. 1989. Annotated checklist of the hermatypic corals of the Philippines. *Pacific Science* **43**: 234-287.
- Veron, J.E.N. and Pichon, M. 1976. Scleractinia of Eastern Australia. I. Families Thamnasteriidae, Astrocoeniidae, Pocilloporidae. *Australian Institute of Marine Science Monograph Series* **1**: 1-86.
- Veron, J.E.N. and Pichon, M. 1980. Scleractinia of Eastern Australia. III. Families Agariciidae, Siderastreidae, Fungiidae, Oculinidae, Merulinidae, Mussidae, Pectiniidae, Caryophyllidae, Dendrophyllidae. *Australian Institute of Marine Science Monograph Series* **4**: 1-422.
- Veron, J.E.N. and Pichon, M. 1982. Scleractinia of Eastern Australia. IV. Family Poritidae. *Australian Institute of Marine Science Monograph Series* **5**: 1-210.
- Veron, J.E.N., Pichon, M., and Wijsman-Best, M. 1977. Scleractinia of Eastern Australia. II. Families Faviidae, Trachyphyllidae. *Australian Institute of Marine Science Monograph Series* **3**: 1-233.
- Veron, J.E.N. and Wallace, C.C. 1984. Scleractinia of Eastern Australia. V. Family Acroporidae. *Australian Institute of Marine Science Monograph Series* **6**: 1-485.
- Wallace, C.C. 1994. New species and a new species-group of the coral genus *Acropora* (Scleractinia: Astrocoeniina: Acroporidae) from Indo-Pacific locations. *Invertebrate Taxonomy* **8**: 961-988.
- Wallace, C.C. 1997a. New species of the coral genus *Acropora* and new records of recently described species from Indonesia. *Zoological Journal of the Linnean Society* **120**: 27-50.
- Wallace, C.C. 1997b. The Indo-Pacific centre of coral diversity re-examined at species level. *Proceedings of the 8th International Coral Reef Symposium* **1**: 365-370.
- Wallace, C.C. 1999. Staghorn corals of the world, a revision of the genus *Acropora*. CSIRO Publ., Collingwood, Australia.
- Wallace, C.C. and Dai, G-F. 1997. Scleractinia of Taiwan (IV): Review of the coral genus *Acropora* from Taiwan. *Zoological Studies* **36**: 288-324.
- Wallace, C.C. and Wolstenholme, J. 1998. Revision of the coral genus *Acropora* in Indonesia. *Zoological Journal of the Linnean Society* **123**: 199-384.

APPENDIX 1(B): FISH BIODIVERSITY

A list of fish species was recorded at each site via underwater observations during two, 60-minute dives. The name of each species identified was marked on a plastic slate. A initial descent was generally made to the base of the reef but occasionally the surveys started beyond the maximum depth of abundant coral growth (approximately 20 m). The majority of the dive consisted of a slow ascent in a 'zigzag' path to the shallowest point of the reef or until further swimming was not possible. Sample areas of all habitats encountered were surveyed, including sandy areas, walls, overhangs, slopes and shallow reef. All but a small number of species were identified in the field, the remaining few were drawn during the dive and identified after the dive from field guide books. Field guides assisted identification (Randall et al., 1990; Allen, and Steene, 1994; Lieske and Myers, 1994; Kuitert and Debelius, 1997).

During each survey, the number of individuals of each species of fish was also counted. The following protocol was used:

Rare species	– numbers represent the total number of individuals
Occasional species	– numbers represent the total number of individuals
Frequent species	– numbers representative of the total, but may not be exact
Abundant species	– counted in units of ten
Species <i>en mass</i>	– large shoals of fish were listed as 'More than 250 individuals'

The fishes of Malaysia can be divided into several general categories, only a few of which were sampled in this study. Freshwater fishes and most fishes inhabiting brackish (partly saline) waters are quite unlikely to be found on coral reefs. Pelagic (open-water) and deepwater fish are only rarely sighted on coral reefs. Cryptic fish which live on the reef but which spend most of their time hiding deep in burrows or holes in the reef are rarely sighted. Such fish (for example gobies, blennies and moray eels) are grossly underestimated in visual surveys and require studies using poisons such as rotenone.

References

- Allen, G.R. and Steene, R. 1994. Indo-Pacific Coral Reef Field Guide. Tropical Reef Research, Singapore.
- Kuitert, R.H. and Debelius, H. 1997. Southeast Asia Tropical Fish Guide. IKAN, Frankfurt.
- Lieske, E., and Myers, R. 1994. Coral Reef Fishes, Indo-Pacific & Caribbean. Collins Pocket Guide, Harper Collins, London.
- Randall, J.E., Allen, G.R. and Steene, R.C. 1990. Fishes of the Great Barrier Reef and Coral Sea. University of Hawaii Press.

APPENDIX 1(C): REEF ZONATION

The reef profile transect survey technique, which was used to assess habitat diversity in this study, utilised a series of plot-less transects. These transects were perpendicular to the reef at each site and started beyond the maximum depth of abundant coral growth (approximately 20 m) and continued into shallow water (<5 m). Team responsibilities during the survey are shown in Figure 1. At the start point of each sub-transect, Diver 2 and 3 remained stationary (with Diver 3 holding one end of a 10 m length of rope), whilst Diver 1 swam away from them, navigating up the reef slope in a pre-determined direction until the 10 m line connecting Diver 1 and 3 became taught. Diver 1 then remained stationary whilst Diver 2 and 3 surveyed towards them. This process is repeated until the end of the planned dive profile. The positions of the surface marker buoy at the start and end of each dive was fixed using a Global Positioning System (GPS).

During the survey, hard corals were recorded to life forms as described by English et al. (1997) and in addition the ecologically important *Porites* 'massive' and *Goniopora* / *Alveopora* were also recorded separately. Sponges and octocorals were recorded in various life form categories. Octocoral life forms included 'Leathery' (commonly from the genera *Lobophyton* and *Sarcophyton*), 'Deadmans finger' (commonly from the genus *Sinularia*) and 'Tree' (commonly from the genus *Dendronephthya*). 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. All sessile invertebrates were recorded to a range of taxonomic levels, such as life form, genera or species. However, only commercially and ecologically important motile invertebrates were surveyed (e.g. *Diadema*, *Acanthaster planci* and lobsters).

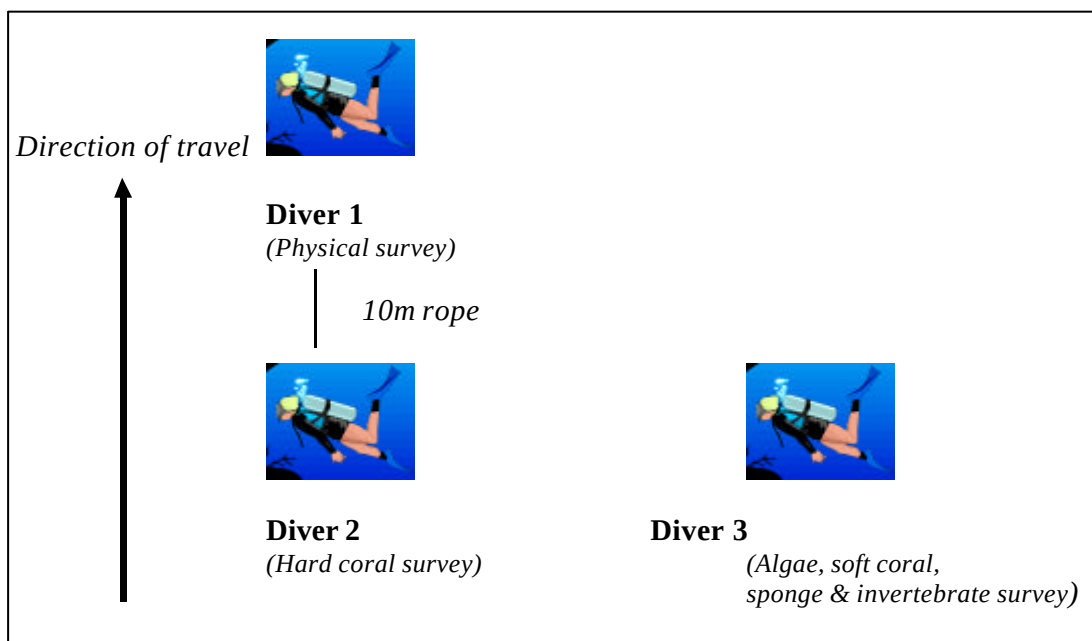


Figure 1. Schematic diagram of a reef profile survey team showing the positions and data gathering responsibilities of all three divers. Details of the role of each diver are given in the text.

Diver 1 was responsible for leading the dive, taking a depth reading at the end of each 10m interval and documenting signs of anthropogenic impacts. Diver 1 also assessed the current direction and strength and took a temperature reading at the start of the transect. Diver 1 also described the substratum along the sub-transect by recording the presence of five substrate categories (dead coral, bedrock, rubble, sand and mud). Diver 2 surveys an area of

approximately 1 metre to each side of the transect line whilst Diver 3 surveyed an area of approximately 2.5 metres to either side of the line. During the course of each transect survey, divers may have traversed two or more apparently discrete habitat types, based upon obvious gross geomorphological or biological differences (e.g. dense coral reef, sand or rubble; Figure 2). Data gathered from each habitat type were recorded separately.

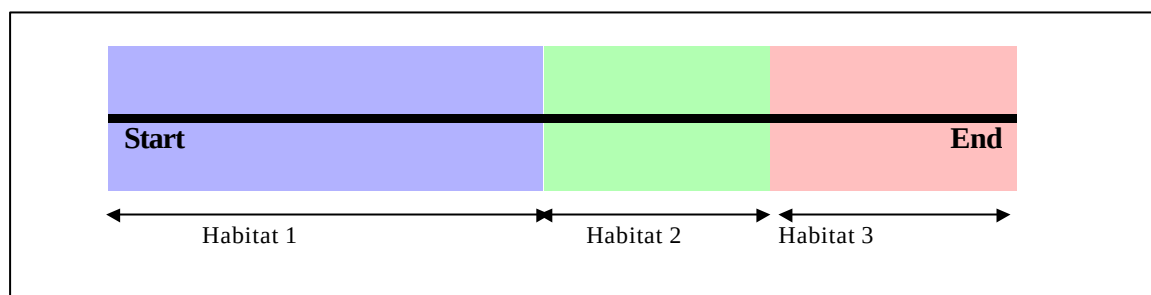


Figure 2. Schematic diagram (aerial aspect) of an example of a reef area mapped by divers during a profile survey. Solid line represents imaginary transect line. Data from habitats 1, 2 and 3 (e.g. reef, sand and rubble) are recorded separately.

Each species, life form or substratum category within each habitat type encountered was assigned an abundance rating from the ordinal scale shown in Table 1.

Table 1. Ordinal scale assigned to life forms and target species during baseline surveys.

ABUNDANCE RATING	CORAL , ALGAE AND SUBSTRATUM	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+

Comparative studies between the surveyors showed that assignment of this ordinal scale and identification of life forms and species was very consistent (Bray-Curtis similarity coefficient of approximately 85% during five paired tests).

During the course of each dive, data on surface water temperature and salinity, vertical turbidity, wind strength and direction, and boating activity were collected by the surface support vessel. Wind strength was estimated using the Beaufort Scale and the vertical turbidity measured using a secchi disk. The numbers and activities of any boats observed during the course of the survey dive were also recorded. During the course of each survey, certain oceanographic data (e.g. temperature and horizontal turbidity) were recorded by the divers.

