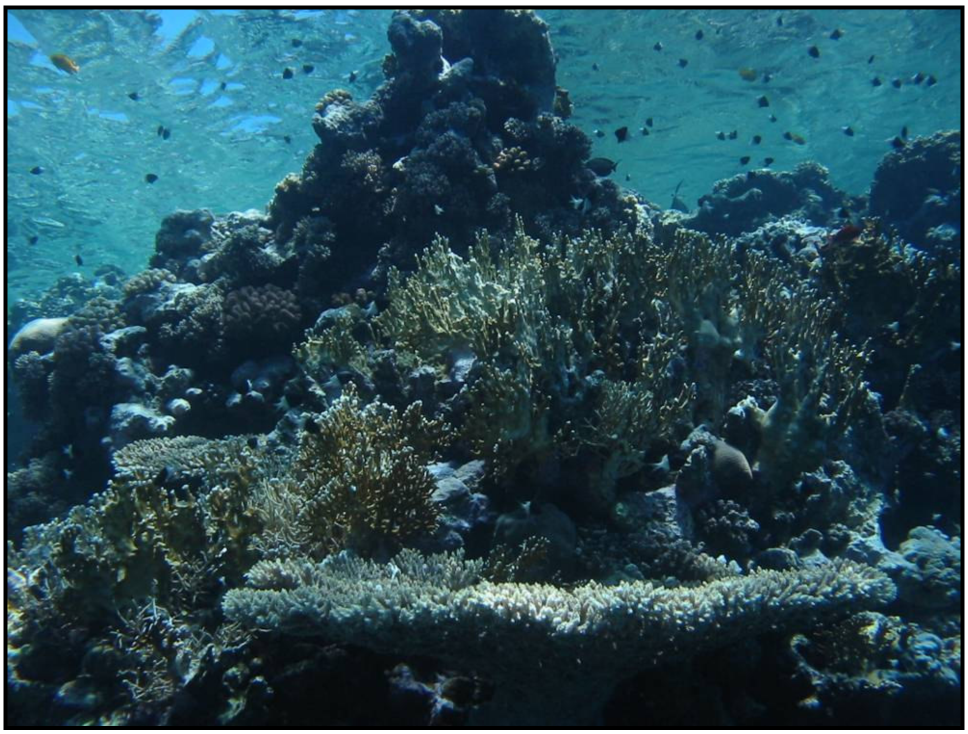
Monitoring Program report

Ras Mohammed National Park

2005



A joint publication by;

University of Essex

OPERATION WALLACEA

Baseline Conservation Value Index assessment of Ras Mohammed National Park

July- September 2005

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Acknowledgements

This study was carried out in the Ras Mohammed National Park, South Sinai, Egypt from July through September 2005 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 input of Essam Saadalla of the EEAA was much appreciated. Thanks to Osama al-Gpely for assistance in access to areas of the park and for the use of facilities at the EEAA research centre in Ras Mohammed. Special thanks to the EEAA park rangers whom assisted with logistics, especially Ahmed Yacout and Mohammed Salla. Many thanks to Sabah and Salim for attentive safety boat cover for all diving activities.

Operation Wallacea provided staff and diving equipment as well as funding the entire project effort. The input of the Operations Manager, (Mr) Ben Farrar was also essential to the success of this project. 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 volunteers who worked with us on the project and made the expedition atmosphere so positive.

Cover photo: Reef Crest at Yolanda Beach (S.M^c^Mellor)

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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

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 establishment of a 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 McMellor (CRRU) and was supported by Operation Wallacea volunteers and EEAA park rangers.

All study sites were surveyed using belt and LIT methodologies, with three replicate 50m transects carried out at each of three depths, (reef crest and 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. All data were recorded into the CVI database and an electronic copy is to follow in 2006.

The study sites included in this preliminary study were limited by logistical limitations to; South Bereika, Shark Observatory, Marsa Ghozlani and Old Quay.

i. Coral diversity and Cover

The percentage cover of live corals (Scleractinia) did not vary significantly between the four study sites. Old Quay showed the lowest hard coral cover at 17.64(±2.00)%, with the highest cover found at South Bereika at 25.02(±2.93)%. Total live benthic cover showed a very highly significant difference ($F_{3,25}=9.73; p<0.001$) with the Old Quay site having the highest cover recorded at almost 50%. No difference was found between the other three 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, with South Bereika having significantly more genera than Shark Observatory (Tukey $p=0.001$), with no significant difference between the other sites. No significant difference in mean hard coral colony size was found between any of the sites, which all had a mean size of 14-16cm. There was however a significant difference between sites when considering the number of individual colonies ($F_{3,25}=5.73; p<0.01$). 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. 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 ($F_{3,25}$=9.92;p<0.001). Rubble cover was lowest at the Shark Observatory site and highest at the heavily visited Old Quay site, which had significantly more rubble than all the other sites (Tukey p=0.001). The Old Quay site seems to show a slight improvement in hard coral cover since the end of the COTs outbreak, increasing from a mean value of 8.7% (after Saleh, unpubl.) to a current mean value of 17.6%. It also appears that the huge area of suitable substrata resulting from the COTs outbreak has been colonised by soft corals, which now dominate the reef.

