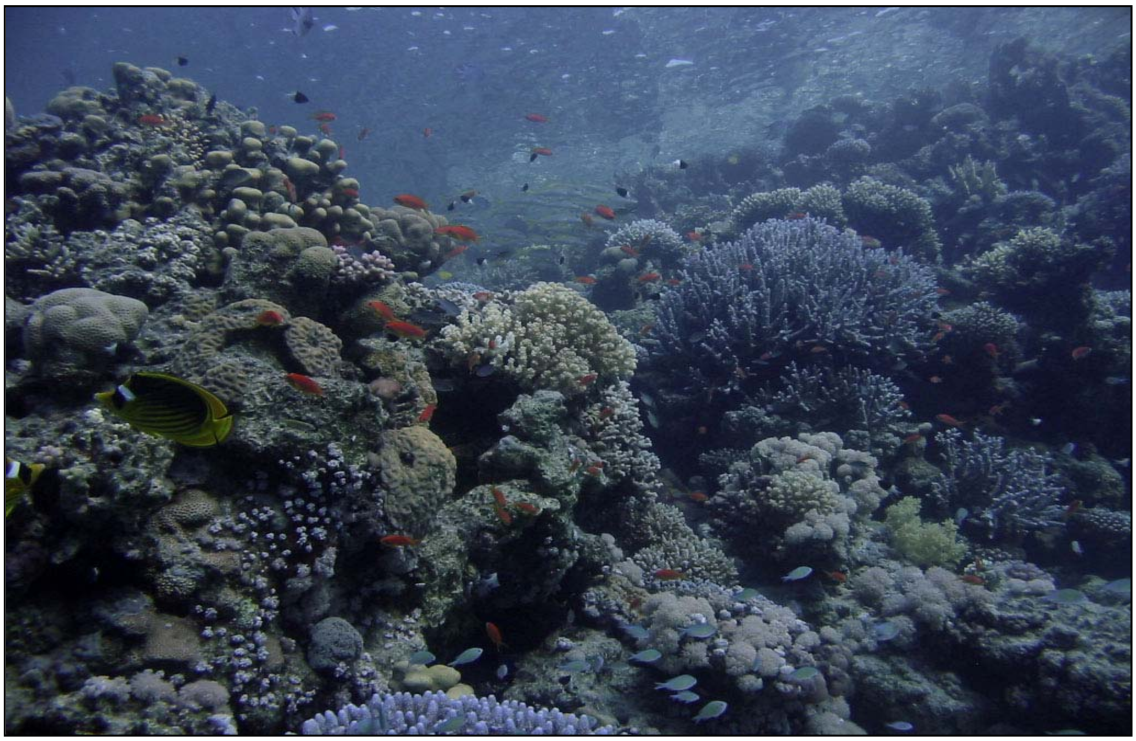
Monitoring Program report

Ras Mohammed National Park

2006



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OPERATION WALLACEA

Conservation Value Index assessment of Ras Mohammed National Park

July- August 2006

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Acknowledgements

This study was carried out in the Ras Mohammed National Park, South Sinai, Egypt during July and August 2006 as a part of the agreement between the Egyptian Environmental Affairs Agency (EEAA) and Operation Wallacea to establish and implement a long term monitoring program for the coral reefs and associated communities within the national park.

The contribution of EEAA staff was vital to the running of this project and the assistance of Essam Saadalla of the EEAA was much appreciated.

The input of the Dive Operations Manager, Gerban Post was also essential to the success of this project, as was the assistance of Joe Taylor (University of Essex). Operation Wallacea are also recognised for providing travel funds for Steve McMellor. The University of Essex Poulter studentship award is recognised for funding the research of Steve McMellor at the CRRU.

Finally we would like to acknowledge the efforts of all the research assistants who worked with us on the project and made the expedition atmosphere so positive, especially Tris, Ning, Maya, Alex and Simon.

Cover photo: Marsa Ghozlani reef crest (S.McMellor)

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List of terms and abbreviations

ALG – Algal cover

COREMAP – Coral Reef Management and Protection Program

CR – Coral Rubble Cover

CRRU – Coral Reef Research Unit, University of Essex

CVI – Conservation Value Index

DC – Dead Coral cover

EEAA – Egyptian Environmental Affairs Agency

GEF – Global Environment Facility of the World Bank

HCC – Hard (Scleractinian) Coral Cover

LC – Total Live cover

LIT – Line Intercept Transect

NCS – Nature Conservation Sector

PERSGA - Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden

SC- Soft Coral Cover (Alcyonacea)

SST – Sea Surface Temperature

TNC – The Nature Conservancy

WWF – World Wildlife Fund

Executive Summary

This report reflects the data collected as part of the ongoing long term coral reef monitoring program set up by Operation Wallacea, Coral Reef Research Unit, University of Essex(UK) and the EEAA. Survey work was carried out by Steve M^{c}Mellor (CRRU) and was supported by Operation Wallacea research assistants and EEAA park rangers.

All study sites were surveyed using belt and LIT methodologies, with four replicate transects carried out at two depths, (upper and lower reef slopes) at each site. Separate surveys were carried out on the same transects for both the benthic and fish communities.

As well as basic statistical analysis, the study sites were classified according to the Conservation Value Index developed at the CRRU.

The study sites included in this study were expanded from the 2005 study, but were still limited by logistical limitations to; South Bereika, Shark Observatory, North Bereika, Ras Umm Sid, Marsa Ghozlani and Old Quay.

i. Coral diversity and Cover

The percentage cover of live corals (Scleractinia) did not vary significantly between the six study sites. A slight improvement in mean cover was observed from the 2005 study, yet it is not possible to confirm if this change is significant as the level of recorded increase in coral cover is on the threshold of the statistical power of the experimental design. The mean Scleractinian coral cover within the National Park was 25.7(±1.5)%. The lower reef slope at Ras Umm Sid showed the lowest hard coral cover at 18.39(±5.84)%, with the highest cover once again found at South Bereika at 33.74(±3.88)%. Total live benthic cover showed a very highly significant difference between sites ($F_{5,43}=7.43; p<0.001$) with the Old Quay site having the highest cover recorded at just over 57%. The Ras Umm Sid and South Bereika sites also had total live cover values in excess of 40%. No difference was found between the other sites. The higher cover ties in with the high soft coral (Alcyonacea) cover at the Old Quay site, which was again significantly higher than at any of the other sites (Tukey $p<0.001$). The Generic richness of the Scleractinia varied significantly between sites($F_{5,43}$=7.45;$p<0.001$), with Shark Observatory having significantly fewer genera than all of the other sites. A significant difference in mean hard coral colony size was found between the sites, which a mean size of 0.15(±0.01)m throughout the park. This was not significantly different to the 2005 study. There was also a significant difference between sites when considering the number of individual colonies ($F_{5,43}$=3.20$p<0.05$). South Bereika ($p<0.01$) had by far the greatest number of individual hard coral colonies, while the fewest were found at the Old Quay site. There was no significant difference in number of colonies between the other site combinations. Significant differences were also found in the abundance of coral rubble between the sites ($F_{5,43}$=3.67;$p<0.01$). Rubble cover was lowest at the Shark Observatory site and highest at the South Bereika site.

The dominant Scleractinian coral Genera included, *Acropora*, *Seriatopora*, *Pocillopora*, *Stylophora*, *Porites* and *Montipora*. There was also significant abundance of the Octocoral *Millepora*, especially at the Old Quay site where it dominated.

The use of randomly placed 1m^2 quadrats identified a mean recruitment rate for Scleractinian corals of 1.21 (±0.13) new recruits per m^2 per year. There was no significant difference in the number of recruits between the different sites.

ii. Fish diversity and abundance

There was a very significant difference in the total abundance of fish observed at each of the study sites ($F_{5,43}$=3.82;p=0.01). Total mean (±s.e.) abundance of fish 1000m^{-2} was highest at Old Quay (3242.9±501.5) and lowest at North Bereika(422.0±11.1). Although no significant difference was found between all the other sites, Shark Observatory, Ras Umm Sid and the Old Quay sites all showed high standard deviation in fish abundance, with values often dependent upon prevailing conditions, predominantly current speed. The total number of different species observed did not vary significantly between the sites with a mean number of 97.8(±2.6) species recorded at each site.

There was a significant difference in the number of Chaetodont species recorded between the sites ($F_{5,43}$=3.26;p=0.01). Pomacentrids and Acanthurids also showed significant variation in species richness between the study sites. No significant difference was shown in species richness of Serranids, Scarrids, Labrids nor Pomacanthids between sites.

Both Principle Component Analysis and Bray Curtis (Group average) cluster analysis identified the similarity between the all of the six sites. The cluster analysis suggested that the fish communities' at all sites shared a similarity in composition of over 85%. The fish communities at all of the sites are still clearly dominated by three very abundant species, the half-and-half chromis (*Chromis dimidiata*), the Orchid dottyback (*Pseudochromis fridmani*) and the Lyretailed anthias (*Pseudoanthias squamipinnis*).

iii. Conservation Value Index Classifications

The classification of the surveyed sites within the park using the CVI developed at the CRRU, showed that the upper slope at the Old Quay site was rated highest with index scores of 49 and 35 for benthic and fishery health respectively, giving a CVI score of B2. The South Bereika lower slope site scored 51 and 13 for benthic and fishery respectively giving an overall CVI value of B4. The Marsa Ghozlani site also scored C3 overall, with a benthic score of 45 and a fishery value of 23. North Bereika scored 49 and 13 respectively giving an overall ranking of B4. Ras Umm Sid upper slope scored 46 and 33 respectively for benthic and fish giving a site ranking of C2. The lowest scoring site was the Shark Observatory, with a benthic score of 44 and a fishery value of 24, giving a CVI rating of C3.

These classifications will allow the dissemination of complex biological survey results to any level of audience, as well as allowing the setting and monitoring of management actions.

iv. Threats

Neither observations of coral disease nor incidence of coral bleaching were made at any of the study sites. Again no Crown-of-Thorns-Starfish (*Acanthaster planci*) were recorded at any of the study sites, (although the occasional solitary individual was observed at the Marsa Ghozlani site). With regard to the abundance of the corallivorous Gastropod *Drupella* spp., none were observed at the Old Quay and Shark Observatory sites, while they were found to be present in 0.5% of coral colonies throughout the park.. They were generally observed on *Acropora* spp. colonies.

Randomly placed 1m^2 quadrats identified that there was a mean number of loose coral fragments of 1.9(±0.4) per m^2. There were significantly higher number of broken fragments at the heavily visited Old Quay site than at the closed North Bereika site ($F_{5,43}$=3.36;p=0.05). With regard to damaged colonies (still attached), again there was a significant difference between sites ($F_{5,43}$=3.30;p=0.05), with the highest number observed at the Shark Observatory site.

vi. Conclusion

All the reefs surveyed in this second year of the study showed similar cover of hard corals and also similar amounts to the preliminary study of 2005. The mean colony size appears relatively small and suggests that the reefs are starting to recover from the COTs event of several years ago. The large amount of substratum available for recruits means many small colonies showing a couple of years growth dominate.

No immediate natural threats were observed during the period of this second year of study, COTs were minimal, and *Drupella* Gastropods inhabited a small percentage of colonies at some sites. No coral bleaching (from any stress) or incidence of coral disease was observed.

The multi-zoned management technique applied to Ras Mohammed offers a number of opportunities to monitor both the recovery of the impacted reefs, as well as the anthropogenic impact of the dive tourists.

The use of quadrats placed at intervals along each transect allowed the monitoring of physical damage to corals by divers and snorkellers, and also allowed the monitoring of coral recruitment of planulae larvae in the form of new coral recruits.

CHAPTER 1. INTRODUCTION

1.1 Project background

Operation Wallacea was been established for over ten years in Indonesia where they are heavily involved in biological, ecological and social monitoring of the Wakatobi Marine National Park, the second largest Marine Protected Area in Indonesia. The monitoring programs established for several years in the Wakatobi are providing valuable data to allow informed management decisions to be made by the stakeholders. Operation Wallacea are also heavily involved with the COREMAP project funded by the World Bank to implement sustainable management of coral reef ecosystems throughout Indonesia. Operation Wallacea's monitoring program is also providing ecological data to the GEF funded management of the Wakatobi MNP implemented by WWF and TNC. Operation Wallacea's marine monitoring program is designed and overseen by members of the Coral Reef Research Unit (CRRU) from the University of Essex (UK), a multidisciplinary research unit based in the Department of Biological Sciences. The CRRU draws on experience from academics based at universities and NGO's around the world and is well placed to advise and recommend suitable management actions or further in depth biological surveys to address threats to the parks coral reef environments.

In late 2004 the Nature Conservation Sector of the Egyptian Environmental Affairs Agency (EEAA) and Operation Wallacea signed an eight year agreement to establish and implement a long term monitoring program for the coral reef habitats of the Ras Mohammed National Park, South Sinai, Egypt. This project was to be established in the Summer of 2005 by the involvement of members of the CRRU, experienced Operation Wallacea staff and research assistants whom assisted with surveys and logistics. The first year (2005) of the agreement was dedicated to establishing links with EEAA staff, implementing the logistical support required for such a long term project, identifying suitable sites for the longer term program, as well as carrying out a baseline survey of a few of the reefs within the Ras Mohammed National Park.