Data collected during each profile survey were transferred to recording forms, prior to incorporation into CCC's GIS-compatible database.

APPENDIX 1(D): REEF HEALTH

The technique used to assess reef health during this study was modified by the protocol used by the 'Reef Check' initiative. Full details of the original protocol can be found at <http://www.ReefCheck.org/>. The major modifications for this study were increased taxonomic resolution to reflect the extensive experience of the surveyors and discounting the fish component.

At each site a survey transect was laid at a depth of between 7 and 10 m. The transect consists of four 20 m sections, following the designated depth contour. Each section is separated by 5 m, giving a total transect length of 95 m (20 + 5 + 20 + 5 + 20 + 5 + 20). Four types of data are recorded via the surveys along the transect line.

Site description

A site description was completed, summarising anecdotal, observational, historical and locational data. This description included GPS co-ordinates, distance to nearest human population and river and qualitative assessments of any observed impacts.

Substratum line transect.

The four 20 m long transects were point sampled at 0.5 m intervals to characterise the substratum types and benthic community at the site. The diver looked at a series of points where the transect tape touched the reef and notes down what lies under those points.

The categories recorded under each 50 cm point were:

Hard Corals. To life form level, following English et al. (1997). Included *Heliopora*, *Millepora* and *Tubipora*. Hard corals less than 5 cm in diameter were noted as juveniles, to give an measure of recruitment. Note was also be made if the coral was bleached.

Soft Coral. All octocorals; gorgonians went into 'Other'.

Sponge.

Zoanthids.

Algae. Algae were recorded in four categories and either as grown on a substrate with visible corallites (i.e. long dead corals) or no visible corallites (i.e. very long dead coral or bedrock). Since it was not possible to look for corallites under coralline algae, the surveyors looked at the substratum at the edge of the algae and assumed that if there are, for example, corallites around the edge then they were also underneath. The algal categories were:

- Coralline algae
- *Halimeda*
- Macro (English et al., 1997 definition)
- Turf (English et al., 1997 definition)

Recently Killed Coral. Coral that has died within the past few months. The coral may have been standing or broken into pieces, but appears fresh, white with corallite structures still recognisable. No / minimal overgrowth by algae.

Rock. Any hard substratum without visible corallite structures and without significant turf algae.

Rubble. Included rocks (often laying over sand) between 0.5 and 15 cm diameter. If it was larger than 15 cm it was rock, smaller than 0.5 cm and it was sand.

Sand. In the water, it was sand if it falls quickly to the bottom.

Silt/clay. Sediment that remained in suspension if disturbed.

Other. Any other sessile organism including sea anemones, tunicates, gorgonians or non-living substrata.

Invertebrate belt transect

Four 5 m wide by 20 m long transects (centred on the transect line) were sampled for invertebrate taxa either ecologically important or typically targeted as food species or collected as curios. The taxa surveyed were banded coral shrimp; *Diadema*; Lobster (all edible species); *Tridacna*; Pencil urchins; Edible sea cucumbers; *Acanthaster planci*; Triton shell; *Drupella* sp.. Quantitative counts were made of each taxa.

The invertebrate surveyor also recorded ant incidences of coral bleaching and counted the number of corals between 1 – 5 cm (i.e. ‘young’ coral) under the whole tape.

Anthropogenic data

During each survey anthropogenic impacts were assessed for coral damage via either 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).

APPENDIX 2: REEF PROFILE DATA ANALYSIS AND RESULTS

APPENDIX 2(A): MULTIVARIATE STATISTICAL ANALYSIS OF REEF PROFILE DATA

Each reef profile transect generated a series of survey forms, with one completed for each individual transect (see Appendix 1(c)). A total of 50 survey forms were completed during this study. Each survey form (representing one 'Record') generated a multivariate 'snap-shot' of the benthic community and substratum present on part of the transect and these data can be assigned to a discrete benthic classes by a combination of cluster and similarity percentage (SIMPER). An overview of the process of assigning each survey to a habitat class is provided in Figure 1.

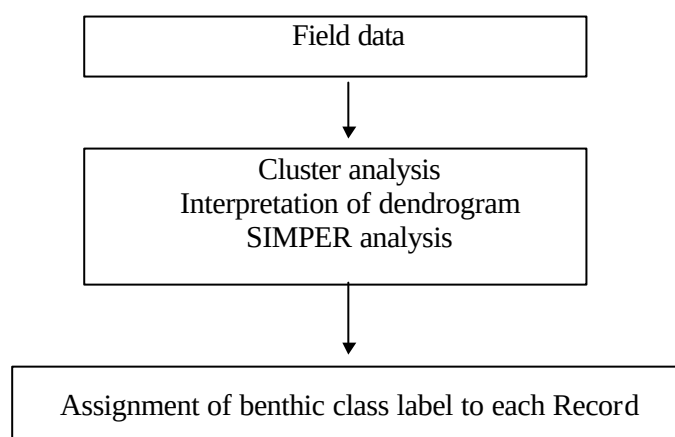


Figure 1. Schematic diagram of the steps required to assign survey data to a benthic class.

Cluster analysis

The first stage of habitat classification was to identify the similarity in benthic assemblages between Records. Similarities were measured objectively using the Bray-Curtis similarity coefficient (Bray and Curtis, 1957). This coefficient has been shown to have a number of biologically desirable properties and to be a particularly robust measure of ecological distance (Faith et al., 1987). Agglomerative hierarchical classification with group-average sorting was used to cluster and classify a sub-set of untransformed field data since it is one of the most popular and widely available algorithms (Clarke 1993). The dendrogram resulting from cluster analysis was then divided into separate 'clusters', each representing a distinct benthic class (Appendix 2(b)).

SIMPER analysis

Characteristic species or substratum categories of each cluster were then determined using Similarity Percentage (SIMPER) analysis (Clarke, 1993) within 'PRIMER' (Plymouth Routines in Multivariate Ecological Research) software. In order to highlight characteristic features of a given cluster, SIMPER calculates the average Bray-Curtis similarity between all pairs of intra-group samples (e.g. between all sites of the first cluster). Since the Bray-Curtis similarity is the algebraic sum of contributions from each species, average similarity between Records of the first cluster can be expressed in terms of average contribution from each species. The standard deviation provided a measure of how consistently a given species contributes to the similarity between Records. A good characteristic species contributed heavily to intra-habitat similarity and had a small standard deviation.

Assignment of benthic class

The results from SIMPER analysis were then used to assign benthic class labels to each cluster and hence each Record within the data set. For example, if *Acropora* and bedrock were highly characteristic of a cluster, it was labelled as 'Bedrock and *Acropora* rich corals'.

References

Bray, J.R. and Curtis, J.T. 1957. An ordination of the upland forest communities of Southern Wisconsin. *Ecological Monographs* **27**: 325-349.

Clarke, K.R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* **18**: 117-143.

Faith, D.P., Minchin, P.R., and Belbin, L. 1987. Compositional dissimilarity as a robust measure of ecological distance. *Vegetatio* **69**: 57-68.

APPENDIX 2(B): RESULTS

The dendrogram resulting from cluster analysis of the data recorded during reef profile surveys in this study is shown in Figure 1. A total of 10 benthic classes were discriminated, of which seven had sufficient replicates for SIMPER analysis ($n > 2$). Descriptions of each benthic class are given in Appendix 3.

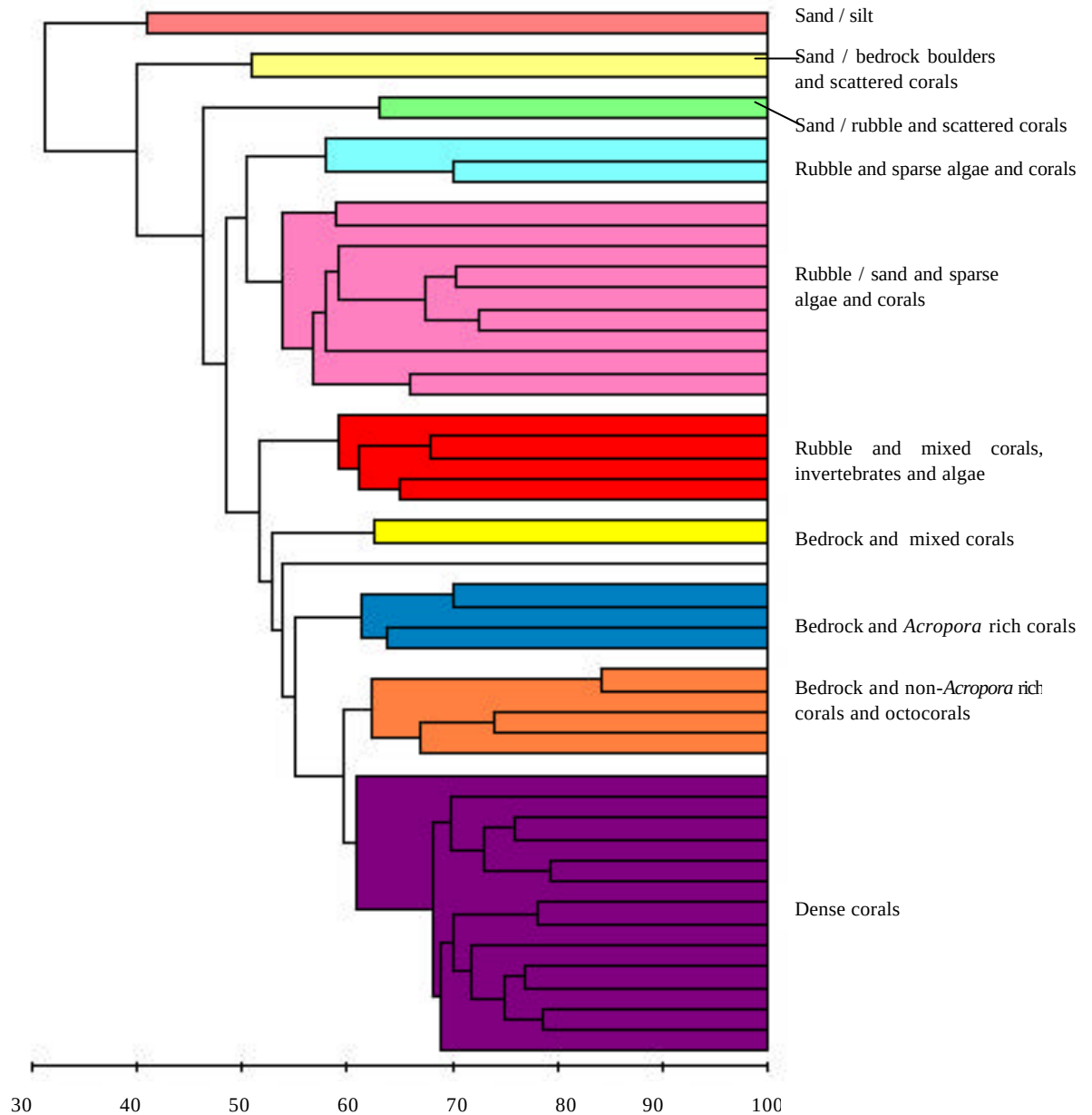


Figure 1. Dendrogram resulting from cluster analysis of reef profile data from the 17 sites. Total number of Records = 50. Axis represent Bray-Curtis similarity coefficient (%).