1.2 Area description

The Red Sea is a relatively ‘new’ sea formed in the Eocene some 40 million years ago when a fault developed between what is now the Arabian peninsula and North Africa and is a continuation of the fault which developed the east African rift valley. The modern Red Sea was formed some five million years ago when Sinai uplifted, cutting the water body off from the Mediterranean (formerly Tethys Sea) and opened a shallow channel to the Indian Ocean, allowing entry of Indo-Pacific organisms to the water body. Subsequent isolation from the Indian Ocean led to speciation and the current situation with so many endemic species, unique to the Red Sea. The Red Sea was again linked to the Indian Ocean some 15000years ago at the end of the last Ice age (Lieske & Myers, 2004). Current literature suggests that between 210 and 270 species of Scleractinian coral are found within the Red Sea, and around 1000 species of fishes, some 15% of which are endemic.

The Ras Mohammed National Park was established in 1983 as Egypt’s first national park, although it is generally agreed (Shehata, 1998) to have existed as a ‘paper park’ until 1988, when the Egyptian government handed the task of management to the EEAA in response to the areas growing popularity as a dive tourism destination.

The Ras Mohammed National Park (Figure 1) exists at the southernmost tip of the Sinai peninsula, protruding into the Red Sea, its is bordered on one side by the Gulf of Suez and on the other buy the Gulf of Aqaba (Frouda, 1984). The coastal plain is narrow with granitic mountains descending almost directly into the sea (Shehata, 1998). To the North and the West are large alluvial plains, the northern of which has undergone rapid and constant development since the mid-eighties and now forms the city of Sharm el-Sheikh.

The cape of Ras Mohammed consists of a large bay and inlet with cliffs of raised fossilised corals backed by low undulating barren hills (Samuel, 1973). In the east and in the west there are clear water creeks with sandy shores. The high bluffs of Ras Mohammed itself are connected to the mainland by a narrow land bridge, 3.5km long and 1km wide. The southern tip of the headland is an island separated from the mainland by a shallow channel filled with mangroves. Exposed coral reefs are found adjacent to open water areas of over 100m in depth. The fringing reef encircles the entire headland and ends in cliff-like ledges at 70m and 100m water depth. By the headland there is an extensive terrace at approximately 15m depth (Wells, 1987). Nearly all areas of shoreline within the park have well developed fringing reefs, often with steep walls dropping thousands of metres in places.

Water temperatures in the park range from 21°C in January to almost 30°C in August, salinity is elevated above 40‰ due to high levels of evaporation and slow rates of water exchange between the Red Sea and the main Indian Ocean basin due to the shallow water connection between the two bodies. Lack of riverine inputs and associated run off and sedimentation gives rise to the world renowned visibility of the regions waters.

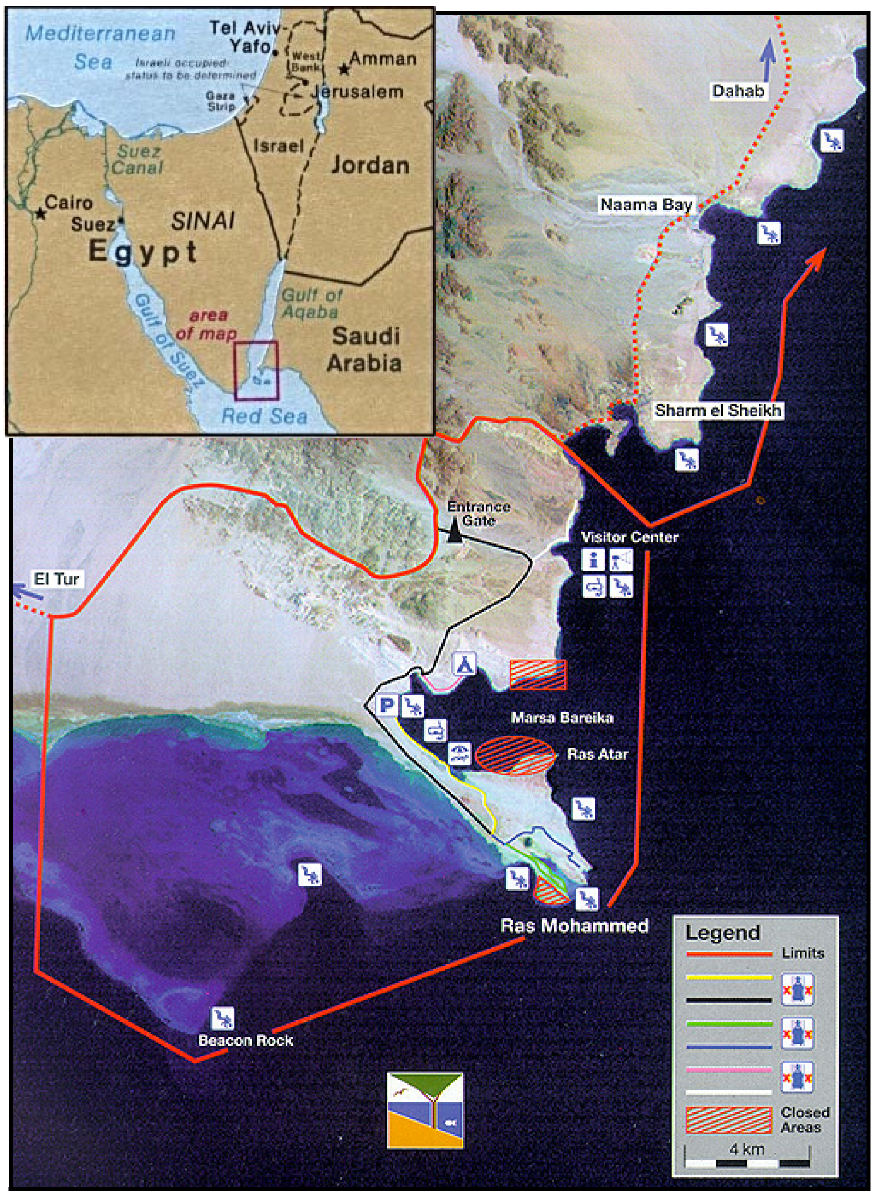

Figure 1. Map of the Ras Mohammed National Park (Source:EEAA)

1.3 Description of sites surveyed

Logistical limitations meant that the preliminary study in 2005 was restricted to four study sites, the 2006 survey was extended to a total of six sites;

1.3.1 South Bereika

Located at the southern side of Marsa Bereika bay (GPS: 27°46.447’N 34°12.760’E), South Bereika has a very narrow reef crest only a few metres in width. The reef then drops vertically to around six to eight metres and then slopes at around 45° down past the 50 metre mark. Below a depth of 10metres spur and groove formations of coral and sandy areas are evident. The large bay is relatively sheltered from the prevailing conditions and hence the site can be considered a low energy site. The area has previously been closed for a period of around ten years to all activities, but has recently been opened for boat diving and snorkelling, however, shore diving is still prohibited. The site is popular with day safari boats and live boards, especially as a mooring site for lunch, mainly due to the sheltered location. It is also the only location in Marsa Bereika bay that is open to visitors. Four moorings provided by the park authorities are regularly full with around eight to twelve boats in attendance.

1.3.2 Marsa Ghozlani (Visitor centre)

Located halfway between Sharm el Maya and Marsa Bereika (GPS: 27°49.319’N 34°15.862’E) a small bay is overlooked by the Ras Mohammed Visitor Centre. The reef flat in this area extends from a few metres at the sides of the bay to around 15metres in the centre where a small sandy channel also exists. The bay has a sandy central area which slopes down to around ten metres where the reef begins. At the sides of the bay the reef crest drops vertically to around four to five metres and then a narrow terrace extends for several metres. The deeper reef is a mixture of slope and steep wall dropping to around 35 metres, getting deeper as the reef extends out of the bay. This small bay is a relatively sheltered low energy environment. The site is extremely popular with snorkelling day boats and the four moorings within the bay are often fully occupied, possibly due to the sites proximity to Sharm el Maya, where the majority of the boats depart from. Shore diving occurs at this site as well as diving from boats.

1.3.3 Old Quay

The Old Quay site is on the western side of the Ras Mohammed headland (GPS:27°44.257' N 34°14.282'E) and technically in the Gulf of Suez. This side of Ras Mohammed is characterised by a very wide, extensive, shallow reef flat. However, the area around the Old Quay site has a small sandy lagoon about 50-70m wide, with patchy seagrass beds occurring within the lagoon. The reef crest rises from the sandy bottom by around 1.5 metres and extends about five metres wide. On the seaward side the reef drops as a wall to around six metres in depth. This part of the reef is characterised by slight spur and groove formations and many large overhangs and caves. Below this depth, the reef slopes gently at around 45° to below 50metres. There are two park provided moorings at this site and one or two dive boats are usually present. The majority of visitors to this site arrive in tourist buses and generally consist of snorkellers and swimmers. It is not unusual to witness over ten buses at this site, leaving the beach and lagoon flat fairly crowded. Visibility at this site is often relatively poor at less than 10 metres. Mixing of waters is visible, as is the sediment load coming onto the reef itself from the reef flat, particularly at low tide when sediment can be seen flowing out through the reef.

The site is relatively sheltered due to its geography, and the settled sediment load present suggests that it is a low energy site.

1.3.4 Shark Observatory

This is the most exposed of the study sites facing South East from the tip of the Ras Mohammed peninsula (GPS: 27°43.903'N 34°15.592'E). It is adjacent to the extremely popular Shark and Yolanda Reefs and hence receives a large number of divers, often as an alternative dive when the moorings for the aforementioned sites are full. The site is also popular with shore divers and jeep safaris as well as with snorkelling tour buses. The site is entered through a narrow bay less than ten metres wide, and access to the reef is through a cavern around 20 metres wide which slopes from six metres to over 30 metres. Either side of the small bay there is no reef flat as such and the reef descends vertically as a steep wall almost straight down from the terrestrial cliffs which surround this site. The reef descends straight down to several hundred metres in depth and is dotted with small caves and overhangs. The site is often subject to moderate to strong currents and as such attracts many pelagic species such as Tuna, Trevally and several Shark species.

1.3.5 North Bereika

This site is on the North side of the sheltered Marsa Bereika bay (GPS: 27°47.127'N 34°12.920'E). The site is adjacent to one of the three closed areas within the park and receives very few divers each year. The reef begins with small network of patch reefs and bommies on a sandy slope to around 8m depth. The reef 'proper' crests at around 10-12m and slopes down at a 45º angle to 50m and deeper. There are several areas of mini inlets and bays within this area of reef and the slope becomes steeper in some areas to almost a 70º slope. This site is adjacent to a military checkpoint and it is understood that this site is closed to boats but open to some shore diving.

1.3.6 Ras Umm Sid

Ras Umm Sid (GPS: 27º50.852' N 34º18.826' E) is one of the most popular and heavily dived sites within the Ras Mohammed National Park. The site is located off the steep cliffs of Hadaba and is a popular location for lunching boats and stopovers on both the way to and return from the Tiran reefs. The reef flat ranges from 20- 60m wide and has several buoyed channels as well as a floating pontoon to help keep visitors off the reef flat. The reef drops down vertically to around 10m and then slopes gently into the depths with several large outcrops and bommies around the 30m mark. The site is relatively exposed with strong currents occurring occasionally.

1.4 References

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CHAPTER 2. CORAL DIVERSITY AND DISTRIBUTION

2.1 Summary

The percentage cover of live corals (Scleractinia) did not vary significantly between the six study sites. Marsa Ghozlani showed the lowest hard coral cover at 20.8(±1.1)%, with the highest cover found at South Bereika at 33.3(±2.4)%. Total live benthic cover showed a very highly significant difference ($F_{5,43}=7.43;p<0.001$) with the Old Quay site having the highest cover recorded at almost 60%. The Ras Umm Sid and South Bereika sites also showed total live cover >40%. No difference was found between the other sites. The Generic richness of the Scleractinia varied significantly between sites, with South Bereika having significantly more genera than Shark Observatory (Tukey p=0.001), with no significant difference between the other sites. There was a significant difference between sites when considering the number of individual colonies ($F_{5,43}=3.20;p<0.05$). Both South Bereika ($p<0.01$) and Marsa Ghozlani ($p<0.05$) had higher numbers of hard coral colonies than did the Old Quay site which had the fewest. Significant differences were also found in the abundance of coral rubble between the sites ($F_{5,43}=3.67;p<0.01$). Rubble cover was lowest at the Shark Observatory site and highest at the South Bereika site.

The mean hard coral cover within the park has increased from 20.3% in 2005 to 25.7% in 2006. Although this increase is statistically significant, the power of the sampling design will only reliably account for changes in excess of around 5%. Hence this change is only very slightly above this threshold and data from future years will be necessary to identify if this is a real trend in increasing coral cover as this study suggests.

There were no detectable annual variations in many of the other recorded benthic parameters.

The dominant Scleractinian coral Genera included, *Acropora*, *Seriatopora*, *Pocillopora*, *Stylophora*, *Porites* and *Montipora*. There was also significant abundance of the Octocoral *Millepora*.

The use of randomly placed 1m^2 quadrats identified a mean recruitment rate for Scleractinian corals of 1.21 (±0.13) new recruits per m^2 per year. There was no significant difference in the number of recruits between the different sites.

2.2 Introduction

Although there appear to have been a number of studies and monitoring programs attempted in the Ras Mohammed park, the data they produced is unfortunately lacking (Pilcher & Zaid, 2000). Any sort of informed management action requires a solid foundation on which to base decisions, often in the form of an in depth biological survey. The hermatypic Scleractinian corals are arguably the most important component of the reef as they are the reef builders themselves and without them reef growth would be very limited. Although important, they are by no means the only organism important to overall reef health. Important interactions between reef benthic organisms are constant with spatial and resource competition high.

Degradation of tracts of reef often involves a ‘phase shift’ from coral dominated to algal dominated states, which in turn has knock on effects to the fish abundance and diversity (McCook,1999; McClanahan *et al*., 2002). A complex interaction between hard corals, soft corals, algae and levels of fish grazing can lead to these phase shifts, but it often requires several factors to occur simultaneously, such as increased eutrophication and removal of important herbivorous fishes, along with ongoing degradation of hard corals. It is due to the complex nature of competition on a coral reef that many of these other factors need to be recorded and considered, before any management action can be taken. It is of vital use to stakeholders and managers that early detection of changes in these interacting factors, be monitored alongside measures of coral cover, to allow the early identification of possible phase shifts in community structure.

The link between the health of the benthic and fish communities is already well established in coral reef ecology. Roberts & Ormond, (1987) showed that substratum biodiversity was positively correlated with overall fish species richness, although total live cover did not show a significant correlation to fish diversity or abundance. Friedlander & Parrish (1998) also identified benthic habitat characteristics affecting fish assemblages. Often these are characteristics which provide habitat for fish and also for fish prey species, such that the benthic and fishery components of a reef system are highly interdependent, with a natural or anthropogenic impact on one community having a knock-on effect on the other. The interaction between various components within the coral reef system means that it is of vital importance to monitor the changes in cover and abundance of many of these factors as coral cover alone cannot give any indication of possible phase shifts or changes in the composition of either community.

Threats to benthic reef health come in a number of both natural and anthropogenic guises and are covered in more detail in Chapter Five.

The Ras Mohammed National Park was originally designated to protect an area of important natural resources which was at risk due to the development of the dive tourism industry. The hermatypic corals provide habitat and resources for a huge variety of different organisms and the sustainable development of tourist activities must be based around the protection of the reef builders themselves.

This study aimed to survey the reef benthos and classify the abundance and diversity of several categories of biota including the hard corals (Scleractinia), the soft corals (Alcyonacea), sponges (Porifera) and algae. Abiotic categories such as areas of sand, coral rubble, dead coral and bare rock were also recorded.

2.3 Methods

The main group studied will be the hermatypic corals (Order Scleractinia). Other groups of sessile reef organisms to be monitored include the soft corals (Alcyonacea), sponges (Porifera), macro algae and Crustose Coralline Algae. The area of coral rubble, dead corals and area of bare substratum available for recruitment was also recorded. Regular monitoring of Echinoderm populations (*Acanthaster planci* and *Diadema* sp.) as well as abundance of corallivorous Gastropods (*Drupella* spp.) was included.

The monitoring program was carried out at a number of sites within the park at two depths on the upper (2-6m) and lower (9-12m) reef slopes. A combination of several survey methods were used to quantify spatial and temporal changes in the benthic community. The principal technique used was the continuous Line Intercept Transect (English *et al*., 1996), combined with belt transects (Loya, 1978). Four 40 metre long transect tapes were laid along depth contours parallel to the shoreline for each depth at each site. All lifeforms intercepting the transect line were recorded to Genus with the length intercepting the transect tape recorded to the nearest centimetre. An individual is defined as any colony/ individual growing independently from its neighbours. In cases where a colony is divided into multiple parts by the death or overgrowth of intermediate parts, each part is considered a separate colony. The area intercepting the transect tape was classified according to the benthic category system as shown in Table 1, after the AIMS methodology of English *et al*., (1996).

Table 1. Benthic classification categories

Abbreviation	**Substratum category**
HC	Hard Coral
SC	Soft Coral
SPG	Sponge
DC	Dead Coral
CR	Coral Rubble
S	Sand
ALG	Macroalgae
RK	Bare Substratum
OTH	Other

Digital photographs were taken of any unknown lifeforms for later identification using keys. While recording the colony size intercepting the transect line, coral predator abundance and the presence (area affected) of bleaching or disease was also be noted. A belt transect extending 2.5metres either side of the transect will be over swam to quantify the abundance of *A. planci* (COTs).

All transect data were square root transformed to satisfy the distribution and variance assumptions of ANOVA. Data was analysed using the statistical computer packages Community Analysis Package (CAP), SPSS and PRIMER.

2.4 Results

There was no significant difference between the percentage Scleractinian coral cover between the six study sites (Figure 2). The highest coral cover was found at South Bereika, with a mean value of 33.3(±2.4)%. The second highest mean coral cover was found at the upper slope of the Ras Umm Sid site, with a mean cover of 28.6 (±7.4)%. Shark Observatory had a mean value of 27.5 (±2.9)% and the lowest hard coral cover was found at the Marsa Ghozlani site with just 19.7 (±1.1)% cover. The ranges (Max and Min cover) and standard error of the mean can be seen in Table 2.

Table 2. Scleractinian coral cover at the six study sites (n=4)
[U=Upper reef slope; L=Lower reef slope]

Site	Percentage hard coral cover			
	Mean	±s.e.	Min	Max
South Bereika (U)	32.8	3.3	26.0	38.9
South Bereika (L)	33.7	3.9	24.3	42.4
North Bereika (L)	24.1	5.8	15.9	37.3
Shark Observatory (U)	27.0	2.8	22.0	34.9
Shark Observatory (L)	28.0	4.6	24.3	38.5
Marsa Ghozlani (U)	19.7	1.1	17.4	22.4
Marsa Ghozlani (L)	21.8	1.8	17.3	26.3
Old Quay (U)	27.2	3.8	16.3	33.0
Old Quay (L)	21.4	7.5	8.6	43.2
Ras Umm Sid (U)	28.6	7.4	13.8	47.2
Ras Umm Sid (L)	18.4	5.8	8.3	34.7

Although the hard coral cover did not vary significantly between sites, the total live cover did vary significantly ($F_{5,43}=7.43; p<0.001$). As can be seen clearly in Figure 3, the Live cover was significantly higher at the Old Quay (Tukey; p=0.001) when compared with all the other sites, between which there was no significant difference.

The dominant Scleractinian coral Genera included, *Acropora*, *Seriatopora*, *Pocillopora*, *Stylophora*, *Porites* and *Montipora*. There was also significant abundance of the Octocoral *Millepora*. The *Acropora*, *Seriatopora* and *Millepora* genera were dominated by branching growth forms, the *Pocillopora* and *Stylophora* were dominated by Sub-massive growth forms, *Porites* colonies were dominated by massive growth forms and *Montipora* generally occurred in the encrusting form.

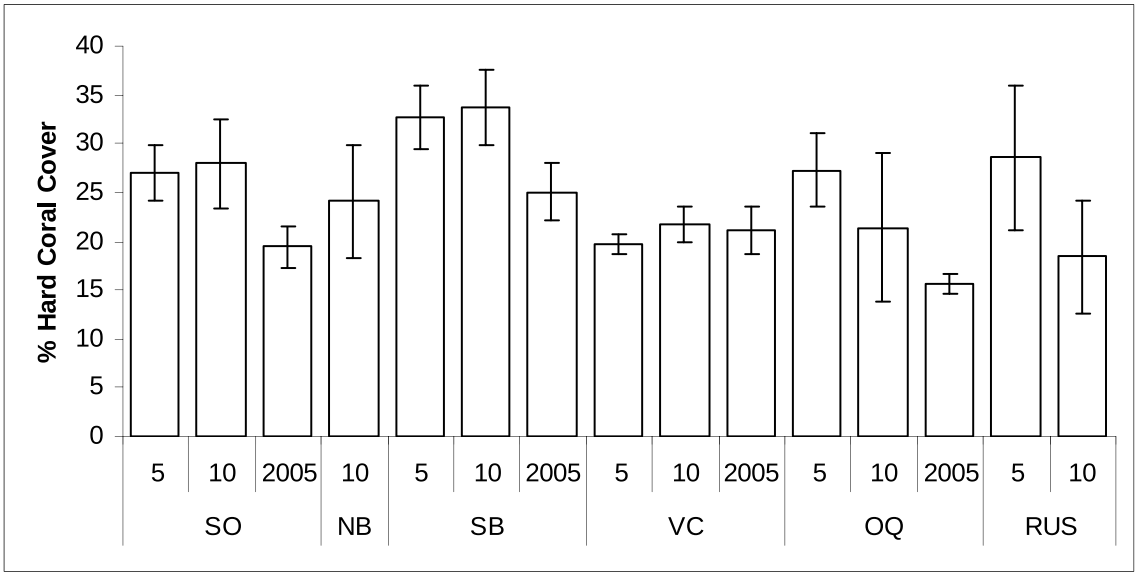

Figure 2. Mean (±s.e., n=8) hard (hermatypic) coral cover on upper[5] and lower[10] reef slopes at the study sites. Mean site values for 2005 are shown for comparison where available

As there was no significant difference between the hard coral cover at the sites, this difference in overall live cover can be attributed to the significantly higher proportion of Soft corals (Alcyonacea) found at the Old Quay site ($F_{5,43}=24.8; p<0.001$). Tukey post hoc tests found no significant difference between the other sites regarding soft coral cover.

This variation in soft coral cover can be seen in Figure 4, along with the proportions of hard corals (Scleractinia) and coral rubble, algae and rocky substratum. The proportion of coral rubble varied very significantly between the four study sites ($F_{5,43}=3.67; p<0.01$) with the highest proportion of rubble, 10.1(±1.3)% found at the South Bereika site (Tukey; $p<0.001$). There was no significant difference in coral rubble cover between the other sites. Although the majority of the algae was recorded at the Marsa Ghozlani site, there was a significant difference in algal cover between the Old Quay and all other sites($F_{5,43}=3.98; p<0.01$), with Old Quay showing less than 0.5% cover.

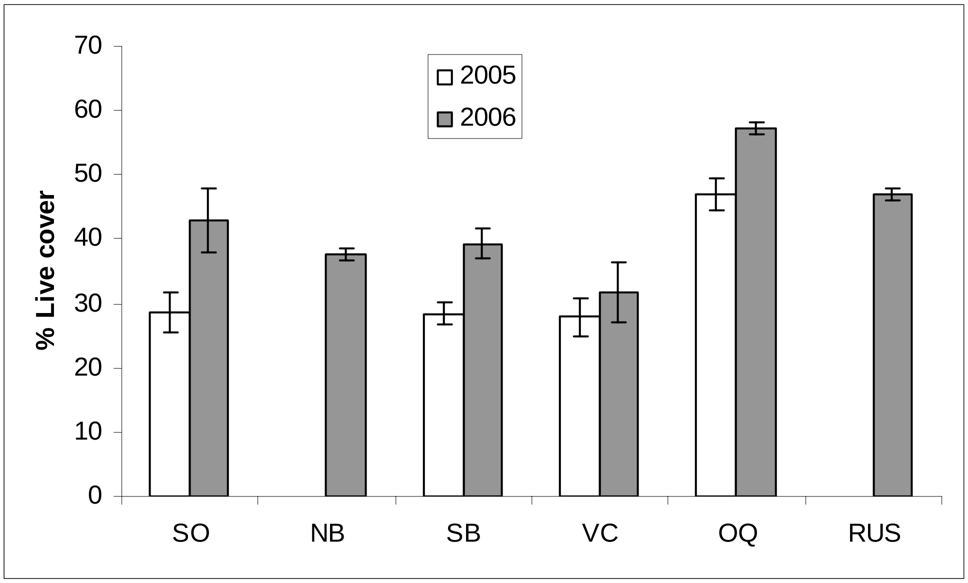

Figure 3. Variation in mean (±s.e.) live benthic cover between sites

All of the sites, with the exception of Old Quay were also shown to be dominated by bare rock substrata, as can be seen in Figure 4.