APPENDIX 3: DESCRIPTION OF THE BENTHIC CLASSES FOUND DURING REEF PROFILE TRANSECTS.

Reef profile transects, using the methodology described in Appendix 1(c), delineated 10 separate benthic classes within the project area. The analysis used to discriminate these classes is documented in Appendix 2. The following table describes the characteristics of each benthic class and includes a photograph, the results of SIMPER analysis (and percentage contribution to intra-class similarity) and additional notes. SIMPER analysis highlights the most characteristic species or substratum categories of each habitat (for more detail see Appendix 2). Where SIMPER analysis was not possible (<2 samples) the characteristic species and substratum categories are listed using via decreasing median abundances and ‘=’ indicates tied ranks (i.e. identical median abundance).

Name	Representative photograph	Ten most characteristic species or substratum categories (SIMPER contribution)	Notes
<i>Bedrock and Acropora rich corals</i>		<i>Acropora</i> branching (10.34) Bedrock (9.83) <i>Acropora</i> tabulate (7.86) Encrusting sponge (6.09) <i>Lobophora</i> (6.09) Non- <i>Acropora</i> massive (5.90) Non- <i>Acropora</i> encrusting (5.90) Non- <i>Acropora</i> branching (5.74) <i>Porites</i> massive (4.51) Coralline algae (4.51)	This benthic class is usually found in relatively shallow water and can have a high coral cover. <i>Acropora</i> branching is the dominant coral life form but <i>Acropora</i> tabulate and non- <i>Acropora</i> life forms are also common. The substratum is dominated by bedrock, often with encrusting sponges and coralline algae.
<i>Bedrock and mixed corals</i>		Encrusting sponge (10.00) Non- <i>Acropora</i> massive (10.00) Bedrock (9.95) Dead coral (6.72) <i>Lobophora</i> (6.72) ‘Lumpy’ sponge (6.72) Zoanthid (6.63) Tunicates (5.00) Non- <i>Acropora</i> foliose (5.00) Non- <i>Acropora</i> encrusting (4.96)	This benthic class is dominated by a bedrock substratum, often encrusted with sponges, and supporting a variety of coral life forms. The most abundant coral life form is non- <i>Acropora</i> massive. Other components of the benthic community, such as macro-algae, zoanthids and tunicates may be common. Dead coral is usually present.
<i>Bedrock and non-Acropora rich corals and octocorals</i>		Bedrock (10.52) Non- <i>Acropora</i> massive (5.99) Encrusting sponge (5.99) Non- <i>Acropora</i> encrusting (5.51) Coralline algae (5.26) Zoanthid (5.26) Sea fan (5.26) ‘Leathery’ octocorals (3.62) <i>Lobophora</i> (3.43) ‘Tree’ octocorals (3.42)	This benthic class is dominated by bedrock but many coral life forms, although more commonly non- <i>Acropora</i> , are present. The most common coral life forms are non- <i>Acropora</i> massive and encrusting. The bedrock is often encrusted with sponges and coralline algae. Octocorals, particularly ‘Leathery’ and ‘Tree’, are frequent.
<i>Dense corals</i>		Non- <i>Acropora</i> massive (4.89) Non- <i>Acropora</i> submassive (4.59) Non- <i>Acropora</i> foliose (4.32) <i>Porites</i> massive (4.31) <i>Acropora</i> branching (4.11) Coralline algae (4.00) <i>Lobophora</i> (3.90) Non- <i>Acropora</i> branching (3.80) Non- <i>Acropora</i> encrusting (3.59) ‘Lumpy’ sponge (3.50)	This benthic class has the highest coral cover and is typical of the forereef from 5-10 m. There is a diverse assemblage of corals, including non- <i>Acropora</i> and <i>Acropora</i> . <i>Porites</i> massive are frequently seen. Between the corals, there are some sponges and algae, generally on a bedrock or dead coral substratum.

Rubble / sand and sparse algae and corals		Rubble (12.79) Sand (12.14) Coralline algae (9.98) <i>Lobophora</i> (5.11) Non- <i>Acropora</i> massive (5.08) Encrusting sponge (4.61) 'Tree' octocorals (4.59) Bedrock (3.80) Red filamentous algae (3.74) Tunicates (3.66)	This benthic class is typical of the deeper reef, below areas of high coral cover (generally > 15 m). This class has minimal coral cover, although there are occasional non- <i>Acropora</i> massives, and is dominated by rubble and sand. Algae are common, particularly coralline and fleshy brown macro-algae. Sponges and octocorals are often present.
Rubble and mixed corals, invertebrates and algae		Coralline algae (7.920) Rubble (7.08) Brown filamentous algae (6.41) Hydroid (6.39) Non- <i>Acropora</i> massive (5.25) Anemone (5.10) 'Lumpy' sponge (4.81) Zoanthid (4.20) Tunicates (3.80) Red filamentous algae (3.79)	This benthic class is characterised by rubble and coralline and filamentous algae. There are occasional non- <i>Acropora</i> massive corals. The invertebrate fauna is relatively abundant, especially hydroids, anemones, zoanthids and tunicates. This benthic class is typically found below areas of high coral cover (generally > 15 m).
Rubble and sparse algae and corals	No picture available	Rubble (23.75) Brown filamentous algae (11.87) Blue-green algae (8.13) Non- <i>Acropora</i> massive (5.94) <i>Acropora</i> branching (5.94) <i>Porites</i> massive (5.94) Encrusting sponge (5.94) 'Leathery' octocorals (5.94) Sand (5.94) Coralline algae (3.77)	This benthic class is dominated by rubble and some sand, often with a significant algal community (especially brown filamentous and blue-green). Corals are present and are commonly massive or branching. Similarly, sponges and octocorals are often present.
Sand / bedrock boulders and scattered corals		Bedrock = Blue-green algae = Brown filamentous algae == <i>Lobophora</i> == Non- <i>Acropora</i> massive == Sand === Green filamentous algae === Red filamentous algae Tied 9 th – Coralline algae, Non- <i>Acropora</i> encrusting, <i>Heliopora</i> , Recently killed coral	This benthic class is relatively uncommon and is characterised by a sandy substratum with boulders of bedrock. The boulders have some coral cover (typically non- <i>Acropora</i> massive) and abundant algae, particularly the filamentous growth form. <i>Lobophora</i> are also frequent.
Sand / rubble and scattered corals		Sand Rubble Bedrock = <i>Lobophora</i> = <i>Acropora</i> branching = Non- <i>Acropora</i> branching Tied 7 th – Encrusting sponge, Rope sponge, <i>Acropora</i> digitate, <i>Acropora</i> tabulate, Non- <i>Acropora</i> encrusting, Non- <i>Acropora</i> foliose, Non- <i>Acropora</i> massive, Non- <i>Acropora</i> submassive, <i>Heliopora</i> , Dead coral 1	This benthic class is a combination of large areas of relatively bare substratum and smaller patches of coral cover. The substratum is a mixture of sand, rubble and bedrock. Most of the corals are found on the bedrock and are a mix of non- <i>Acropora</i> and <i>Acropora</i> life forms. Dead coral is also commonly present and often covered with fleshy macro-algae such as <i>Lobophora</i> .
Sand / silt		Sand Red filamentous algae = Brown filamentous algae = Sea whip = Mud Tied 6 th - 'Lumpy' sponge, Non- <i>Acropora</i> massive, Hydroids, Bryozoans Tunicates, Bedrock	This benthic class has little topographic relief and is typically below areas of high coral cover (generally > 15 m), particularly close to the east coast of Peninsula Malaysia. The benthic community is sparse and consists of some filamentous algae, occasional coral heads, some octocorals and a few sponges and hydroids

APPENDIX 4: CORAL SPECIES LISTS.

APPENDIX 4(A): CORALS RECORDED AT EACH SITE

Species listed as 'sp.', as in '*Montipora* sp.1', are species that will be named in Veron (2000). Where species were only found at one site, that site is highlighted in blue. Species names highlighted in blue are of species which were previously reported in only one country, either the Philippines or Japan. Species with a '?' after their name are species for which the correct identification is in some doubt. There is no doubt that a distinct species was present, but the correct name needs to be confirmed from a collected specimen.

Sites were: 1 = Teluk Mat Delah, Pulau Redang; 2 = Chagar Hutang, Pulau Redang; 3 = Pulau Ling; 4 = Pulau Lima; 5 = Pulau Lang Tengah; 6 = Terumbu Kili; 7 = Batu Malang; 8 = Teluk Juara, Pulau Tioman; 9 = Pulau Gut; 10 = Pulau Tokong Bahara; 11 = Pulau Seri Buat; 12 = Kadar Bay, Pulau Tulai; 13 = Pulau Renggis. 14 = Teluk Jawa, Pulau Dayang; 15 = Teluk Pontianak, Pulau Pemanggil; 16 = Pulau Simbang; 17 = Batu Tikus. 'A' refers to three sites that were not used for complete surveys, but from which coral species data were taken.

Species	P. Redang						P. Tioman							P. Tinggi				A
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
<i>Stylocoeniella guentheri</i>							X	X	X	X							X	X
<i>Pocillopora damicornis</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Pocillopora danae</i>	X	X	X	X	X		X	X				X	X					X
<i>Pocillopora eydouxi</i>								X	X									X
<i>Pocillopora meandrina</i>								X	X									
<i>Pocillopora verrucosa</i>	X	X	X	X			X		X			X	X	X	X			
<i>Stylophora pistillata</i>							X											
<i>Stylophora subseriata</i>		X	X	X	X		X		X			X			X	X		
<i>Montipora aequituberculata</i>		X	X	X	X	X	X	X		X	X	X	X	X				
<i>Montipora altisepta</i>		X		X	X						X							X
<i>Montipora cebuensis</i>															X			
<i>Montipora confusa</i>								X										
<i>Montipora</i> sp. 1															X			
<i>Montipora foliosa</i>		X								X								
<i>Montipora gaimardi</i>				X	X	X	X				X	X	X	X	X	X		X
<i>Montipora hispida</i>		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
<i>Montipora informis</i>	X	X	X	X		X			X									X
<i>Montipora malampaya?</i>					X	X	X								X		X	X
<i>Montipora millepora</i>						X												
<i>Montipora mollis</i>		X													X	X	X	
<i>Montipora tuberculosa</i>	X		X	X			X	X				X		X	X			X
<i>Montipora</i> sp. 2												X						
<i>Montipora</i> sp. 3												X		X				
<i>Anacropora matthai</i>												X		X	X			