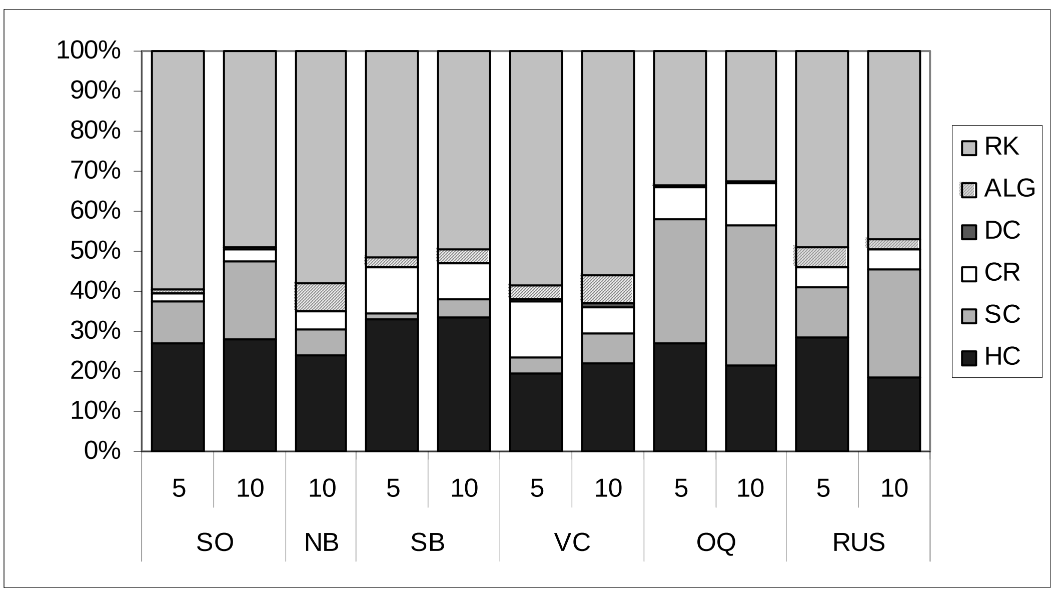

Figure 4. Breakdown of benthic cover by category [RK=Rock;CR=Coral Rubble;ALG=Macroalgae;SC=Soft Coral;HC=Hard Coral;DDC=Dead Coral]

There was a significant difference ($F_{5,43}$=7.45;p<0.001) in the number of hard coral Genera found at the six study sites (Figure 5). South Bereika had the highest number of coral Genera (19), which was significantly higher than the number of Genera recorded at the Shark Observatory(11) site (Tukey p<0.001), as was the number of

Genera found at North Bereika($p<0.001$), whereas there was no significant difference in numbers between the other sites.

There was no significant difference in the Generic richness recorded in this study with that observed during 2005 at any of the sites.

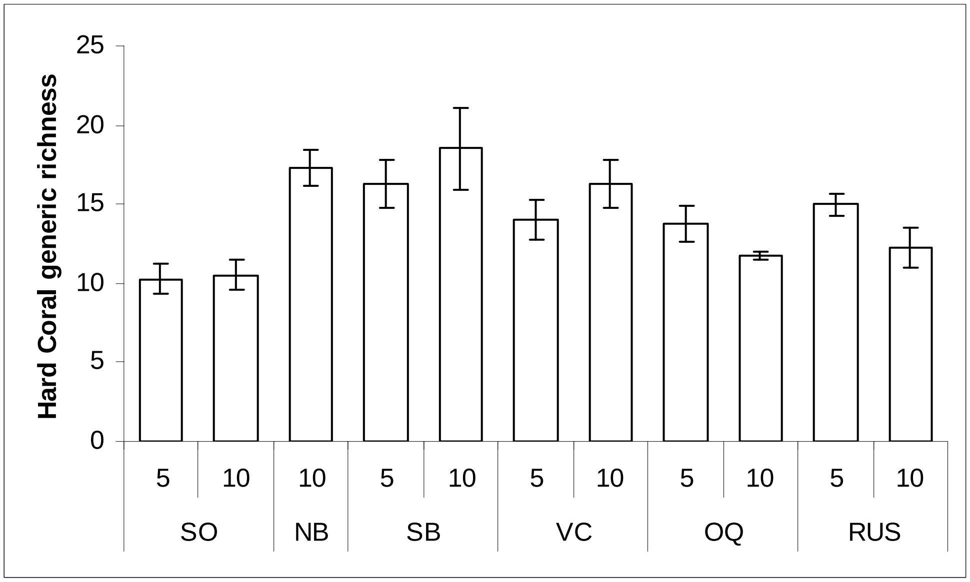

Figure 5. Mean(±s.e.) hard coral Generic richness

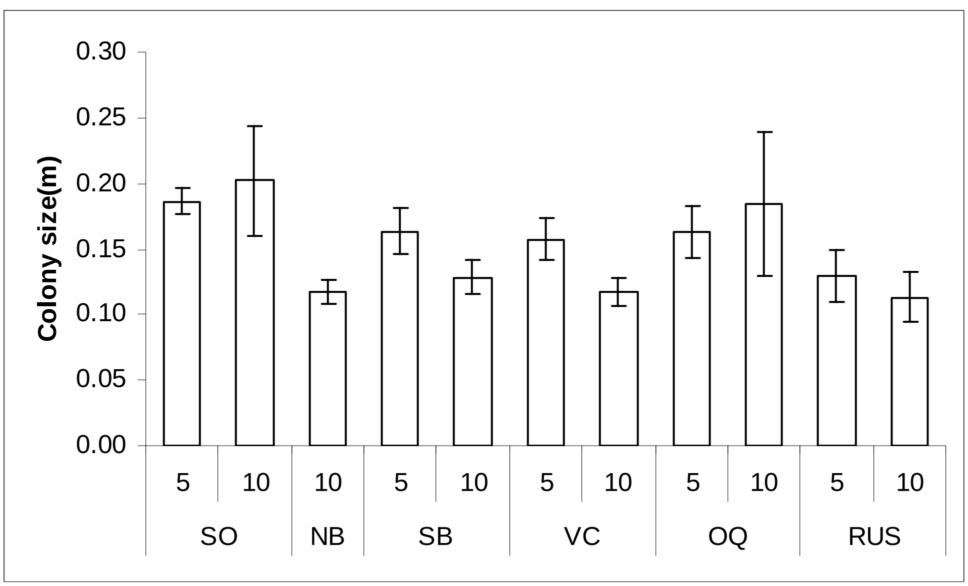

Figure 6. Mean (±s.e.) hard coral colony size

There was a significant difference in the mean size of the hard coral colonies (Figure 6) between all the sites($F_{5,43}=2.71;p<0.05$), with an overall average size of 0.15m (Range 0.12-0.20m).This mean size showed no significant difference to the value recorded in 2005. There was also a very significant difference in the number of coral colonies per transect area between the sites ($F_{5,43}$=3.20;$p<0.05$)(Figure 7). South Bereika site had a higher mean number of coral colonies, (Tukey $p<0.01$) than the Old Quay site, while the Marsa Ghozlani site also showed a significantly higher number of colonies ($p<0.05$), than at Old Quay. Again these values did not differ significantly from those observed during the 2005 preliminary study.

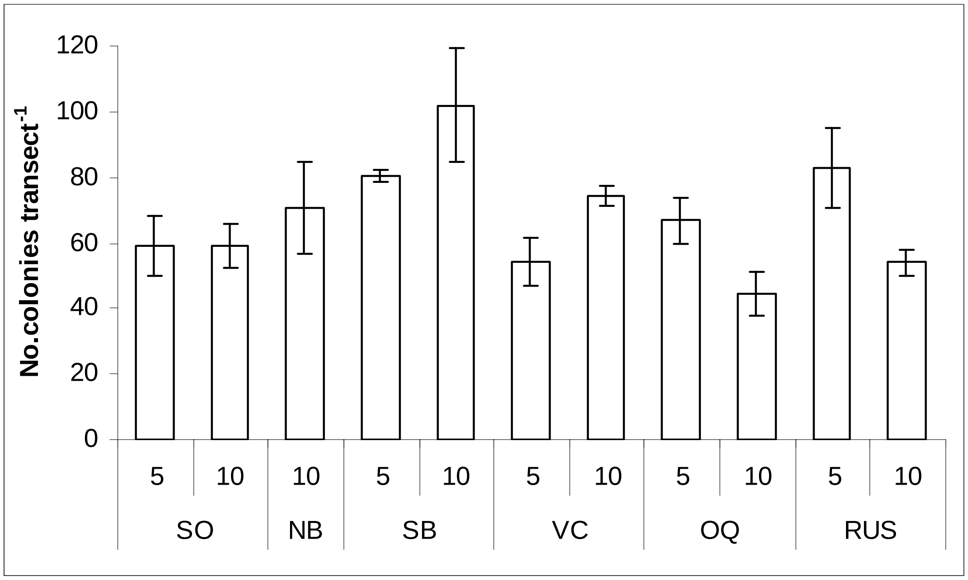

Figure 7. Mean(±s.e.) number of hard coral colonies at each site

The use of randomly placed 1m^2 quadrats identified a mean recruitment rate for Scleractinian corals of 1.21 (±0.13) new recruits per m^2 per year. The number of recruits ranged from 0.8 m^{-2} at the Old Quay site to 1.93m^{-2} at the Marsa Ghozlani site. There was no significant difference in the number of recruits between all the different sites.

2.5 Discussion

The uniformity of coral cover at all sites is somewhat surprising as the sites were selected for their varied factors such as sheltered and exposed, heavily dived and minimally dived. This suggests that some other over-riding factor, such as the COTs outbreak in 1998, has had a more important influence on the benthic communities.

With the lowest mean hard coral cover, the Old Quay site showed almost 50% lower cover than other sites in the southern Gulf of Suez as reported by Perkol-Finkel *et al*., (2005), although the high soft coral cover observed at this site is in line with values for the Gulf of Suez. This study found that the soft coral communities were dominated by the *Xenia* genus, again in line with the findings of Perkol-Finkel *et al*., (2005). However, the level of hard coral cover is some 10% higher than that reported by PERSGA (2005). The South Bereika site also showed the highest levels of coral rubble, which may be attributable to the number of snorkeller boats observed at this site during the course of this study. The number of individual hard coral colonies at Old Quay was lower than the other survey sites, possibly due to the increased levels of spatial competition, with the high soft coral cover preventing recruitment of coral planulae, although no significant difference in levels of recruitment was observed.

The Shark Observatory site had the second lowest hard coral cover of the study sites, and this level is only 50% of that reported by the ReefCheck website (Hodgson, 2005), and is still 30% lower than the reported levels before the 1998 COTs outbreak. It should however be noted that direct comparisons are not suitable due to the different methodology used to collect the ReefCheck data. Levels of soft coral cover are slightly higher than those currently reported by ReefCheck although still only around 55% of the pre-1998 cover. The Generic richness of hard corals was the lowest at this site, which is surprising as it is the most exposed of the four sites as it is at the very southern tip of Ras Mohammed and exposed to the prevalent currents from the south. The lack of richness and cover may be somewhat attributable to the steep ‘walled’ topography of the site. Although the number of divers visiting this site is reported to be among the lowest in the park (<1000 yr^{-1}) by the PERSGA(2005) report, during the period of this study, more divers were again observed at this site than at any other(Ras Umm Sid excepted), in line with the observations from 2005. The topography of this site, with its steep vertical walls, may however, limit impacts from divers who do not swim directly above the substratum.

The coral cover at the Marsa Ghozlani site was slightly lower than that estimated by a 2003 ReefCheck survey, but slightly higher than that identified in the PERSGA report (2005). The soft coral cover identified by this study was only half that reported by ReefCheck, while the amount of coral rubble at the site was constant. This site is one of the most heavily utilised by visitors with some 30000 dives per year (PERSGA,2005). There were five boat moorings at this site which were often all occupied by two or more boats. The majority of visitors were snorkellers, with some shore diving also noted. The number of coach visitors to the beach at this site was likely responsible for the huge amounts of litter both on shore and on the reef, in the form of plastic bags, soiled nappies, and plastic water bottles. Further studies into the nutrient status of the bay are suggested as this was the only site with a significant abundance of turf algal cover. Anthropogenic disturbance may also be behind the fact that this site also had the lowest mean coral colony size, although it did support the second highest number of coral colonies.

The South Bereika site had the highest coral cover of the four sites and the recorded cover agreed with the values in both the PERSGA report (2005) and also the work of Saleh(unpubl.). This site was also found to contain the highest Generic richness of hard corals in this study as well as largest number of colonies per area. This site has been closed since the mid 1980’s and has only recently re-opened to divers, although shore diving is still prohibited. According to the PERSGA records, this site receives over 15000 divers per year. Over the period of this study, all the moorings at this site were often occupied, yet the majority of day boats appear to utilise the site as a lunch time mooring, with some snorkelling, as very little diving was observed.

The total coral Genera found throughout this study comprised just fewer than 50% of the Genera known to occur in the Red Sea region (Veron, 2000), with all of the common genera found, but few of the rarer genera recorded.

As the mean coral colony size is relatively small at all the sites, this seems to suggest that the reefs are starting to recover from the COTs episode and hence many of the colonies are small and likely recruited since the COTs problems.

It is worth noting that there is a general lack of published data for the Ras Mohammed national park, and so the data used for comparison with this study is mainly from the ReefCheck database. It should be noted that due to the methodology used, these ReefCheck data may be subjective and not give a reliable estimation of true reef condition.

There was no significant difference in the mean number of Scleractinian coral recruits to each of the six study sites. This suggests that recruitment is fairly stable throughout the park and although the figures are somewhat lower than other reported studies, the uniformity of the recruitment rates suggests that there is plenty of available substratum and there are no site specific impacts preventing recruitment. Grazing by Scarridae may be keeping recruitment rates lower than would be expected in a region where the fish population was being exploited.

In summary, the benthic communities of the Ras Mohammed national park appear to be continuing to recover from the devastation caused by the COTs outbreak in 1998. Although there was significant coral bleaching in the Red Sea in 1998, this did not affect the Ras Mohammed region. Although large areas of bare substratum exist, these are generally free of turf algae and available for recruitment of other benthic invertebrates. However, the recruitment rate within the park is relatively low when compared to other reported rates of recruitment. The variation, although not statistically significant, can be explained to some extent as the sites with the lowest rates of recruitment, such as Old Quay have high levels of competition and predation. The higher abundance of soft corals is known to inhibit coral recruitment (Maida *et al*.,1995) and the higher number of scraping and grazing Scarids also appears to be inhibiting the success of the new recruits. Whereas at the sites with the highest rates of recruitment, like the Marsa Ghozlani site, both the abundance of soft corals and Scarids are somewhat reduced. Further monitoring over the coming years is vital to monitor this recovery and identify further problems. Increasing the number of survey sites again in 2007 should allow the generation of a regression formula to predict rates of recovery and the effect of varied diver pressures. Continued monitoring should include completely closed areas which can act as a control to monitor the rates of change in benthic cover and relate this to the levels of visitors to the sites.

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CHAPTER 3. FISH DIVERSITY AND ABUNDANCE

3.1 Summary

There was a very significant difference in the total abundance (1000m^{-2}) of fish observed at each of the study sites ($F_{3,22}$=4.80;p=0.01). Total abundance was highest at Old Quay (6278.7±1113.8) and lowest at Marsa Ghozlani (1414.7±249.9), although no significant difference was found between South Bereika and Shark Observatory with all the other sites.

There were significant differences in the number of Chaetodont, Pomacentrid and Acanthurid species found at the different sites, while the other major fish families showed no significant differences.

Cluster analysis suggested that the fish communities at all four sites shared a similarity in composition of around 85%. The fish communities at all of the sites are clearly dominated by three very abundant species, the half-and-half chromis (*Chromis dimidiata*), the Orchid dottyback (*Pseudochromis fridmani*) and the Lyretailed anthias (*Pseudoanthias squamipinnis*).

3.2 Introduction

Any form of reef assessment must include the fish species present as they perform vital roles in the maintenance of diversity on a healthy reef system. Many fish species are important algal grazers and as such help maintain the competition for substratum between benthic organisms, by keeping the faster growing ruderal algae in check (Thacker *et al*., 2001; Sluka & Miller, 2001). Removal or loss of some of this functional redundancy (Bellwood, *et al.*, 2004) can lead to phase shifts and changes in community structure.

Although unlike many reef areas, the Ras Mohammed park is not subject to adverse fishing techniques and/ or over-extraction of resources, it is still vital to monitor the fish assemblages for signs of impact or change. Removal of predators by overfishing is known to deplete both biomass and diversity of other non-target fish species (Jennings & Polunin, 1997).

Again, as with benthic data, many monitoring efforts have been targeted at the park previously, yet the data still remains somewhat lacking. This study aims to estimate the size and diversity of the fish populations on the studied reefs, to identify their trophic structure and functional redundancy as well as gaining estimates of overall abundance and species richness.

3.3 Methods

The following section outlines the procedure for undertaking visual census surveys at the permanent monitoring sites after the AIMS fish monitoring protocol (Halford and Thompson, 1994).

The site is located from the surface using a GPS. Two divers enter the water. The first diver (observer) is equipped with a slate, pencil and data sheets, the second diver (tape layer) carries the tapes. Before reaching the first transect the tape layer runs out 2.5 metres of tape to allow the observer an initial visualization of the desired transect width.

The observer conducts the 50 metre by 5 metre by 5 metre surveys by swimming along the centre line of the transects. The observer counts all fish sighted within the area 2.5 metres either side of and up to five metres above the centre line, recording species and number of individuals.

The tape layer follows the observer approximately five metres behind, laying a tape measure along the centre line of the transect.

Eight of these 50m belt transects were completed at each site, four at each of the two depths on the upper and lower reef slopes. This gave a total survey area of 8000m^2 per site (each belt giving 1000m^2).

Census technique

A visual census aims at recording an instantaneous estimate of abundance for the target species present within the bounds of the transect. Unfortunately this theoretical goal can never be realised due to factors such as the time taken to count and record each individual, and commonly, the inability to scan the entire transect area at any one time. Consequently there is a need to employ a sampling technique which best approximates this ideal. Although it is impossible to census the entire transect in a given instant, it is possible to treat the transect as a series of instantaneous counts, such that each portion of the transect area is only viewed once for any given target species. In practice this is achieved by viewing ahead and counting target species in an area of the transect contained well within the bounds of visibility. During the first scan of the section the most mobile target species should be counted and recorded, with progressively less mobile species recorded in consecutive counts. Fish entering the transect during, or after, that area of transect is sampled are not included as they were not present during the initial count. The total transect survey time is standardized at 25 minutes for the 50 metre belt transect. Once the most mobile species have been counted the observer moves along the centre of the transect searching for the more cryptic and slower moving target species, being careful to include individuals of the most mobile species which were obscured from view by the structure of the reef during the initial count of the area.

Timing of census

In an attempt to reduce variability in fish densities (due to diurnal influences on behaviour) sampling excludes the high activity periods of early morning and late afternoon. Sampling has been limited to between 0900 and 1600. This time window also excludes periods of poor visibility caused by low sun angle.

Sources of Error

No survey method is perfect and underwater visual censuses include several sources of error. Errors can appear form three sources, the observer, fish behaviour and the sampling method. Observers should be comfortable working underwater so that the environment, psychological and physical conditions do not influence data recording. Training and practice runs should also help to minimize error due to over or under-estimating fish class size. The divers presence in the water may lead to errors from fish-diver interactions which should be minimized by descending away from the transects and allowing an adjustment time between arriving at a transect and starting the survey to allow the fish to become accustomed to diver presence. (This may not be a problem at some heavily dived sites). Errors due to fish behaviour are also affected by parameters associated with habitat and activity cycles. Any interpretation of results must take into account that not all species behave or are perceived in the same way. Finally, samples can also be a source of error; samples not taken according to the strict sampling plan will not be representative of the target fish population. Transects should cover homogenous environments, rather than several different environments and transitional areas should be avoided.

3.4 Results

The survey sites showed significant variation in three of the fish survey metrics used but not for the richness of Serranids, Scarrids, Labrids and Pomacanthids. The total number of species recorded at each site also showed no significant difference between sites, which ranged from 93 to 102 species.

With regard to abundance of fishes at the six sites (Figure 8), there was a very significant difference ($F_{5,43}$=3.82;p=0.01) between the Old Quay site (Tukey p<0.05) and the Marsa Ghozlani (Visitor Centre) and North Bereika sites. There was no significant difference in the mean fish abundance between all other sites. The Old Quay site had a mean (±s.e.;n=8) abundance of 3242.9(±501.5), while the lowest abundance was found at the North Bereika site, with 422.0(±11.1). The abundance values varied quite considerably between individual samples with a minimum value of 125 at the Marsa Ghozlani site to a maximum value of 8075 at the Shark Observatory (Table 3).

Table 3. Mean(±s.e.) fish abundance per 1000m^2 with minimum and maximum counts for each study site

	Mean	s.e.	Min	Max
SO (u)	1213.3	198.5	809	1704
SO (l)	3120.8	1750.7	645	8075
NB (l)	422.0	13.6	392	445
SB(u)	1119.3	580.8	421	2850
SB(l)	453.0	119.1	212	740
VC(u)	968.3	244.4	475	1644
VC(l)	380.5	114.3	125	671
OQ(u)	4339.8	348.1	3490	4969
OQ(l)	2146.0	500.6	1191	3557
RUS(u)	2014.0	997.7	680	4963
RUS(l)	1546.5	712.0	745	3674

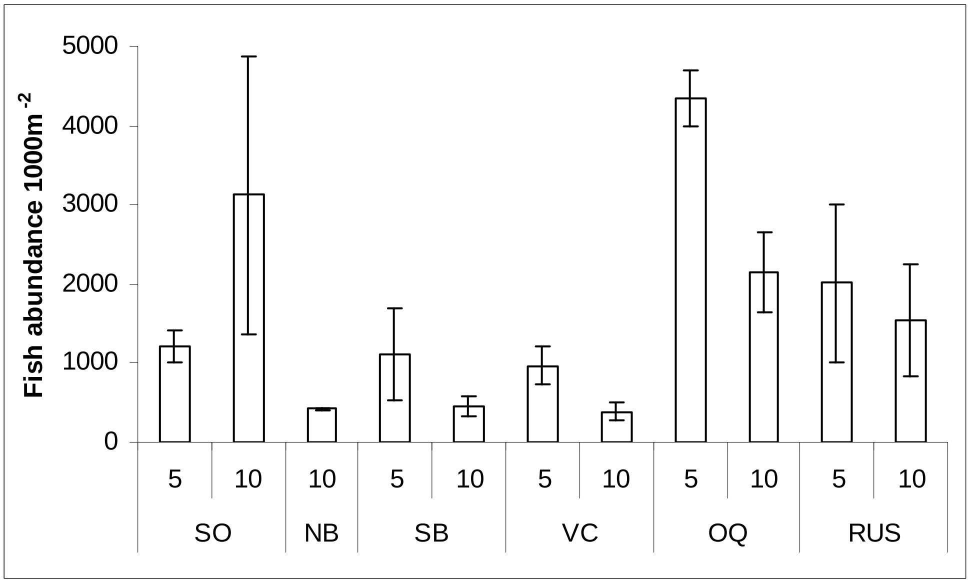

Figure 8. Total mean (± s.e.) fish abundance per 1000m^2 at each study site

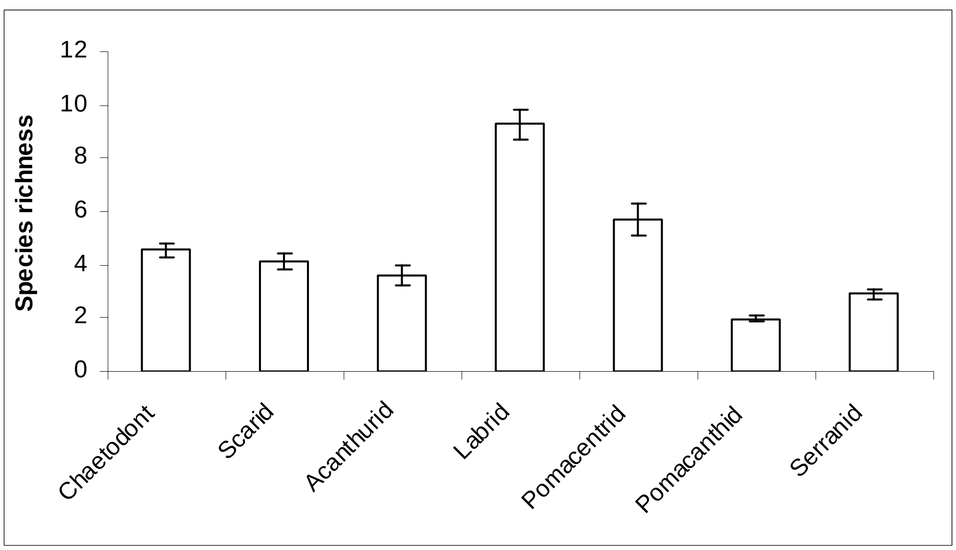

Figure 9. Mean(±s.e.) species richness of the seven main fish Families

Both Principle Component Analysis (Figure 10) and Bray Curtis (Group average) cluster analysis (Figure 11) identified the similarity between all sites, which PCA also identified as similar. The cluster analysis suggested that the fish communities at all four sites shared a similarity in composition of around 85%.