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A
<i>Acropora aspera</i>	X	X			X	X	X		X	X	X	X	X	X	X			X
<i>Acropora austera?</i>								X										
<i>Acropora bruggemanni</i>			X			X			X				X		X	X		
<i>Acropora cerealis?</i>			X												X			
<i>Acropora cytherea</i>	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
<i>Acropora digitifera</i>	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	
<i>Acropora divaricata</i>	X	X												X				
<i>Acropora elseyi</i> (cf Wallace)					X	X												
<i>Acropora florida</i>	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X	X
<i>Acropora formosa</i>					X	X	X	X							X			
<i>Acropora gemmifera</i>					X	X		X	X			X		X				
<i>Acropora hoeksemai?</i>															X			
<i>Acropora horrida</i>	X		X			X		X						X				
<i>Acropora humilis</i>		X	X			X		X					X	X	X	X		
<i>Acropora hyacinthus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Acropora latistella</i>	X	X	X		X	X		X						X	X			X
<i>Acropora loripes</i>			X	X				X							X			
<i>Acropora microphthalma</i>	X	X	X	X	X		X						X		X			
<i>Acropora millepora</i>							X	X	X	X	X	X	X		X	X	X	
<i>Acropora monticulosa</i>								X			X	X		X	X			
<i>Acropora nasuta</i>		X	X	X	X	X	X	X	X				X	X	X			
<i>Acropora nobilis</i>	X	X	X	X	X	X	X	X	X	X			X		X	X		
<i>Acropora palifera</i>												X			X			
<i>Acropora pinguis</i>	X	X		X	X	X	X	X	X		X	X	X	X	X		X	
<i>Acropora prostrata</i>												X				X	X	
<i>Acropora robusta</i>							X	X	X			X		X			X	
<i>Acropora rosaria</i>	X	X		X	X									X				
<i>Acropora samoensis</i>	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
<i>Acropora secale</i>								X	X				X			X		
<i>Acropora selago?</i>										X							X	
<i>Acropora solitaryensis?</i>	X		X	X					X								X	X
<i>Acropora stoddarti?</i>																	X	
<i>Acropora tenuis</i>	X				X	X	X			X	X		X	X	X	X		
<i>Acropora valenciennesi</i>	X	X	X	X	X	X												X
<i>Acropora valida</i>									X						X			
<i>Acropora vermiculata</i>															X			
<i>Acropora yongei</i>															X			
<i>Astreopora gracilis</i>								X	X			X						
<i>Astreopora myriophthalma</i>	X	X	X	X	X	X	X	X			X	X	X	X	X	X		X
<i>Astreopora ocellata</i>	X	X						X										
<i>Porites annae</i>	X	X					X				X	X		X		X	X	
<i>Porites cylindrica</i>	X	X	X		X	X	X		X			X	X	X	X			
<i>Porites evermanni</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A
<i>Porites horizontalata</i>	X	X	X		X	X	X	X				X	X					X
<i>Porites monticulosa</i>	X	X	X				X											X
<i>Porites nigrescens</i>							X						X					
<i>Porites rus</i>	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X
<i>Porites solida?</i>							X						X	X				
<i>Goniopora planulata?</i>								X										
<i>Pseudosiderastrea tayami</i>				X				X					X			X	X	X
<i>Psammocora contigua</i>	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X		
<i>Psammocora digitata</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
<i>Psammocora explanulata</i>														X				X
<i>Psammocora haimeana?</i>	X																	
<i>Psammocora nierstraszi</i>							X											
<i>Psammocora profundacella</i>		X					X	X									X	
<i>Psammocora superficialis</i>		X	X	X	X		X		X									
<i>Coscinaraea collumna</i>		X		X				X	X	X	X						X	X
<i>Coscinaraea exesa</i>											X						X	
<i>Coscinaraea hahazimaensis</i>								X										
<i>Pavona bipartita</i>						X	X									X	X	
<i>Pavona cactus</i>	X	X	X	X	X	X	X		X	X	X		X			X		X
<i>Pavona clavus</i>							X											
<i>Pavona decussata</i>	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X
<i>Pavona explanulata</i>	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
<i>Pavona frondifera</i>	X																	X
<i>Pavona varians</i>	X			X	X	X	X	X	X					X		X	X	X
<i>Leptoseris explanata</i>			X	X					X								X	X
<i>Leptoseris incrustans?</i>			X	X														X
<i>Leptoseris mycetoseroides</i>				X							X	X			X		X	X
<i>Leptoseris papyracea</i>							X											X
<i>Leptoseris scabra?</i>								X										X
<i>Gardineroseris planulata</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X
<i>Pachyseris foliosa</i>				X			X	X		X		X						
<i>Pachyseris rugosa</i>	X	X			X		X	X			X	X	X	X	X	X	X	
<i>Pachyseris speciosa</i>	X	X	X		X		X	X	X	X				X	X	X	X	
<i>Cycloseris erosa</i>																		
<i>Cycloseris patelliformis?</i>																		X
<i>Diaseris distorta</i>													X					X
<i>Diaseris fragilis</i>				X						X								X
<i>Heliofungia actiniformis</i>										X								
<i>Fungia concinna</i>	X	X	X	X		X	X						X		X	X		X
<i>Fungia fungites</i>		X	X		X	X				X			X			X		X
<i>Fungia granulosa</i>			X	X	X	X	X	X	X	X				X				
<i>Fungia klunzingeri</i>	X	X	X													X		X
<i>Fungia moluccensis</i>		X	X	X				X	X	X			X		X		X	X

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A
<i>Fungia paumotensis</i>	X	X	X	X	X	X	X	X		X			X	X	X			
<i>Fungia repanda</i>		X								X								
<i>Fungia scruposa</i>				X	X											X	X	X
<i>Ctenactis albitentaculata</i>	X	X	X									X	X					X
<i>Ctenactis crassa</i>				X	X	X		X					X	X			X	X
<i>Ctenactis echinata</i>	X	X	X	X		X	X	X	X	X			X	X	X	X	X	
<i>Herpolitha limax</i>	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
<i>Herpolitha weberi</i>		X				X							X				X	
<i>Polyphyllia talpina</i>	X	X	X	X	X	X	X	X	X	X		X	X			X	X	X
<i>Sandalolitha robusta</i>	X	X	X	X	X	X	X	X	X	X		X	X	X	X			X
<i>Lithophyllon undulatum</i>				X	X	X					X					X	X	
<i>Podabacia crustacea</i>		X	X	X	X	X	X		X	X	X		X			X	X	X
<i>Galaxea sp. 1</i>													X					
<i>Galaxea astreata</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
<i>Galaxea fascicularis</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Echinophyllia aspera</i>	X	X	X	X	X		X	X				X		X		X	X	
<i>Echinophyllia echinata</i>																		X
<i>Echinophyllia orpheensis</i>			X															
<i>Oxypora crassispinosa</i>											X							
<i>Oxypora lacera</i>				X	X		X			X		X			X	X	X	
<i>Mycedium elephantotus</i>										X						X	X	
<i>Pectinia alcicornis</i>								X		X	X	X	X					
<i>Pectinia lactuca</i>	X					X	X	X										
<i>Pectinia maxima</i>				X						X			X					
<i>Pectinia paeonia</i>	X	X	X													X		
<i>Blastomussa wellsi</i>				X				X										
<i>Cynarina lacrimalis</i>																		X
<i>Scolymia australensis</i>				X						X							X	
<i>Scolymia vitiensis</i>				X						X							X	
<i>Acanthastrea echinata</i>																X	X	
<i>Acanthastrea hemprichii</i>				X	X	X	X	X	X	X	X	X		X	X	X	X	X
<i>Acanthastrea lordhowensis</i>								X					X				X	
<i>Acanthastrea sp. 1</i>									X		X			X				
<i>Lobophyllia corymbosa</i>														X				
<i>Lobophyllia sp. 1</i>	X		X	X	X		X	X	X	X	X		X	X		X	X	X
<i>Lobophyllia hataii</i>	X			X				X	X									
<i>Lobophyllia hemprichii</i>	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
<i>Lobophyllia sp. 2</i>														X				
<i>Lobophyllia robusta</i>														X				
<i>Lobophyllia undescribed</i>																	X	
<i>Symphyllia agaricia</i>	X	X	X	X		X	X	X		X	X	X	X	X	X	X		X
<i>Symphyllia radians</i>	X	X	X		X	X	X	X	X			X	X		X	X	X	
<i>Symphyllia recta</i>	X	X	X	X	X		X	X	X		X	X	X	X				X

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A
<i>Symphyllia valenciennesi</i>				X						X		X						
<i>Hydnophora exesa</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Hydnophora grandis</i>	X	X	X	X	X	X	X	X		X		X	X	X	X	X		X
<i>Hydnophora microconos</i>	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	
<i>Merulina ampliata</i>	X	X	X	X	X	X		X	X		X	X		X	X	X	X	X
<i>Merulina scabricula</i>							X	X			X	X	X	X	X	X	X	
<i>Scapophyllia cylindrica</i>								X		X	X			X		X		
<i>Caulastrea tumida</i>			X											X				
<i>Favia maritima</i>				X				X	X							X	X	
<i>Favia maxima</i>									X									
<i>Favia pallida</i>							X								X			
<i>Favia stelligera</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
<i>Favia sp. 1</i>								X										
<i>Favia veroni</i>								X										
<i>Barabattoia amicornum</i>	X		X	X							X				X			X
<i>Favites abdita</i>	X				X	X	X		X		X	X		X	X	X		
<i>Favites acuticollis</i>				X				X										
<i>Favites halicora</i>	X					X	X										X	
<i>Favites sp. 1</i>																	X	
<i>Favites pentagona?</i>						X												
<i>Goniastrea edwardsi</i>	X							X				X				X		
<i>Goniastrea favulus</i>								X								X		
<i>Goniastrea sp. 1</i>	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X
<i>Goniastrea pectinata</i>	X	X	X		X		X				X	X		X	X	X		X
<i>Goniastrea retiformis</i>								X										
<i>Platygyra sp. 1?</i>					X													
<i>Platygyra daedalea</i>	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X
<i>Platygyra lamellina</i>				X		X			X	X			X	X		X	X	X
<i>Platygyra sinensis</i>	X	X			X	X			X		X				X			
<i>Platygyra verweyi</i>					X	X			X		X							
<i>Leptoria phrygia</i>	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	
<i>Oulophyllia bennettiae</i>										X	X					X	X	
<i>Oulophyllia crispa</i>	X		X		X	X		X	X	X	X	X		X		X	X	
<i>Montastrea sp. 1</i>								X										
<i>Montastrea curta</i>								X						X		X		
<i>Montastrea magnistellata</i>						X		X				X		X				
<i>Oulastrea crispata</i>																		X
<i>Plesiastrea versipora</i>				X			X		X	X	X	X				X	X	X
<i>Diploastrea heliopora</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Leptastrea pruinosa</i>		X		X	X		X				X		X		X		X	
<i>Leptastrea purpurea</i>	X	X		X	X		X	X						X	X			X
<i>Echinopora gemmacea</i>	X	X	X	X	X	X	X			X	X	X	X	X	X	X		
<i>Echinopora horrida</i>	X		X	X	X	X							X					

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A
<i>Echinopora lamellosa</i>	X	X			X			X	X	X								X
<i>Echinopora pacificus</i>	X	X	X	X	X	X		X			X					X		X
<i>Trachyphyllia geoffroyi</i>													X					
<i>Euphyllia ancora</i>								X	X	X	X	X		X		X	X	
<i>Euphyllia divisa</i>	X	X	X	X	X			X				X	X	X	X			
<i>Euphyllia glabrescens</i>			X	X	X			X	X	X		X			X	X		X
<i>Euphyllia yaeyamensis</i>								X										
<i>Catalaphyllia jardini</i>				X														
<i>Plerogyra sinuosa</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
<i>Turbinaria frondens</i>				X														X
<i>Turbinaria irregularis</i>							X	X	X		X				X			
<i>Turbinaria mesenterina</i>				X	X	X	X		X			X	X			X	X	X
<i>Turbinaria peltata</i>	X			X	X			X	X	X			X			X	X	X
<i>Turbinaria stellulata</i>			X	X	X	X	X		X	X							X	X
<i>Balanophyllia sp.</i>									X								X	
<i>Rhizopsammia verrilli</i>							X						X					
<i>Tubastraea coccinea</i>				X		X	X		X	X						X	X	
<i>Tubastraea diaphana</i>							X		X	X						X		
<i>Tubastraea micranthus</i>					X		X		X	X			X			X	X	
<i>Heliopora coerulea</i>		X	X	X	X	X	X				X	X	X	X	X			X
<i>Millepora dichotoma</i>				X			X	X					X	X				
<i>Millepora exaesa</i>	X	X																X
<i>Millepora platyphylla</i>		X	X	X	X	X	X	X	X		X	X			X	X		X
<i>Millepora tenera?</i>									X									
<i>Distichopora violacea</i>					X				X							X		
Total species per site	84	87	92	96	86	78	96	105	84	70	68	75	82	81	82	82	79	5

APPENDIX 4(B): NEW CORAL RECORDS FOR MALAYSIA

The following species have not previously been recorded from Malaysia in published literature. Species with a '?' after their name are species for which the correct identification is in some doubt. There is no doubt that a distinct species was present, but the correct name needs to be confirmed from a collected specimen.