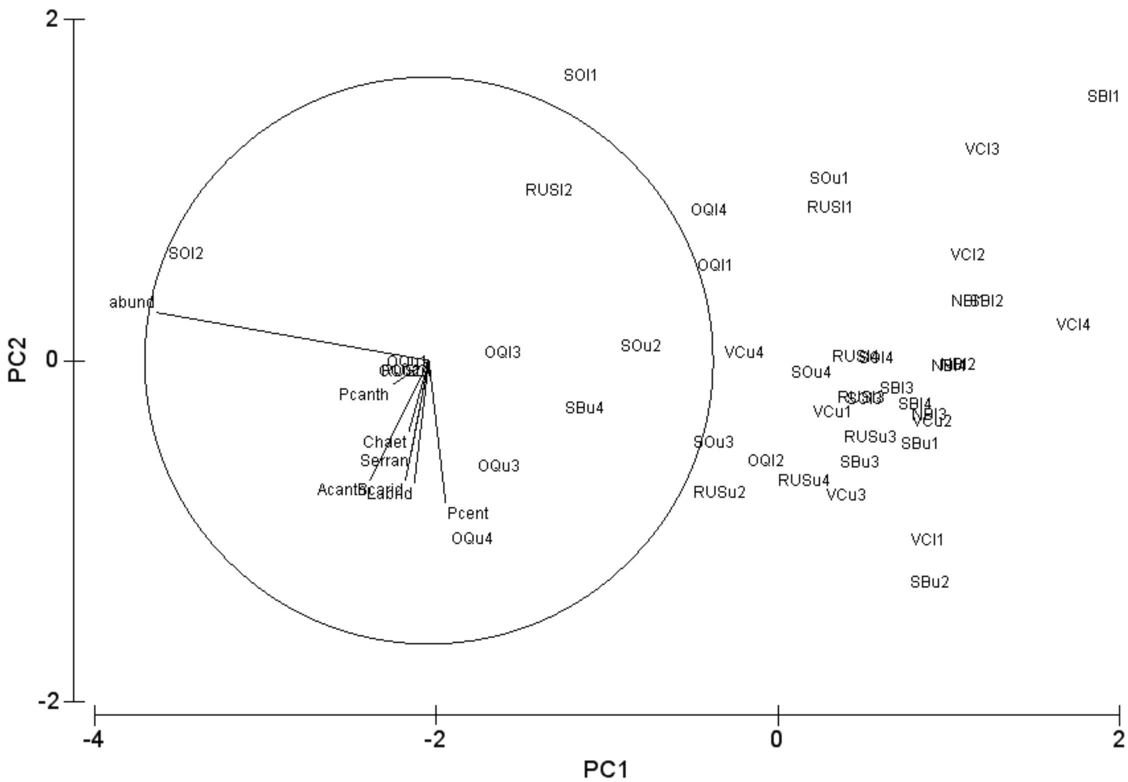

Figure 10. PCA plot of fish community attributes

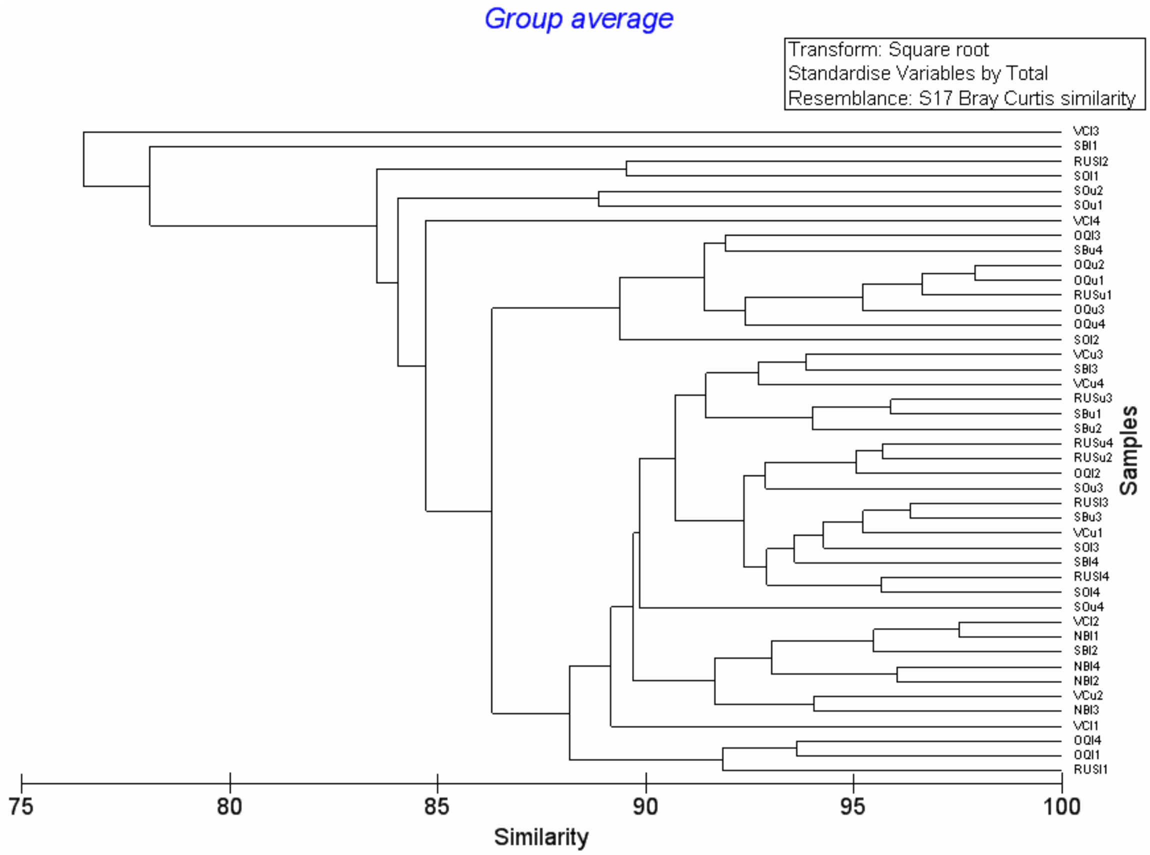

Figure 11. Dendrogram of cluster analysis (Bray-Curtis, group average linkage) of fish assessment metrics

The fish communities at all of the sites are clearly dominated by three very abundant species, the half-and-half chromis (*Chromis dimidiata*), the Orchid dottyback (*Pseudochromis fridmani*) and the Lyretailed anthias (*Pseudoanthias squamipinnis*).

The functional redundancy of the four sites, i.e. the number of different species present within a Family, (Figure 9), shows that there were very limited differences between the different sites in the number of species representing each of the dominant seven Families. The Cheatodontidae showed a significant difference between sites($F_{5,43}$=3.26;$p<0.001$), with both South Bereika and Old Quay having a mean of 5.0(±0.4) species, while the North Bereika site had a mean of just 2.7(±0.2) species per site. The Pomacentridae also showed significant differences in species richness between sites($F_{5,43}$=5.74;$p<0.001$), with a mean 7.5(±1.0) at the South Bereika site and just 3.0(±0.6) at the Shark Observatory site.

3.5 Discussion

The abundance of fish varies surprisingly little between the sites, with only the one significant difference between the Old Quay and Marsa Ghozlani/ North Bereika sites. This may be due to the protection offered by the Ras Mohammed park. Fishing is prohibited in all areas of the park and has been for some period of time. It appears that the ban is generally observed and that there are only minor infringements. This lack of fishing pressure means that natural competitive interactions are occurring and hence most of the fish communities are similar in abundance and composition, with local variations attributable to natural variations possibly linked to localised reef conditions and habitat variation.

For the Marsa Bereika (South) and Ras Umm Sid sites, the abundance compares favourably with the findings of Leujak (2005), although due to the use of slightly different methods, the data are not directly comparable.

Unfortunately no abundance data was available in the literature regarding the Shark Observatory, Marsa Ghozlani, North Bereika and Old Quay sites.

It is interesting to note the variation in the individual samples (transects), as the fish surveys were carried out at a similar time of day to avoid any diurnal variation. The greatest variation was recorded at the Shark Observatory site, attributable to the varied strength of the currents at this very exposed site. When the current was running at this site it was often moderate to strong and hence larger numbers of pelagic species were recorded, such as Jacks and Trevally. At the Old Quay site the local conditions varied considerably with the state of the tide. Large volumes of sediment can be seen flowing from the reef flat onto the reef at low tides reducing visibility and again the abundance of the pelagic fish species. The lowest variation was found at the North Bereika site which had the most stable, sheltered conditions, but the lowest overall abundance of fishes.

The number of reef fish species observed during this study relates to around 10% of the reported total 1000 species present in the Red Sea. Again this value compares favourably with the findings of Leujak (2005), with this study identifying species richness as almost double that of the other study, though again the two methods used mean that the data are not statistically comparable.

Those sites with high abundance tended to have lower diversity as they were dominated by vast numbers of several common planktivorous species, such as the Anthiases (*Pseudoanthias squamipinnis*), which were found in great numbers at the Shark Observatory site. The two low abundance sites did not appear to be dominated by a few species and hence showed greater diversity. It is also worth noting that the cluster analysis also confirms that all of the sites have similar fish communities, when regarding abundance and diversity.

With regard to the functional redundancy of the fish populations at the study sites, there were very limited differences between sites, with similar numbers of species from each family present. The exceptions being the increased Chaetodont species richness at the Old Quay and South Bereika sites and lower richness of Pomacentrids at the Shark Observatory site. The latter may be explained by the topography at the Shark Observatory site, where the steep wall may not provide a suitable habitat for some species, along with increased predation from the large numbers of pelagic predators that congregate there. Similarly, the steep wall at this site is often in deep shade in the afternoons and hence algal production is likely to be reduced, as shown in the lack of algal cover at this site, removing the primary food source for many of the Pomacentrids. Many Pomacentrids also show close associations with branching Scleractinian colonies, which were limited in number at this site, possibly helping to explain their reduced abundance there.

The only available data for temporal comparison is that provided by the ReefCheck database for the Chaetodont, Serranid and Scarrid families. The species richness and hence functional redundancy of the Chaetodontidae (Butterflyfish) has shown a steady decline at the Shark Observatory site from the mid-1990's to the present survey, with the current richness less than a third of the recorded levels before the 1998 COTs outbreak, in line with the report of Wilkinson, (2002). The removal of coral substrata by the COTs, would have impacted the obligate corallivorous species, which are known to migrate to seek food elsewhere (Crosby & Reese, 1996), leaving the non-corallivores behind, giving a lower species richness. The numbers of Chaetodonts has also declined from pre-1998 levels at the Marsa Ghozlani and South Bereika sites. No comparable data was available for neither Old Quay, Ras Umm Sid nor North Bereika.

On a more positive note, the species richness of Serranids (Grouper) seems to be increasing at both the Marsa Ghozlani and Shark Observatory sites, when compared to ReefCheck data from previous years (Hodgson, 2005). Scarrid (Parrotfish) richness also appears to be increasing at the same two sites when compared to ReefCheck data, and are clearly above pre-1998 levels. This may be explained by the removal of coral substrata by the COTs outbreak, leaving more calcareous substrata and algae, suitable for the Scarrid diet, which supports a greater diversity of Scarrid species.

In summary, all of the sites in this study have similar fish populations, although the exposed Shark Observatory, Ras Umm Sid and Old Quay sites are characterised by low species diversity but high abundance, while the sheltered Marsa Ghozlani, North and South Bereika sites show low abundance but high diversity.

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CHAPTER 4. CONSERVATION VALUE INDEX CLASSIFICATIONS

4.1 Summary

The classification of the surveyed sites within the park using the CVI developed at the CRRU, showed that the Old Quay upper slope site was rated highest with index scores of 49 and 35 for benthic and fishery health respectively, giving a CVI score of B2. The South Bereika site scored 47 and 33 for benthic and fishery respectively giving an overall CVI value of C2. The Marsa Ghozlani site scored C3 overall, with a benthic score of 45 and a fishery value of 23. The Ras Umm Sid site scored 46 and 33 for benthic and fish respectively, rating it as C2. The North Bereika site showed a benthic score of 49 with a low fish score of just 13, ranking the site B4. The lowest scoring site was the Shark Observatory, with a benthic score of 44 and a fishery value of 20, giving a CVI rating of C3.

These classifications will allow the dissemination of complex biological survey results to any level of audience, as well as allowing the setting and monitoring of management actions.

Although these scores have been established for these sites, it should be noted that the CVI index is still undergoing extensive trials and may be subject to future adjustment. However, the retention of all the individual metric scores will allow the recalculating of previous CVI values from these extensive datasets.

4.2 Introduction

Due to the importance of coral reefs to local communities and the increasing level of natural and anthropogenic impacts upon them, accurate monitoring and assessment of reef condition is necessary to allow the management and sustainable use of these resources. Most coral reefs around the world are over-exploited and damaged by over-extraction, pollution, excess sediment and inappropriate development. Their loss will destroy the social fabric of many coastal communities and ruin the massive tourism industry that supports many of the developing tropical countries (Wilkinson, 2004). Many coral reef countries lack the resources of trained personnel, equipment and finances to effectively conserve coral reefs, establish MPA's and enforce existing regulation.

With the aforementioned limited resources of many tropical nations, coupled with the increasing rates of over-exploitation and degradation, finding an effective and methodical way to prioritise areas for conservation efforts is critical (McKenna and Allen, 2000). Although coral reef monitoring programs around the world generate important volumes of data and information on various coral reef parameters, standardized and easily accessible data from these programs is often lacking (Noordeloos *et al*., 2004). The relevant measurement endpoint for biological monitoring is biological condition; detecting change in that endpoint, comparing the change with a minimally impacted baseline, identify the causes of change and communicate all of this to policy makers and stakeholders, these are the combined tasks of biological monitoring programs (Karr and Chu, 1999). That living corals themselves are highly productive and account for the net positive production of a coral reef (Yap *et al*., 1994), as well as being the actual reef building organisms, means that they are of vital importance to reefs and should be central to any form of assessment of coral reef health. However, coral reef ecosystems are highly diverse and complex environments and cannot be adequately quantified according to Scleractinian coral cover alone, the method that is currently most prominent. As reported by Ben-Tzvi *et al*., (2004) and Ablan *et al*., (2004), and is also apparent from the proliferation of different indicator methods available, there are no well-accepted reliable means of indication for a 'healthy reef' and none of the commonly used parameters is accepted as an indication that reliably represents reef community health. McClanahan *et al*., (2002) identified the great need to monitor coral reef resources and develop a scientific infrastructure and a conceptual platform for the interpretation of the collected data. Eakin *et al*., (1997) had also previously identified a particular need for the ability to quickly and accurately assess the health of ecosystems and the level of threat that they face, and called for further research to develop criteria and cost-effective procedures for the assessment of coral reef health.

To provide stakeholders with the information necessary for successful management of the fisheries and reefs within an area, as well is to increase social capital (Pretty, 2003), it is necessary to have a method of reef assessment that can be understood by the local community, many of whom are poorly educated. According to Karr and Chu (1999) policy makers, citizens and scientists faced with making decisions about complex systems need multiple levels of information. Ablan *et al*., (2004) identified the similarity between biological metrics and economic metrics used in economic analysis (e.g. FTSE100, retail price index).

Therefore, there is the need for a simple non-specialist means of transferring information about reef and fisheries quality to the stakeholders. This also allows an easily understandable overview to be given to policymakers and funding agencies.

Several studies have identified problems with classifying habitats by the use of a single factor index (Loya, 1972; Pielou, 1972; Hughes 1978). The development of a single readily understood multivariate/ multimetric index would be of greater use than the reporting of numerous or single factor indices (Extence *et al.*, 1987). The work of Karr and Chu (1999) identified that multimetric biological indexes calculated from ambient biological monitoring data provide a similar integrative approach for measuring condition and diagnosing causes in complex ecological systems. The resulting multimetric approach to biological monitoring is dependent upon the selection of suitable metrics that reflect diverse responses of biological systems to human activities.

Before building a multimetric index, you must convert each metric into a common scoring base. Typically metrics are quantified with different units and have different absolute numerical values. Some metrics will increase in response to disturbance whereas some will decline. To resolve this, each metric is assigned a score based on expectations for that metric at a minimally impacted site for that region, either from direct survey or from historic literature. The metrics that are not significantly different to the regional control are awarded the top score with those sites that do differ, receiving progressively lower scores dependent on the scale of difference from the controls. The final multimetric index is a sum of all these scores.

Jameson *et al*., (1998) provided a complete review of biological criteria for coral reef ecosystem assessment, but also noted that the high level of natural variation on such systems means that multiple species assemblages must be monitored. The study noted that such multimetric assessment will also aid management as well as giving a snapshot of reef condition. This form of bio-assessment will allow the identification of causative factors, if not from the multimetric score, and then from the individual metric scores which are also retained. Jameson *et al*., (1999) went on to identify that if we are to go beyond traditional non-diagnostic monitoring techniques, then we need to explore new coral reef attributes and develop dose-response curves for them across a gradient of human influence, and formulate these metrics into an index. The same report noted that well constructed indices from other ecosystems typically examine two or more assemblages because different groups of organisms respond differently to different impacts (e.g. benthic lifeforms and fish). Therefore, the more diverse the measures used, the more robust the index and hence more confidence can be placed in the results. In their continuing review of coral reef attributes, Jameson *et al*., (2001) identified the need for the development of a coral reef classification system as well as selection and sampling of representative minimally disturbed sites to define regional expectations. They also noted the advantage of measuring biological condition with a continuous yardstick such as a multimetric index which puts a site along a continuum of condition in comparison with other sites (or times), allowing thresholds to be adjusted as necessary. This also permits the ranking of many sites, which would simply be labelled as degraded by traditional assessments, so that priorities may be set for budget-constrained protection and restoration efforts. This same study of Jameson *et al.*, (2001) noted that the wide-ranging responsiveness of multimetric biological indexes makes them ideal tools for assessing the effectiveness of management decisions. They point out that if the individual metrics are correctly calibrated, it is possible to compare sites across different class of reef and also to use the index as an effective early warning system, although they note that to diagnose the exact stressor(s) requires focus on the individual metrics. Noordeloos *et al*., (2004) also remind us that the key objective of status reporting is to provide managers, policymakers and other stakeholders with a reliable but simple indication of whether the reefs within their own area are in good condition, whether they are at risk from threats that may alter reef condition and whether effective management actions are in place to deal with the threats.

There are wealth of studies that call for the development of such management tools if we are to successfully protect coral reefs (Wilkinson and Chou, 1997; Bryant *et al*., 1998; Edinger and Risk, 2000; Ahmed *et al*., 2004).

4.3 Methods

Once the data sets were complete, the tested metrics were combined into an index of biotic integrity (Jameson *et al.*, 1998), consisting of two parts, a benthic index containing 13 coral reef benthic variables and a fishery index consisting of 17 metrics. The benthic index is converted into five categories and scored from A-E, while the fisheries index is divided into five categories labelled 1-5, giving a two part index (e.g. a top quality site would score A1). The site with the highest perceived quality from the multivariate site rankings was made the regional control, as a site of expected condition for a minimally impacted site within the National Park. All other sites were then scored in comparison to the regional control. The various metrics were standardized to allow the comparison of surveyed sites with expectations for the regional control. If the sites were not significantly different from the control, they were awarded a top score of five points for that metric. The possible scores were divided up into quartiles for the range and scored on a declining scale as three, one or zero depending on the difference from the control. The overall index score is a sum of all the possible metric scores.

4.4 Results

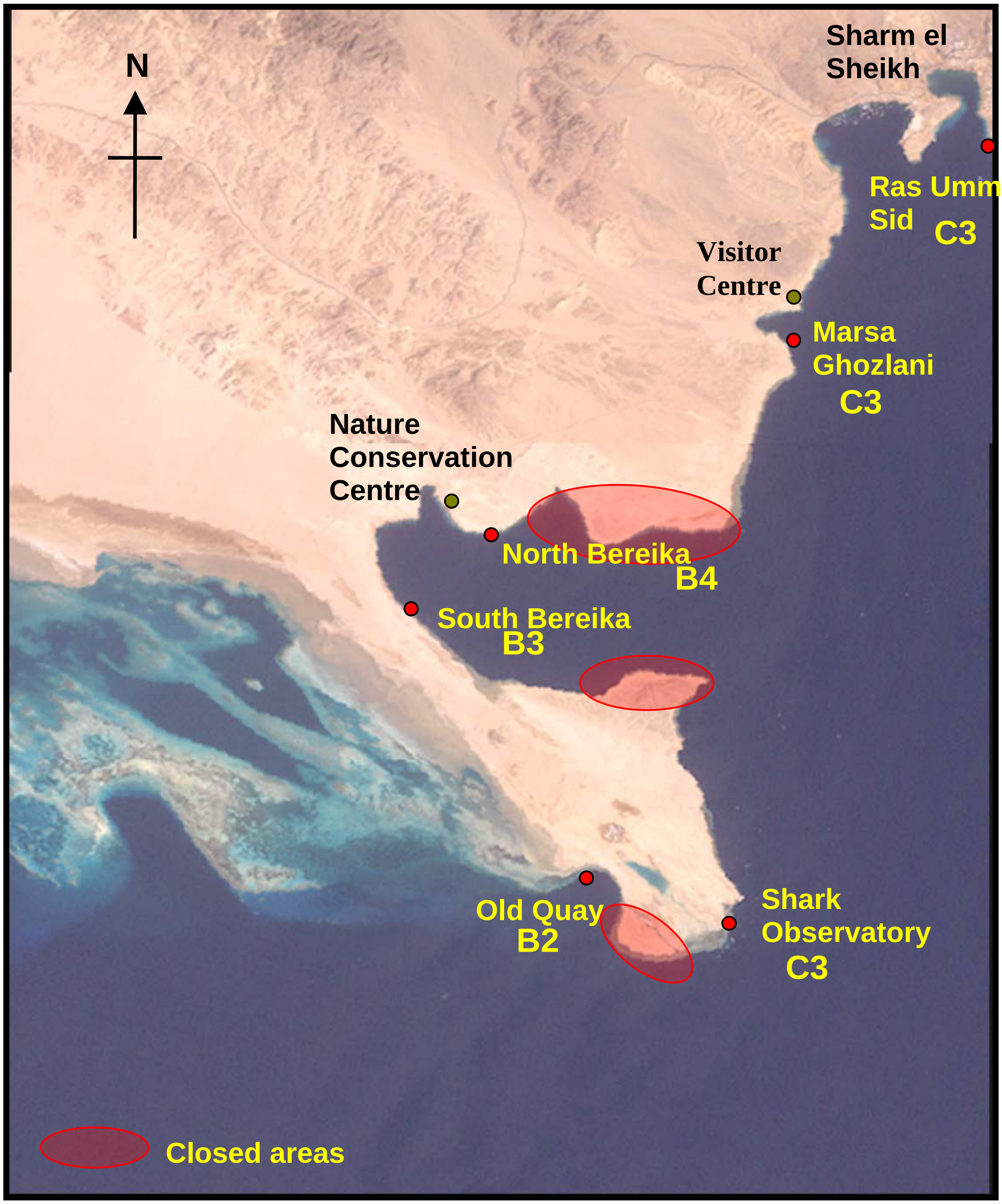

Figure 12. Satellite image of Ras Mohammed National Park with overlaid CVI values for the study sites
(Source: Landsat millennium coral reef archive)

Table 4: CVI benthic and fish values with final CVI codes

Site	CVI Benthic score	CVI Fishery score	CVI code
Shark Observatory (u)	48	48	**C3**
Shark Observatory (l)	48	40	**C3**
North Bereika (l)	51	26	**B4**
South Bereika (u)	51	66	**B2**
South Bereika (l)	53	26	**B4**
Marsa Ghozlani (u)	49	46	**B3**
Marsa Ghozlani (l)	46	22	**C4**
Old Quay (u)	53	70	**B2**
Old Quay (l)	52	48	**B3**
Ras Umm Sid	48	66	**C2**
Ras Umm Sid	46	32	**C4**

The CVI scores for the six sites are displayed in Table 4 and can also be seen in Figure 12, where they are overlaid on a satellite image as an example of the output from the CVI GIS database.

For the benthic component of the index, the South Bereika and Old Quay sites scored the highest with a score of 53 out of a maximum of 80 points. The second highest benthic score was found at the North Bereika site at 51. Shark Observatory and Ras Umm Sid showed the lowest benthic score at 33. The Marsa Ghozlani (Visitor Centre) site had a score of 49. This meant that North and South Bereika and Old Quay was classified as a ‘B’ ranked site, while the other three sites were all ranked as ‘C’.

For the fishery component of the index, the Old Quay site scored highest with 70 (out of 90), closely followed by the South Bereika and Ras Umm Sid sites at 66. The Shark Observatory site scored 48, while the Marsa Ghozlani site scored 46. The North Bereika site rated at just 26, giving a CVI ranking of ‘4’. The upper slope sites at Ras Umm Sid, Old Quay and South Bereika all scored highly at a rank of ‘2’. The lower slopes at these sites as well as all other sites scored ‘3’ and four of the sites scored the lowest with a ranking of ‘4’.

4.5 Discussion

Although the CVI index does rank the sites in a logical order that also ties in with the traditional reporting methods in previous sections,(i.e.Total live cover etc.), it should be noted that this is still a preliminary version of the CVI and as such is liable to future adjustment as the index is still under development. Although the retention of the individual metric scores in the CVI database will allow the recalculating of previous years CVI scores should the need arise. It may be necessary to remove some of the individual metrics from the index if further testing reveals that they are not responsive to change, (or are too responsive).

The expansion of these baseline CVI values to more sites this year will allow the monitoring for temporal change, while also giving an early warning about changes in community composition. The CVI output can be adjusted for any level of audience from community stakeholders, to scientists and government.

As well as monitoring the common reef metrics, the inclusion of the fish community trophic structure metrics, will allow the monitoring of functional redundancy (Bellwood *et al*., 2004), a factor vital for the early detection of changes in community structure, increasingly linked to phase shifts.

By establishing the monitoring program over a far wider range of sites throughout the park, managers can have an overview of trends in reef condition as well as the 'snapshot' that a single survey provides.

The outputs of the CVI can be used to monitor management actions and their effectiveness, for example the usefulness of closing areas to the public can be assessed by monitoring changes in the CVI score over the course of the management action. If the scores improve the action can be judged successful, whereas if there is no change or a decline in values, then alternative management strategies may be necessary. The inclusion of such a wide range of metrics can reassure managers that the reef community is responding to action, where the monitoring of a single factor such as hard coral cover may not.