1. *Pocillopora danae*
2. *Pocillopora meandrina*
3. *Stylophora subseriata*
4. *Montipora altisepta*
5. *Montipora cebuensis*
6. *Montipora confusa*
7. *Montipora* sp. 1
8. *Montipora gaimardi*
9. *Montipora malampaya?*
10. *Montipora* sp. 2
11. *Montipora* sp. 3
12. *Anacropora matthai*
13. *Acropora austera?*
14. *Acropora bruggemani*
15. *Acropora digitifera*
16. *Acropora gemmifera*
17. *Acropora hoeksemai?*
18. *Acropora horrida*
19. *Acropora monticulosa*
20. *Acropora prostrata*
21. *Acropora rosaria*
22. *Acropora samoensis*
23. *Acropora selago*
24. *Acropora solitaryensis?*
25. *Acropora stoddarti?*
26. *Acropora vermiculata?*
27. *Acropora yongei*
28. *Porites evermanni*
29. *Porites monticulosa*
30. *Goniopora planulata?*
31. *Psammocora explanulata*
32. *Psammocora superficialis*
33. *Coscinaraea exesa*
34. *Coscinaraea hahazimaensis*
35. *Pavona bipartita*
36. *Leptoseris incrustans?*
37. *Pachyseris foliosa*
38. *Fungia klunzingeri*
39. *Fungia moluccensis*
40. *Ctenactis albitentaculata*
41. *Podabacia motuporensis*
42. *Galaxea* sp. 1
43. *Oxypora crassispinosa*
44. *Pectinia maxima*
45. *Scolymia australis*
46. *Acanthastrea hemprichii*
47. *Acanthastrea lordhowensis*

48. *Acanthastrea* sp. 1
49. *Lobophyllia* sp. 1
50. *Lobophyllia* sp. 2
51. *Lobophyllia* sp. 3
52. *Hydnophora grandis*
53. *Favia maritima*
54. *Favia* sp. 1
55. *Favia veroni*
56. *Favites acuticollis*
57. *Favites* sp. 1
58. *Goniastrea favulus*
59. *Goniastrea* sp. 1
60. *Montastrea* sp. 1
61. *Platytyra contorta*
62. *Platygyra verweyi*
63. *Echinopora pacificus*
64. *Euphyllia yaeyamensis*
65. *Turbinaria irregularis*
66. *Balanophyllia* sp.
67. *Rhizopsammia verrilli*

APPENDIX 4(C): NEW CORAL RECORDS FOR PENINSULA MALAYSIA

The following species have not previously been recorded from Peninsula Malaysia in published literature. Species with a '?' after their name are species for which the correct identification is in some doubt. There is no doubt that a distinct species was present, but the correct name needs to be confirmed from a collected specimen.

1. *Pocillopora danae*
2. *Pocillopora meandrina*
3. *Stylophora subseriata*
4. *Montipora aequituberculata*
5. *Montipora altisepta*
6. *Montipora cebuensis*
7. *Montipora confusa*
8. *Montipora* sp. 1
9. *Montipora gaimardi*
10. *Montipora malampaya?*
11. *Montipora millepora*
12. *Montipora* sp. 2
13. *Montipora* sp. 3
14. *Anacropora matthai*
15. *Acropora austera?*
16. *Acropora bruggemani*
17. *Acropora cerealis*
18. *Acropora cytherea*
19. *Acropora digitifera*
20. *Acropora gemmifera*
21. *Acropora hoeksemai?*
22. *Acropora horrida*
23. *Acropora loripes*
24. *Acropora monticulosa*
25. *Acropora nobilis*
26. *Acropora prostrata*
27. *Acropora rosaria*
28. *Acropora samoensis*
29. *Acropora secale*
30. *Acropora selago*
31. *Acropora solitaryensis*
32. *Acropora stoddarti?*
33. *Acropora valenciennesi*
34. *Acropora valida*
35. *Acropora vermiculata?*
36. *Acropora yongei*
37. *Astreopora gracilis*
38. *Astreopora ocellata*
39. *Porites annae*
40. *Porites evermanni*
41. *Porites monticulosa*
42. *Goniopora planulata?*
43. *Psammocora explanulata*
44. *Psammocora nierstraszi*
45. *Psammocora profundacella*
46. *Psammocora superficialis*
47. *Coscinaraea collumna*

48. *Coscinaraea exesa*
49. *Coscinaraea hahazimaensis*
50. *Pavona bipartite*
51. *Leptoseris explanata*
52. *Leptoseris incrustans?*
53. *Leptoseris mycetoseroides*
54. *Leptoseris papyracea*
55. *Leptoseris scabra?*
56. *Pachyseris foliosa*
57. *Cycloseris erosa*
58. *Cycloseris patelliformis?*
59. *Diaseris distorta*
60. *Diaseris fragilis*
61. *Fungia concinna*
62. *Fungia granulosa*
63. *Fungia klunzingeri*
64. *Fungia moluccensis*
65. *Fungia paumotensis*
66. *Fungia scruposa*
67. *Ctenactis albitentaculata*
68. *Ctenactis crassa*
69. *Herpolitha weberi*
70. *Lithophyllon undulatum*
71. *Podabacia motuporensis*
72. *Galaxea* sp. 1
68. *Echinophyllia echinata*
73. *Echinophyllia orpheensis*
74. *Oxypora crassispinosa*
75. *Mycedium elephantotus*
76. *Pectinia alcorni*
77. *Pectinia maxima*
78. *Pectinia paeonia*
79. *Blastomussa wellsi*
80. *Cynarina lacrimalis*
81. *Scolymia australis*
82. *Scolymia vitiensis*
83. *Acanthastrea hemprichii*
84. *Acanthastrea lordhowensis*
85. *Acanthastrea* sp. 1
86. *Lobophyllia corymbosa*
87. *Lobophyllia* sp. 1
88. *Lobophyllia* sp. 2
89. *Lobophyllia* sp. 3
90. *Hydnophora grandis*
91. *Merulina scabricula*
92. *Caulastrea tumida*
93. *Favia maritima*
94. *Favia* sp. 1
95. *Favia veroni*
96. *Favites acuticollis*
97. *Favites* sp. 1
98. *Goniastrea favulus*
99. *Goniastrea* sp. 1
100. *Platytyra contorta*
101. *Platygyra verweyi*

- 102. *Montastrea curta*
- 103. *Montastrea* sp. 1
- 104. *Montastrea magnistellata*
- 105. *Plesiastrea versipora*
- 106. *Leptastrea pruinosa*
- 107. *Echinopora gemmacea*
- 108. *Echinopora pacificus*
- 109. *Trachyphyllia geoffroyi*
- 110. *Euphyllia ancora*
- 111. *Euphyllia divisa*
- 112. *Euphyllia yaeyamensis*
- 113. *Catalaphyllia jardini*
- 114. *Turbinaria irregularis*
- 115. *Turbinaria mesenterina*
- 116. *Turbinaria stellulata*
- 117. *Balanophyllia* sp.
- 118. *Rhizopsammia verrilli*
- 119. *Tubastraea coccinea*

APPENDIX 5: FISH SPECIES LISTS.

APPENDIX 5(A): FISH RECORDED AT EACH SITE

Species listed as 'sp.', are records that represent a distinct species but identification was not possible. Where species were only found at one site, that site is highlighted in blue.

Sites were: 1 = Teluk Mat Delah, Pulau Redang; 2 = Chagar Hutang, Pulau Redang; 3 = Pulau Ling; 4 = Pulau Lima; 5 = Pulau Lang Tengah; 6 = Terumbu Kili; 7 = Batu Malang; 8 = Teluk Juara, Pulau Tioman; 9 = Pulau Gut; 10 = Pulau Tokong Bahara; 11 = Pulau Seri Buat; 12 = Kadar Bay, Pulau Tulai; 13 = Pulau Renggis. 14 = Teluk Jawa, Pulau Dayang; 15 = Teluk Pontianak, Pulau Pemanggil; 16 = Pulau Simbang; 17 = Batu Tikus.

Abundance ratings are calculated from mean abundance from each survey (n = 34). 1 (Rare) = Mean abundance >0 to <5; 2 (Occasional) = Mean abundance >5 to <20; 3 (Frequent) = Mean abundance >20 to < 50; 4 (Abundant) = Mean abundance >50 to < 250; 5 (Dominant) = Mean abundance > 250.