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CHAPTER 5. THREATS TO THE REEF ENVIRONMENT IN RAS MOHAMMED

5.0 Summary

Due to its prohibition, fishing does not seem to be a significant problem in the Ras Mohammed park. Neither observations of coral disease nor incidence of coral bleaching were made at any of the study sites. Again this year, no COTs were recorded at any of the study sites, (although the occasional solitary individual was observed at the Marsa Ghozlani site). With regard to the abundance of the corallivorous Gastropod *Drupella* spp., none were observed at the Old Quay and Shark Observatory sites, while they were found to be present in less than 1% of coral colonies at the other four sites. They were generally observed on *Acropora* spp. colonies.

It was observed that there were a number of broken live coral fragments on the study reefs, these varied significantly between sites ($F_{5,43}=3.36; p<0.05$) with the highest volume of loose fragments found at the Old Quay site (3.10(±0.51)) and the fewest found at the un-dived North Bereika site (1.05(±0.13)).

The number of damaged colonies (still attached) also varied significantly between sites($F_{5,43}=3.30; p<0.05$) with the highest number at the Shark Observatory site (0.68(±0.13)) and the fewest damaged colonies were recorded at the Old Quay site (0.05(±0.03)).

5.1 Introduction

The threats to the Ras Mohammed National Park environment fall into two categories, natural and anthropogenic.

Natural threats include predation on the important reef building corals by Crown of Thorns Starfish (*Acanthaster planci*) and corallivorous gastropods such as *Drupella* spp. and *Coralliophilla* spp.. Both of these organisms are natural components of any reef system and usually occur in small numbers where they feed directly on hard coral tissues. However, outbreaks or population explosions of both of these coral predators are known to occur and have both been recorded over recent years in and around the Ras Mohammed National Park.

Feeding aggregations of *Drupella* spp. have caused considerable coral damage on reefs across the Indo-West Pacific. They usually aggregate in small clusters of less than ten individuals, but have been recorded in densities from around 200 to over several thousand individuals. These gastropods have adapted radula for stripping the live coral tissue from the skeleton, leaving behind characteristic white feeding scars that are quickly colonised by turf algae (Cumming,1999). The populations tend to exhibit stable periods punctuated by rapid population increases, often associated with changes in ecological structure. The outbreaks tend to occur in areas with high coral cover (McClanahan,1994).

The Ras Mohammed park has recently (1998-2002) suffered a catastrophic outbreak of the COTs (Saleh, unpubl.), with thousands of individuals being removed from the reefs of the park. Again, the COTs is a predator of the reef building Scleractinia and such outbreaks can lead to a collapse in spatial heterogeneity, resulting in very slow recovery of the impacted reefs, although recovery can take around twelve years if the structural integrity of the reef remains intact (Hart & Klumpp, 1996). The State of the reefs (Wilkinson, 2004), reported that coral cover was reduced from 37% to 13% during the recent outbreak at some sites in the Gulf of Aqaba. The loss of the hard coral cover often leads to shifts in community structure to an algal dominated system. This in turn can affect the community structure of fish populations with changes in the abundance of various roving herbivores, such as the Surgeonfishes (Acanthuridae) and Parrotfishes (Scaridae)[Hart *et al*., 1996]. Johnson *et al*., (1995) found that loss of coral cover (from COTs outbreak) lead to a reduction in Carbon flow through the reef system, with the volume recycled reduced and that turning to detritus increasing. This in turn had an impact on the trophic level of many secondary consumers as well as reducing the efficiency of all trophic categories.

Other natural threats to the regions coral reefs include coral bleaching and coral disease. Coral bleaching is the loss of symbiotic zooxanthellae due to a number of different stresses, the most commonly reported being elevated SST. The incidence of coral diseases is believed to be increasing worldwide, yet little data exist for the entire Indo-Pacific region. It has been suggested (Green & Bruckner, 2000) that the increasing incidence of disease may be linked to declines in marine environmental health generally due to anthropogenic influences.

Major anthropogenic threats include the continued development of the tourism industry with direct physical impacts on the reefs caused by the visiting divers and snorkellers. Tourism activity in and around the Ras Mohammed park is intense with Kotb *et al*., (2004) reporting over 75000 divers per year at some sites. The State of the reefs report (Kotb *et al*., 2004) also reports major indirect anthropogenic threats from tourism in the form of land fills, dredging and sedimentation, sewage discharge and effluent from desalination plants all associated with continued coastal development.

Anthropogenic impacts on coral reefs can be assumed to be cumulative with natural impacts, and hence practically there would appear to be little qualitative difference between anthropogenic and natural stress on coral reefs and both these sources of stress are important in controlling reef community structure (Grigg & Dollar, 1990).

5.2 Methods

The survey methods were the same as for the general benthic survey, utilising three 40m long LIT at each depth at each site (eight replications per site). All colonies recorded by the benthic transect were observed and all those showing signs of disease, bleaching or predation by COTs or Gastropod (e.g. *Drupella* spp.) were noted. This allowed the calculation of proportions of infected/affected colonies. COTs abundance used the same transects but extended a belt 5m either side of the transect to produce a belt area of half a square kilometre.

Five 1m^2 quadrats were placed randomly along the transects and the number of broken loose coral fragments were recorded along with the number of damaged colonies still attached to the substratum.

5.3 Results

No observations of *A. planci* were made on any of the survey transects, only one individual was seen over the course of this study at the Marsa Ghozlani site. The individual was a mature specimen at over 50cm diameter. There were several small patches of dead coral in the immediate vicinity.

The corallivorous gastropod *Drupella* spp. was present on several coral colonies at the Marsa Ghozlani and South Bereika sites. At South Bereika they were found to be present in small aggregations (<10) on 1% of colonies intersecting the line transects, while at Marsa Ghozlani they occurred , again in small aggregations on 0.6% of colonies. All observations were made on *Acropora* spp. corals.

No incidence of coral bleaching were observed either on the transects or in the park in general during the period of this study. Only one incidence of coral disease was observed in the park , which appeared to be a form of 'red-band' disease at the Marsa Ghozlani site. This same disease has also been observed at several Operation Wallacea study sites in Indonesia. Further molecular studies would be helpful in categorising this disease and its vectors.

The volume of litter left behind by tourist visitors from boats and on shore, should be of concern, especially at the Marsa Ghozlani site which receives well in excess of 30000 visitors per year. Although litter bins are provided, there was often large numbers of disposed plastic water bottles on the shoreline and floating in the sea. A wide range of litter was encountered upon the reefs at this site. Litter left around the shelters at the site ranged from disposable nappies to sacks of waste from entire coach parties.

Visitors were also observed collecting corals from the reef flat at this site, but returned them, under protest with the intervention of one of the park rangers.

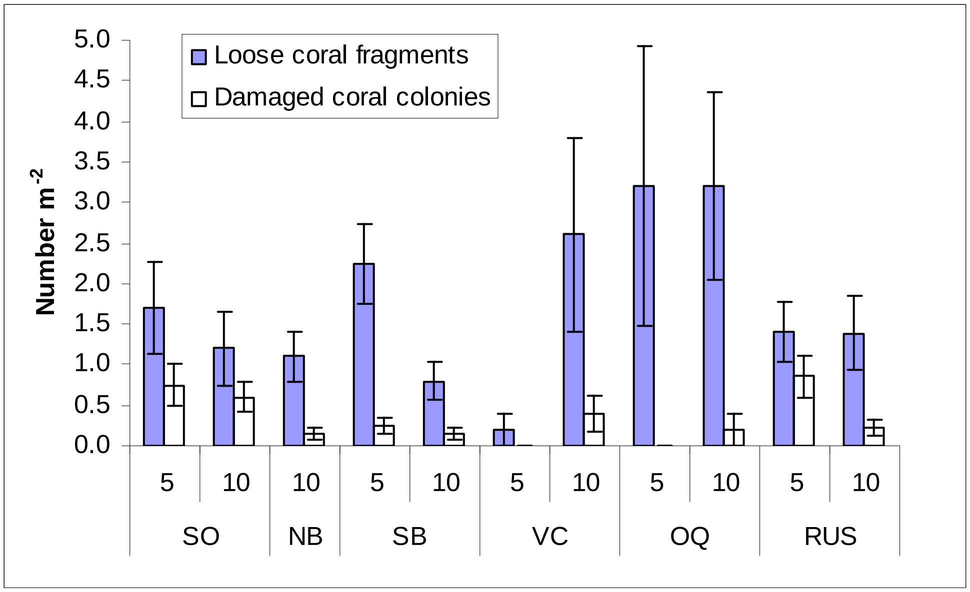

Figure 13. Incidence of physical damage to hard corals

There were a mean number of 1.7(±0.2) broken coral fragments observed per metre squared throughout the park (Figure 13). There was a significant difference in the number of broken fragments at each site($F_{5,43}$=3.36;$p<0.05$). The highest occurrence of broken fragments was at the Old Quay site (3.1(±0.5)), where branching *Millepora* dominates the substratum. The lowest incidence occurred at the undived North Bereika site (1.1(±0.1)).

There was also a significant difference in the number of broken or damaged coral colonies at the sic sites ($F_{5,43}$=3.30;$p<0.05$). Fewest damaged colonies were observed at the Old Quay site (0.05(±0.03)), while the most damage was observed at the Shark Observatory site (0.68(±0.13)). The average number of damaged colonies throughout the park was 0.35(±0.06) per metre squared.

5.4 Discussion

The survey results suggest that COTs (*A.planci*) are no longer a significant problem on the reefs of the Ras Mohammed park, with no quantitative values for their abundance. The sighting of the odd single individual suggests that the reefs within the park are now back to their normal, non-outbreak state. Although the reefs are appearing to recover from the devastation the 1998-2002 outbreak caused, future monitoring is vital to allow immediate action to be taken, should numbers begin to rise significantly once more. This future monitoring is essential if the reefs of the park are to survive as studies suggest that if the outbreaks start occurring more regularly than every 15 years, then the reefs will continue to decline and there will not be enough time between outbreaks for then reef communities to recover (Hart & Klumpp, 1996).

Again, as with the COTs, the population of the corallivorous Gastropod *Drupella* spp. seems to be in a natural state with just a few individuals aggregating on certain corals especially of the *Acropora* genus. Again, their presence in such small densities is no cause for concern and a natural part of the reef communities. The population needs ongoing monitoring as large increases in their abundance could have a considerable effect on the coral communities of the park, especially in tandem with other impacts.

Thankfully, no signs of coral bleaching or disease were recorded in any of the surveys, and only a single incidence of disease was observed while diving within the park in general. As both bleaching and diseases have previously been identified within the park, it is again, essential to continue to monitor for either impact.

As the impacts of SCUBA divers and snorkellers are one of the greatest threats to the health of the parks benthic communities, it makes sense to include their effects in any monitoring program. The number of broken coral fragment throughout the park seems somewhat higher than would be expected naturally and it seems logical to attribute this to anthropogenic damage caused by divers and snorkellers. The high number of broken colonies at Shark Observatory may be due to the high number of visitors this site receives, the fact that more fragments aren't also found here can be attributed to the wall style topography meaning fragments sink into the depths and are not recorded as they are at some of the sites with sloping topographies. In future this can be compared to data from areas closed to the public to confirm that it is the visitors causing the damage and not some other factor. Establishment of monitoring in closed areas will also provide data to monitor the rates of recovery of the reefs from the COTs outbreak. This is needed as there does seem to be a relationship between the rates of increase in coral cover since the outbreak and the number of visitors to each site. Although the correlation was not significant for this study, the expansion of the surveys to more sites in future years may give a more realistic picture of the true effect of the tourist visitors.

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APPENDIX I

MEAN VALUES FOR RAS MOHAMMED NATIONAL PARK ATTRIBUTES

ATTRIBUTE	2005 mean	±s.e.	2006 mean	±s.e.
Hard Coral cover	20.6	1.6	25.7	1.5
Soft Coral cover	12.3	6.1	14.4	3.5
Coral Rubble	8.4	2.7	7.2	1.1
Total Live Cover	33.8	4.9	40.2	3.3
Dead Coral	0.3	0.2	0.3	0.1
Macro Algae	0.9	0.8	3.0	0.8
Mean Colony Size(m)	0.15	0.01	0.15	0.01
Number of Colonies	66.8	7.7	68.0	4.9
Bleached Colonies	0.0	0.0	0.2	0.1
Diseased Colonies	0.0	0.0	0.0	0.0
COTs abundance	0.0	0.0	0.0	0.0
Drupella abundance	0.3	0.2	0.5	0.2
Loose Fragments	ND	ND	1.9	0.4
Broken Colonies	ND	ND	0.3	0.1
Generic Coral Richness	11.9	1.0	14.2	0.8
Coral recruits (m^{-2})	ND	ND	1.2	0.1
Chaetodont richness	4.7	0.3	4.6	0.3
Scarid richness	3.1	0.1	4.2	0.3
Acanthurid richness	2.6	0.9	3.6	0.4
Labrid richness	6.7	0.8	9.3	0.6
Pomacentrid richness	5.3	0.6	5.7	0.6
Pomacanthid richness	2.0	0.2	2.0	0.1
Serranid richness	2.9	0.3	2.9	0.2
Total fish abundance	990.4	239.6	1611.2	372.5

ND = NO DATA