Species	P. Redang						P. Tioman							P. Tinggi				A
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
<i>Carcharhinus melanopterus</i>						X			X	X			X					1
<i>Nebrius ferrugineus</i>				X														1
<i>Triaenodon obesus</i>				X														1
<i>Torpedo fuscumaculata</i>																X		1
<i>Taeniura lymma</i>				X		X			X	X	X		X	X		X		1
<i>Himantura sp.</i>		X																1
<i>Gymnothorax javanicus</i>				X												X		1
<i>Sideria prosopion</i>																X		1
<i>Diademichthys lineatus</i>							X	X	X	X	X		X		X	X		1
<i>Synodus sp.</i>	X			X	X	X	X	X	X	X	X	X	X	X				1
<i>Strongylura incisa</i>	X	X		X		X	X		X	X		X	X	X	X		X	2
<i>Myripristis murdjan</i>		X	X	X	X	X	X	X	X	X	X	X	X		X		X	2
<i>Sargocentron caudimaculatum</i>														X	X			1
<i>Sargocentron praslin</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	3
<i>Fistularia commersonii</i>														X				1
<i>Dendrochirus zebra</i>														X				1
<i>Aethaloperca rogaa</i>						X	X	X							X			1
<i>Cephalopholis boenack</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	2
<i>Cephalopholis cyanostigma</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	2
<i>Cephalopholis formosa</i>			X			X			X	X	X	X	X			X	X	1
<i>Cephalopholis microprion</i>												X	X	X	X			1
<i>Cephalopholis miniata</i>	X	X								X	X			X	X	X	X	1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A
<i>Cromileptes altivelis</i>								X	X	X							X	1
<i>Epinephelus corallicola</i>										X								1
<i>Epinephelus erythrus</i>																	X	1
<i>Epinephelus fasciatus</i>	X	X	X	X	X	X	X	X	X			X	X	X	X			1
<i>Epinephelus fuscoguttatus</i>											X							1
<i>Epinephelus macrospilus</i>																	X	1
<i>Epinephelus merra</i>																	X	1
<i>Epinephelus polyphekadion</i>	X																	1
<i>Plectropomus aerolatus</i>						X		X	X	X	X			X		X	X	1
<i>Plectropomus leopardus</i>		X				X		X	X	X	X			X		X	X	1
<i>Plectropomus maculatus</i>	X	X			X	X		X	X	X		X	X	X		X	X	1
<i>Diplorion bifasciatum</i>												X						1
<i>Pseudochromis diadema</i>														X				1
<i>Apogon aureus</i>																	X	1
<i>Apogon chrysopomus</i>													X					1
<i>Apogon compressus</i>		X		X	X	X			X	X	X		X					2
<i>Apogon cookii</i>	X	X	X	X				X	X		X	X	X			X		2
<i>Apogon cyanosoma</i>	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	3
<i>Apogon trimaculatus</i>													X					1
<i>Archamia fucata</i>	X		X	X	X		X	X	X	X	X	X		X		X	X	4
<i>Archamia zoesterophora</i>	X											X						2
<i>Cheilodipterus macrodon</i>	X	X	X	X		X	X	X	X	X	X	X	X			X	X	3
<i>Cheilodipterus quinquelineatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	4
<i>Cheilodipterus artus</i>		X		X			X	X			X			X	X	X	X	1
<i>Siphamia versicolor</i>													X					1
<i>Psammoperca waigiensis</i>											X							1
<i>Priacanthus blochii</i>		X				X												1
<i>Priacanthus hamrur</i>		X																1
<i>Gerres oyena</i>							X											2
<i>Echeneis naucrates</i>		X	X				X						X	X				1
<i>Alectis indicus</i>													X					1
<i>Carangoides bajad</i>		X		X	X	X			X	X			X					1
<i>Carangoides chrysophys</i>			X	X	X							X	X					3
<i>Carangoides ferdau</i>										X				X	X	X	X	1
<i>Carangoides gymnostethus</i>			X		X	X			X									2
<i>Caranx melampygus</i>				X														1
<i>Caranx sexfasciatus</i>				X	X													1
<i>Caranx tille</i>				X		X												1
<i>Gnathanodon speciosus</i>	X	X	X	X		X	X		X	X			X					2
<i>Elegatis bispinnulata</i>				X														1
<i>Scomberoides commersonianus</i>							X											1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A
<i>Scomberoides lysan</i>				X														2
<i>Leiognathus bindus</i>																	X	2
<i>Leignathus leuciscus</i>																	X	1
<i>Trachiotus bailloni</i>				X			X		X									1
<i>Trachiotus blochii</i>						X												1
<i>Lutjanus argentimaculatus</i>		X				X		X	X	X	X		X				X	1
<i>Lutjanus bohar</i>						X			X								X	1
<i>Lutjanus carponatus</i>								X	X	X	X	X		X	X	X	X	1
<i>Lutjanus decussatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	2
<i>Lutjanus ehrenbergi</i>												X						1
<i>Lutjanus fulviflamma</i>	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	2
<i>Lutjanus johnii</i>	X			X		X			X		X			X	X	X	X	1
<i>Lutjanus kasmira</i>	X	X	X	X	X	X		X										2
<i>Lutjanus lutjanus</i>	X	X	X	X	X	X		X	X	X						X	X	4
<i>Lutjanus quinquelineatus</i>								X		X				X			X	1
<i>Lutjanus vitta</i>	X	X	X	X	X			X			X							2
<i>Macolor niger</i>		X											X					1
<i>Caesio caerulaurea</i>		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	4
<i>Caesio cuning</i>	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	4
<i>Caesio lunares</i>												X						1
<i>Caesio teres</i>									X									1
<i>Pterocaesio chrysozona</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	4
<i>Pterocaesio marri</i>	X											X		X				1
<i>Plectorhinchus albovittatus</i>		X		X		X												1
<i>Plectorhinchus chaetodonoides</i>										X						X	X	1
<i>Plectorhinchus flavomaculatus</i>													X			X		1
<i>Plectorhinchus gibbosus</i>				X		X				X								1
<i>Plectorhinchus lessoni</i>	X		X															1
<i>Plectorhinchus vittatus</i>	X																	1
<i>Pentapodus caninus</i>	X	X			X						X	X		X			X	1
<i>Pentapodus emeryii</i>					X							X						1
<i>Pentapodus setosus</i>								X	X	X	X	X	X				X	1
<i>Pentapodus trivittatus</i>									X							X		1
<i>Scolopsis affinis</i>	X	X	X	X	X	X	X				X	X	X	X	X	X	X	2
<i>Scolopsis bilineatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	2
<i>Scolopsis ciliatus</i>		X				X	X	X		X	X		X		X	X	X	2
<i>Scolopsis lineatus</i>	X	X	X	X	X	X	X	X			X	X			X	X		2
<i>Scolopsis margaritifer</i>	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	2
<i>Scolopsis monogramma</i>	X	X	X	X	X	X	X	X	X		X	X		X		X	X	1
<i>Scolopsis vosmeri</i>	X	X	X	X	X	X		X		X	X		X			X	X	1
<i>Lethrinus erythropterus</i>	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A
<i>Lethrinus harak</i>											X			X		X		1
<i>Lethrinus microdon</i>		X																1
<i>Lethrinus olivaceus</i>		X	X		X	X		X										1
<i>Lethrinus ornatus</i>				X			X		X	X				X		X	X	1
<i>Mulloidichthys flavolineatus</i>					X		X				X					X	X	1
<i>Parupeneus barberinus</i>							X		X			X	X	X				1
<i>Parupeneus ciliatus</i>						X												1
<i>Parupeneus indicus</i>		X	X			X												1
<i>Parupeneus pleurostigma</i>									X						X			1
<i>Upeneus tragula</i>				X		X	X	X	X		X	X	X				X	1
<i>Pempheris oualensis</i>	X		X	X	X	X	X	X	X	X			X			X	X	3
<i>Pempheris schwenkii</i>	X		X	X	X	X		X	X	X			X			X	X	2
<i>Kyphosus sp.</i>	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	2
<i>Monodactylus argenteus</i>				X		X		X	X							X		3
<i>Platax batavianus</i>										X								1
<i>Platax sp.</i>		X										X	X		X		X	1
<i>Platax pinnatus</i>																	X	1
<i>Platax teira</i>	X		X	X				X	X	X			X	X				2
<i>Chaetodon adiergastos</i>						X				X				X	X			1
<i>Chaetodon auriga</i>			X	X		X												1
<i>Chaetodon baronessa</i>		X		X	X	X	X		X			X		X	X		X	1
<i>Chaetodon lineolatus</i>				X								X	X					1
<i>Chaetodon melannotus</i>														X				1
<i>Chaetodon octofasciatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	3
<i>Chaetodon speculum</i>															X			1
<i>Chaetodon trifascialis</i>				X		X	X		X		X		X		X			1
<i>Chaetodon trifasciatus</i>				X			X	X		X			X	X	X			1
<i>Chaetodon weibeli</i>						X									X			1
<i>Chelmon rostratus</i>		X		X	X	X	X	X	X	X	X	X	X	X		X	X	1
<i>Coradion chrysozonus</i>	X	X	X	X	X	X	X	X	X	X	X	X		X			X	1
<i>Heniochus accuminatus</i>	X	X	X	X	X	X								X			X	1
<i>Heniochus varius</i>				X									X					1
<i>Chaetodontoplus mesoleucus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	2
<i>Centropyge tibicen</i>							X	X	X					X	X			1
<i>Centropyge vrolikii</i>								X						X	X			1
<i>Pomacanthus annularis</i>	X	X	X	X	X	X		X	X	X	X	X	X	X			X	1
<i>Pomacanthus semicirculatus</i>									X									1
<i>Pomacanthus sexstriatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1
<i>Pomacanthus xanthometopon</i>				X														1
<i>Pygoplites diacanthus</i>														X				1
<i>Abudefduf notatus</i>				X	X		X		X	X		X	X	X				1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A
<i>Abudefduf septemfasciatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	1
<i>Abudefduf sexfasciatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	4
<i>Abudefduf sordidus</i>	X	X		X	X	X	X		X	X	X	X	X	X		X	X	1
<i>Abudefduf vaigiensis</i>	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	4
<i>Amblyglyphidodon aureus</i>				X		X		X	X	X		X	X	X			X	2
<i>Amblyglyphidodon curacao</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		5
<i>Amblyglyphidodon leucogaster</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	4
<i>Amphiprion clarkii</i>	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	2
<i>Amphiprion frenatus</i>	X	X	X	X	X	X	X				X	X			X		X	1
<i>Amphiprion ocellaris</i>	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	3
<i>Amphiprion perideraion</i>	X	X	X	X	X	X	X		X	X		X	X		X	X	X	2
<i>Amphiprion sandaracinos</i>													X		X			1
<i>Cheiloprion labiatus</i>	X	X		X	X	X	X		X	X	X	X	X	X	X	X		1
<i>Chromis atripectoralis</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	4
<i>Chromis cinarescens</i>							X	X	X	X	X	X	X	X	X	X	X	4
<i>Chromis lepidolepsis</i>					X													1
<i>Chromis ternatensis</i>					X	X												1
<i>Chromis weberii</i>	X		X	X		X						X		X				2
<i>Chromis xanthura</i>														X				1
<i>Chrysiptera leucopoma</i>															X	X		1
<i>Chrysiptera rollandi</i>												X	X	X	X	X	X	2
<i>Dascyllus reticulatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	4
<i>Dascyllus trimaculatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	4
<i>Dischistodus chrysopoecilus</i>															X	X		1
<i>Dischistodus melanotus</i>	X	X	X	X	X	X	X		X			X	X		X			2
<i>Dischistodus perspicillatus</i>		X																1
<i>Dischistodus prosopotaenia</i>																X		1
<i>Hemiglyphidodon plagiometapon</i>	X	X	X	X	X	X							X					1
<i>Neoglyphidodon melas</i>	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	2
<i>Neoglyphidodon nigroris</i>							X				X			X	X		X	1
<i>Neoglyphidodon oxyodon</i>	X	X			X						X							1
<i>Neoglyphidodon thoracotaeniatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	3
<i>Neopomacentrus anabatoides</i>						X	X	X	X	X	X	X	X	X	X	X	X	4
<i>Neopomacentrus azyros</i>						X		X	X	X			X			X		3
<i>Neopomacentrus bankieri</i>									X		X					X	X	3
<i>Neopomacentrus cyanomos</i>				X	X	X	X	X	X	X	X	X	X	X		X	X	4
<i>Plectroglyphidodon lacrymatus</i>					X		X	X	X	X	X	X	X	X	X	X	X	2
<i>Pomacentrus alexanderae</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	5
<i>Pomacentrus amboinensis</i>							X	X	X	X	X	X	X	X		X	X	1
<i>Pomacentrus brachialis</i>												X						1
<i>Pomacentrus chrysurus</i>	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A
<i>Pomacentrus coelestris</i>			X	X	X	X	X	X	X	X	X	X		X	X	X	X	3
<i>Pomacentrus grammorhynchus</i>		X	X		X											X		1
<i>Pomacentrus lepidogenys</i>			X				X	X	X	X		X	X	X	X	X	X	4
<i>Pomacentrus moluccensis</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	4
<i>Pomacentrus philippinus</i>	X	X	X	X	X	X		X				X	X	X	X			3
<i>Pomacentrus tripunctatus</i>											X					X		1
<i>Segastes albifasciatus</i>											X				X	X		1
<i>Anampses caeruleopunctatus</i>								X						X				1
<i>Bodianus diana</i>						X	X		X					X				1
<i>Bodianus mesothorax</i>				X		X	X	X	X		X	X		X	X		X	1
<i>Cheilinus chlorourus</i>	X		X	X	X	X	X	X	X	X	X	X	X	X	X		X	1
<i>Cheilinus fasciatus</i>	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X		2
<i>Cheilinus trilobatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1
<i>Choerodon anchorago</i>							X			X	X					X	X	1
<i>Choerodon schoenleinii</i>						X	X	X	X	X	X	X	X	X		X	X	1
<i>Cirrhilabrus cyanopleura</i>									X					X	X			1
<i>Coris pictoides</i>								X	X	X		X	X	X	X		X	1
<i>Diproctacanthus xanthurus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	2
<i>Epibulus insidiator</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	2
<i>Gomphosus varius</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			1
<i>Halichoeres biocellatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	2
<i>Halichoeres chloropterus</i>			X				X		X	X	X	X	X	X	X	X	X	1
<i>Halichoeres hortulanus</i>	X		X	X			X	X	X	X		X	X	X	X			1
<i>Halichoeres dussumieri</i>								X	X	X	X	X	X		X	X	X	2
<i>Halichoeres marginatus</i>		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	2
<i>Halichoeres melanochir</i>	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	1
<i>Halichoeres ornatissimus</i>											X	X		X	X	X	X	1
<i>Halichoeres prosopeion</i>				X				X	X	X		X		X				1
<i>Halichoeres purpurascens</i>			X	X		X	X	X	X	X	X	X	X		X	X	X	1
<i>Halichoeres scapularis</i>	X	X			X	X	X		X	X			X		X			1
<i>Halichoeres vrolikii</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	2
<i>Hemigymnus fasciatus</i>													X	X				1
<i>Hemigymnus melapterus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	2
<i>Labrichthys unilineatus</i>	X	X	X	X	X	X	X	X				X	X	X	X			1
<i>Labroides dimidiatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	2
<i>Leptojulius cyanopleura</i>						X	X	X	X			X	X	X	X	X	X	4
<i>Macropharyngodon meleagris</i>	X												X	X				1
<i>Novaculichthys taenirourus</i>															X			1
<i>Oxycheilinus celebicus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	1
<i>Oxycheilinus diagrammus</i>		X	X	X	X	X	X		X	X	X	X	X	X	X	X		1
<i>Oxycheilinus orientalis</i>			X		X	X	X	X	X			X	X	X				1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A
<i>Paracheilinus filamentous</i>				X	X	X	X	X	X	X		X		X	X			3
<i>Pseudocheilinus evanides</i>		X			X	X				X		X		X				1
<i>Pseudocheilinus hexataenia</i>									X	X		X		X	X			1
<i>Pteragogus cryptus</i>			X		X	X	X	X	X								X	1
<i>Stethojulis bandanensis</i>	X						X	X	X				X					1
<i>Stethojulis interrupta</i>									X	X				X	X	X	X	1
<i>Stethojulis trilineata</i>		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	1
<i>Thalassoma hardwicke</i>						X			X			X	X	X	X			1
<i>Thalassoma lunare</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	3
<i>Thalassoma quinquevittatum</i>									X									1
<i>Scaridae sp.</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	4
<i>Bolbometopon muricatum</i>		X								X				X				1
<i>Cetoscarus bicolor</i>														X				1
<i>Scarus ghobban</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	2
<i>Scarus niger</i>	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		2
<i>Scarus tricolor</i>	X			X	X	X												1
<i>Sphyraena barracuda</i>									X				X					1
<i>Sphyraena flavicauda</i>		X	X															3
<i>Sphyraena jello</i>	X												X					1
<i>Sphyraena quenie</i>						X												1
<i>Mugilidae sp.</i>										X	X		X	X	X	X		1
<i>Parapercis snyderi</i>					X	X	X	X				X	X	X	X		X	1
<i>Parapercis xanthozona</i>	X				X		X	X	X		X	X	X	X	X	X	X	1
<i>Atrosalaris fuscus</i>	X	X					X		X			X	X	X	X	X	X	1
<i>Ecsenius bicolor</i>			X				X		X			X	X	X	X		X	1
<i>Ecsenius lineatus</i>			X					X				X						1
<i>Ecsenius yaeyamaensis</i>	X	X					X					X		X	X			1
<i>Meiacanthus grammistes</i>	X				X	X	X	X	X	X	X	X	X	X	X		X	1
<i>Amblygobius hectori</i>											X	X		X				1
<i>Amblygobius phalaena</i>							X	X			X	X	X		X	X		1
<i>Crossosalaris macrospilus</i>												X		X				1
<i>Cryptocentrus cinctus</i>					X			X										1
<i>Ptereleotris evides</i>														X				1
<i>Gunnelichthys monostigma</i>					X	X	X	X	X	X	X	X	X	X	X		X	4
<i>Gunnelichthys viridescens</i>													X					1
<i>Valenciennea muralis</i>							X	X			X	X	X					1
<i>Valenciennea puellaris</i>							X	X			X	X	X		X	X	X	1
<i>Valenciennea strigata</i>																	X	1
<i>Zanclus cornutus</i>				X		X				X								1
<i>Acanthurus dussumieri</i>		X			X													1
<i>Acanthurus lineatus</i>				X		X			X					X				1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A
<i>Acanthurus nigricans</i>															X			1
<i>Naso lituratus</i>	X	X	X	X					X			X		X				1
<i>Naso unicornis</i>				X														1
<i>Siganus argenteus</i>		X	X	X	X	X			X	X				X				1
<i>Siganus corallinus</i>	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	2
<i>Siganus guttatus</i>	X	X	X	X	X	X	X		X	X	X		X	X	X		X	2
<i>Siganus javus</i>									X									1
<i>Siganus puellus</i>	X					X	X							X				1
<i>Siganus spinus</i>					X	X				X		X	X	X	X			1
<i>Siganus virgatus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	3
<i>Siganus vermiculatus</i>		X		X		X												2
<i>Siganus vulpinus</i>	X	X	X	X	X	X	X	X				X	X	X				1
<i>Euthunnus affinis</i>									X									1
<i>Balistapus undulatus</i>						X												1
<i>Balistoides viridescens</i>	X	X	X	X	X	X		X	X			X	X	X				1
<i>Melichthys niger</i>															X			1
<i>Melichthys vidua</i>				X														1
<i>Pseudobalistes flavimarginatus</i>		X	X	X	X	X												1
<i>Sufflamen bursa</i>	X													X				1
<i>Sufflamen chrysopterus</i>												X		X				1
<i>Aluterus monoceres</i>						X												1
<i>Aluterus scriptus</i>	X	X			X	X			X				X	X				1
<i>Cantherhines dumerilii</i>			X										X	X	X			1
<i>Cantherhines perdalis</i>													X	X	X			1
<i>Ostracion cubicus</i>						X	X	X	X			X			X		X	1
<i>Arothron mappa</i>									X	X	X					X		1
<i>Arothron nigropunctatus</i>		X	X	X		X	X		X					X			X	1
<i>Arothron stellatus</i>	X		X			X			X			X	X					1
<i>Diodon liturosus</i>					X												X	1
<i>Diodon hystrix</i>				X	X	X			X	X			X	X				1
Total species at each site	106	114	105	132	117	147	123	120	152	131	111	142	148	156	121	112	133	

APPENDIX 5(B): NEW FISH RECORDS FOR MALAYSIA

The following species have not previously been recorded from Malaysia in published literature. Species listed as 'sp.', are records that represent a distinct species but identification was not possible.

- 1 *Torpedo fuscomaculata*
- 2 *Himantura* sp.
- 3 *Sideria prosopeion*
- 4 *Diademichthys lineatus*
- 5 *Strongylura incisa*
- 6 *Sargocentron caudimaculatum*
- 7 *Sargocentron praslin*
- 8 *Fistularia commersonii*
- 9 *Dendrochirus zebra*
- 10 *Aethaloperca rogaa*
- 11 *Cephalopholis cyanostigma*
- 12 *Cephalopholis formosa*
- 13 *Cephalopholis microprion*
- 14 *Epinephelus corallicola*
- 15 *Epinephelus erythurus*
- 16 *Epinephelus fuscoguttatus*
- 17 *Epinephelus macrospilus*
- 18 *Epinephelus merra*
- 19 *Epinephelus polyphekadion*
- 20 *Plectropomus aerolatus*
- 21 *Plectropomus leopardus*
- 22 *Apogon aureus*
- 23 *Apogon chrysopomus*
- 24 *Apogon compressus*
- 25 *Apogon cookii*
- 26 *Apogon cyanosoma*
- 27 *Apogon trimaculatus*
- 28 *Archamia fucata*
- 29 *Archamia zoesterophora*
- 30 *Cheilodipterus artus*
- 31 *Siphamia versicolor*
- 32 *Psammoperca waigiensis*
- 33 *Priacanthus blochii*
- 34 *Priacanthus hamrur*
- 35 *Gerres oyena*
- 36 *Alectis indicus*
- 37 *Carangoides bajad*

- 38 *Carangoides chrysophys*
- 39 *Carangoides ferdau*
- 40 *Carangoides gymnostethus*
- 41 *Caranx melampygus*
- 42 *Caranx sexfasciatus*
- 43 *Caranx tille*
- 44 *Scomberoides commersonianus*
- 45 *Scomberoides lysan*
- 46 *Leiognathus bindus*
- 47 *Leiognathus leuciscus*
- 48 *Trachiotus bailloni*
- 49 *Trachiotus blochii*
- 50 *Lutjanus bohar*
- 51 *Lutjanus carponatus*
- 52 *Lutjanus ehrenbergi*
- 53 *Lutjanus quinquelineatus*
- 54 *Caesio teres*
- 55 *Pterocaesio marri*
- 56 *Plectorhinchus albobittatus*
- 57 *Plectorhinchus flavomaculatus*
- 58 *Plectorhinchus gibbosus*
- 59 *Plectorhinchus lessoni*
- 60 *Plectorhinchus vittatus*
- 61 *Pentapodus emeryii*
- 62 *Pentapodus trivittatus*
- 63 *Scolopsis affinis*
- 64 *Scolopsis margaritifera*
- 65 *Scolopsis monogramma*
- 66 *Lethrinus erythropterus*
- 67 *Lethrinus harak*
- 68 *Lethrinus microdon*
- 69 *Lethrinus olivaceus*
- 70 *Lethrinus ornatus*
- 71 *Mulloidichthys flavolineatus*
- 72 *Parupeneus ciliatus*
- 73 *Parupeneus indicus*
- 74 *Parupeneus pleurostigma*
- 75 *Pempheris schwenkii*
- 76 *Platax batavianus*
- 77 *Platax sp.*
- 78 *Chaetodon weibeli*
- 79 *Pomacanthus semicirculatus*

- 80 *Amphiprion sandaracinos*
- 81 *Chromis cinarescens*
- 82 *Chromis lepidolepsis*
- 83 *Chrysiptera leucopoma*
- 84 *Dischistodus chrysopoecilus*
- 85 *Neopomacentrus azyros*
- 86 *Neopomacentrus bankieri*
- 87 *Neopomacentrus cyanomos*
- 88 *Pomacentrus grammorhynchus*
- 89 *Segastes albifasciatus*
- 90 *Bodianus diana*
- 91 *Cheilinus trilobatus*
- 92 *Choerodon schoenleinii*
- 93 *Cirrhilabrus cyanopleura*
- 94 *Coris pictoides*
- 95 *Halichoeres biocellatus*
- 96 *Halichoeres chloropterus*
- 97 *Halichoeres dussumieri*
- 98 *Halichoeres melanochir*
- 99 *Halichoeres ornatissimus*
- 100 *Halichoeres prosopeion*
- 101 *Halichoeres purpurascens*
- 102 *Halichoeres vrolikii*
- 103 *Labrichthys unilineatus*
- 104 *Leptojulis cyanopleura*
- 105 *Macropharyngodon meleagris*
- 106 *Novaculichthys taenirourus*
- 107 *Oxycheilinus celebicus*
- 108 *Oxycheilinus diagrammus*
- 109 *Oxycheilinus orientalis*
- 110 *Paracheilinus filamentous*
- 111 *Pseudocheilinus evanides*
- 112 *Pseudocheilinus hexataenia*
- 113 *Pteragogus cryptus*
- 114 *Stethojulis bandanensis*
- 115 *Stethojulis interrupta*
- 116 *Stethojulis trilineata*
- 117 *Thalassoma quinquevittatum*
- 118 *Scaridae*
- 119 *Scarus tricolor*
- 120 *Sphyraena flavicauda*
- 121 *Sphyraena quenie*

- 122 *Mugilidae* sp.
- 123 *Parapercis snyderi*
- 124 *Parapercis xanthozona*
- 125 *Atrosalaris fuscus*
- 126 *Ecsenius bicolor*
- 127 *Ecsenius lineatus*
- 128 *Ecsenius yaeyamaensis*
- 129 *Meiacanthus grammistes*
- 130 *Amblygobius hectori*
- 131 *Amblygobius phalaena*
- 132 *Crossosalaris macrospilus*
- 133 *Cryptocentrus cinctus*
- 134 *Ptereleotris evides*
- 135 *Gunnelichthys monostigma*
- 136 *Gunnelichthys viridescens*
- 137 *Valenciennea muralis*
- 138 *Valenciennea puellaris*
- 139 *Valenciennea strigata*
- 140 *Acanthurus dussumieri*
- 141 *Acanthurus nigricans*
- 142 *Naso unicornis*
- 143 *Siganus argenteus*
- 144 *Siganus javus*
- 145 *Siganus spinus*
- 146 *Siganus vermiculatus*
- 147 *Euthunnus affinis*
- 148 *Melichthys vidua*
- 149 *Pseudobalistes flavimarginatus*
- 150 *Sufflamen chrysopterus*
- 151 *Aluterus monoceres*
- 152 *Aluterus scriptus*
- 153 *Cantherhines dumerilii*
- 154 *Cantherhines perdalis*
- 155 *Ostracion cubicus*
- 156 *Arothron mappa*
- 157 *Diodon liturosus*
- 158 *Nebrius ferrugineus*

APPENDIX 5(C): NEW FISH RECORDS FOR PENINSULA MALAYSIA

The following species have not previously been recorded from Peninsula Malaysia in published literature. Species listed as 'sp.', are records that represent a distinct species but identification was not possible.

- 1 *Triaenodon obesus*
- 2 *Torpedo fuscomaculata*
- 3 *Himantura sp.*
- 4 *Sideria prosopeion*
- 5 *Diademichthys lineatus*
- 6 *Synodus sp.*
- 7 *Strongylura incisa*
- 8 *Sargocentron caudimaculatum*
- 9 *Sargocentron praslin*
- 10 *Fistularia commersonii*
- 11 *Dendrochirus zebra*
- 12 *Aethaloperca rogaa*
- 13 *Cephalopholis cyanostigma*
- 14 *Cephalopholis formosa*
- 15 *Cephalopholis microprion*
- 16 *Cromileptes altivelis*
- 17 *Epinephelus corallicola*
- 18 *Epinephelus eryhturus*
- 19 *Epinephelus fuscoguttatus*
- 20 *Epinephelus macrospilus*
- 21 *Epinephelus merra*
- 22 *Epinephelus polyphekadion*
- 23 *Plectropomus aerolatus*
- 24 *Plectropomus leopardus*
- 25 *Plectropomus maculatus*
- 26 *Diplorion bifasciatum*
- 27 *Pseudochromis diadema*
- 28 *Apogon aureus*
- 29 *Apogon chrysopomus*
- 30 *Apogon compressus*
- 31 *Apogon cookii*
- 32 *Apogon cyanosoma*
- 33 *Apogon trimaculatus*
- 34 *Archamia fucata*
- 35 *Archamia zoesterophora*
- 36 *Cheilodipterus artus*
- 37 *Siphamia versicolor*

- 38 *Psammoperca waigiensis*
- 39 *Priacanthus blochii*
- 40 *Priacanthus hamrur*
- 41 *Gerres oyena*
- 42 *Alectis indicus*
- 43 *Carangoides bajad*
- 44 *Carangoides chrysophys*
- 45 *Carangoides ferdau*
- 46 *Carangoides gymnostethus*
- 47 *Caranx melampygus*
- 48 *Caranx sexfasciatus*
- 49 *Caranx tille*
- 50 *Scomberoides commersonianus*
- 51 *Scomberoides lysan*
- 52 *Leiognathus bindus*
- 53 *Leiognathus leuciscus*
- 54 *Trachiotus bailloni*
- 55 *Trachiotus blochii*
- 56 *Lutjanus bohar*
- 57 *Lutjanus carponatus*
- 58 *Lutjanus ehrenbergi*
- 59 *Lutjanus quinquelineatus*
- 60 *Macolor niger*
- 61 *Caesio caerulea*
- 62 *Caesio lunares*
- 63 *Caesio teres*
- 64 *Pterocaesio marri*
- 65 *Plectorhinchus albobittatus*
- 66 *Plectorhinchus chaetodonoides*
- 67 *Plectorhinchus flavomaculatus*
- 68 *Plectorhinchus gibbosus*
- 69 *Plectorhinchus lessoni*
- 70 *Plectorhinchus vittatus*
- 71 *Pentapodus caninus*
- 72 *Pentapodus emeryii*
- 73 *Pentapodus setosus*
- 74 *Pentapodus trivittatus*
- 75 *Scolopsis affinis*
- 76 *Scolopsis ciliatus*
- 77 *Scolopsis margaritifer*
- 78 *Scolopsis monogramma*
- 79 *Lethrinus erythropterus*

- 80 *Lethrinus harak*
- 81 *Lethrinus microdon*
- 82 *Lethrinus olivaceus*
- 83 *Lethrinus ornatus*
- 84 *Mulloidichthys flavolineatus*
- 85 *Parupeneus barberinus*
- 86 *Parupeneus ciliatus*
- 87 *Parupeneus indicus*
- 88 *Parupeneus pleurostigma*
- 89 *Upeneus tragula*
- 90 *Pempheris schwenkii*
- 91 *Platax batavianus*
- 92 *Platax sp.*
- 93 *Platax pinnatus*
- 94 *Chaetodon baronessa*
- 95 *Chaetodon lineolatus*
- 96 *Chaetodon melannotus*
- 97 *Chaetodon speculum*
- 98 *Chaetodon weibeli*
- 99 *Heniochus varius*
- 100 *Centropyge tibicen*
- 101 *Centropyge vrolikii*
- 102 *Pomacanthus semicirculatus*
- 103 *Pomacanthus xanthurus*
- 104 *Pygoplites diacanthus*
- 105 *Amblyglyphidodon aureus*
- 106 *Amphiprion sandaracinos*
- 107 *Chromis cinarescens*
- 108 *Chromis lepidolepsis*
- 109 *Chromis ternatensis*
- 110 *Chrysiptera leucopoma*
- 111 *Chrysiptera rollandi*
- 112 *Dischistodus prosopocentrus*
- 113 *Hemiglyphidodon plagiometapon*
- 114 *Neoglyphidodon oxyodon*
- 115 *Neopomacentrus azyros*
- 116 *Neopomacentrus bankieri*
- 117 *Neopomacentrus cyanomos*
- 118 *Pomacentrus brachialis*
- 119 *Pomacentrus grammorhynchus*
- 120 *Pomacentrus lepidogenys*
- 121 *Segastes albifasciatus*

- 122 *Bodianus diana*
- 123 *Cheilinus trilobatus*
- 124 *Choerodon anchorago*
- 125 *Choerodon schoenleinii*
- 126 *Cirrhilabrus cyanopleura*
- 127 *Coris pictoides*
- 128 *Halichoeres biocellatus*
- 129 *Halichoeres chloropterus*
- 130 *Halichoeres hortulanus*
- 131 *Halichoeres dussumieri*
- 132 *Halichoeres marginatus*
- 133 *Halichoeres melanochir*
- 134 *Halichoeres ornatissimus*
- 135 *Halichoeres prosopeion*
- 136 *Halichoeres purpurascens*
- 137 *Halichoeres vrolikii*
- 138 *Hemigymnus fasciatus*
- 139 *Labrichthys unilineatus*
- 140 *Leptojulis cyanopleura*
- 141 *Macropharyngodon meleagris*
- 142 *Novaculichthys taenirourus*
- 143 *Oxycheilinus celebicus*
- 144 *Oxycheilinus diagrammus*
- 145 *Oxycheilinus orientalis*
- 146 *Paracheilinus filamentous*
- 147 *Pseudocheilinus evanides*
- 148 *Pseudocheilinus hexataenia*
- 149 *Pteragogus cryptus*
- 150 *Stethojulis bandanensis*
- 151 *Stethojulis interrupta*
- 152 *Stethojulis trilineata*
- 153 *Thalassoma hardwicke*
- 154 *Thalassoma quinquevittatum*
- 155 *Scaridae*
- 156 *Cetoscarus bicolor*
- 157 *Scarus tricolor*
- 158 *Sphyraena flavicauda*
- 159 *Sphyraena quenie*
- 160 *Mugilidae sp.*
- 161 *Parapercis snyderi*
- 162 *Parapercis xanthozona*
- 163 *Atrosalaris fuscus*

- 164 *Ecsenius bicolor*
- 165 *Ecsenius lineatus*
- 166 *Ecsenius yaeyamaensis*
- 167 *Meiacanthus grammistes*
- 168 *Amblygobius hectori*
- 169 *Amblygobius phalaena*
- 170 *Crossosalaries macrospilus*
- 171 *Cryptocentrus cinctus*
- 172 *Ptereleotris evides*
- 173 *Gunnelichthys monostigma*
- 174 *Gunnelichthys viridescens*
- 175 *Valenciennea muralis*
- 176 *Valenciennea puellaris*
- 177 *Valenciennea strigata*
- 178 *Acanthurus dussumieri*
- 179 *Acanthurus nigricans*
- 180 *Naso unicornis*
- 181 *Siganus argenteus*
- 182 *Siganus javus*
- 183 *Siganus puellus*
- 184 *Siganus spinus*
- 185 *Siganus vermiculatus*
- 186 *Euthunnus affinis*
- 187 *Balistoides viridescens*
- 188 *Melichthys niger*
- 189 *Melichthys vidua*
- 190 *Pseudobalistes flavimarginatus*
- 191 *Sufflamen bursa*
- 192 *Sufflamen chrysopterus*
- 193 *Aluterus monoceres*
- 194 *Aluterus scriptus*
- 195 *Cantherhines dumerilii*
- 196 *Cantherhines perdalis*
- 197 *Ostracion cubicus*
- 198 *Arothron mappa*
- 199 *Diodon liturosus*
- 200 *Nebrius ferrugineus*