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

The recovery of the hard coral communities shows a negative association to the number of divers visiting each site with the heaviest dived sites showing the smallest recovery rates.

It is envisaged that future surveys will include the use of quadrats to record rates of coral growth and recruitment.

ii. Fish diversity and abundance

There was a very significant difference in the total abundance of fish observed at each of the study sites ($F_{3,22}$=4.80;p=0.01). Total mean (±s.e.) abundance of fish 1000m^{-2} 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. The total number of different species observed did not vary significantly between the four sites with 96 species observed at the Shark Observatory, 102 at the Old Quay site, 100 at Marsa Ghozlani and 93 at South Bereika. The three diversity measures calculated all showed significant differences between the study sites. With regard to Shannon-Weiner index of diversity ($F_{3,22}$=13.24;p<0.001), both South Bereika and Marsa Ghozlani had significantly higher fish diversity than Shark Observatory (p<0.05) and Old Quay(p<0.001). For Simpsons measure of diversity, again the South Bereika (p<0.001) and Marsa Ghozlani (p<0.001) sites had higher values, but

Shark Observatory was also significantly different ($p<0.05$) to the Old Quay site. It is worth noting that all the measures of diversity used follow the same pattern and rate the sites the same way. A definitive negative correlation was also found between the abundance and diversity of the fish population ($r_p=0.63;p=0.001$). Two sites (Old Quay and Shark Observatory) had high abundance, but relatively low diversity, whereas the other two sites (Marsa Ghozlani and South Bereika) were characterised by lower abundance, but higher diversity.

Both Principle Component Analysis and Bray Curtis (Group average) cluster analysis identified the similarity between the South Bereika and Marsa Ghozlani sites as well as the difference of these sites to the other two, which PCA also identified as different from one another. However, the cluster analysis suggested that the fish communities at all four sites shared a similarity in composition of around 87%. 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*).

iii. Conservation Value Index Classifications

The classification of the surveyed sites within the park using the CVI developed at the CRRU, showed that the Old Quay site was rated highest with index scores of 44 and 62 for benthic and fishery health respectively, giving a CVI score of B2. The South Bereika site scored 35 and 63 for benthic and fishery respectively giving an overall CVI value of C2. The Marsa Ghozlani site also scored C2 overall, with a benthic score of 39 and a fishery value of 55. The lowest scoring site was the Shark Observatory, with a benthic score of 33 and a fishery value of 47, 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 within the CVI database will allow the recalculating of previous CVI values from these extensive datasets.

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 0.58% and 1.01% of coral colonies at Marsa Ghozlani and South Bereika sites respectively. They were generally observed on *Acropora* spp. colonies.

As it was regularly observed that there were a number of broken live coral fragments on the study reefs, in future studies the volume of physical damage from divers and snorkellers will be included from quadrat data.

v. Conservation SWOT analysis

Strengths and Opportunities;

The Ras Mohammed Park is already well established in the area and there appears to be a general agreement of compliance from the local dive tourism industry.

The Multi-zoned management which is in place should prove a suitable framework for the long-term management and recovery of the park, particularly after the COTS problems of previous years. Use of 'Closed' areas as control sites will allow the study of rates of reef recovery as well as acting as a benchmark to identify levels of damage caused by visitors to the park.

The majority of the visitors to the park do not seem to object to the fee for park entry and there may be the possibility to increase this fee as it has not varied since its introduction in the 1990's. This would provide increased funding for the EEAA park rangers to invest in vehicles and patrol craft so long as the extra monies could be retained by the park authorities.

If successful over the next year or two, there is the potential to expand the monitoring program to all dive sites within the park, with involvement of the park rangers and possibly also representatives from the local dive tourism industry.

Weaknesses and Threats;

The immediate weakness of any park management is a lack of enforcement of existing regulation due to lack of resources.

The main threat to the Ras Mohammed reefs is quite clearly the number of divers/ snorkellers visiting them. Several studies have estimated the carrying capacity of Red Sea reefs in this area, with the most prominent suggesting a carrying capacity of around six to eight thousand dives per year (Hawkins & Roberts, 1997). Even the sites receiving the lowest numbers of visitors exceed this by almost 100%, while the heavily dived sites exceed the recommended levels by over ten times.

Large amounts of litter were regularly observed at popular shore sites such as Marsa Ghozlani, even though litter bins are provided.

Due to previous problems it makes sense to monitor the COTs population within the park. It would also be prudent to monitor the *Drupella* population as observed during this study.

Evidence of illegal fishing was observed at all sites in the form of nets and monofilament lines tangled around the reef benthos.

vi. Conclusion

All the reefs surveyed in this preliminary study showed similar cover of hard corals and also similar amounts of total live cover, although the abundance of soft corals at the Old Quay site means a higher total cover was observed here. 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.

It may be valuable to note that the greatest increases in coral cover since the COTs event are found at the sites with the lowest number of visitors, while the slower recovery rates (and some loss) can be observed at the most heavily dived sites.

The relationship between fish community diversity and overall fish abundance is also interesting. Higher diversity at the sites with lower overall abundance may also be linked to the number of visitors at each site, as the most heavily dived sites have lower abundance, but high diversity, while the least dived sites have higher abundance, but lower diversity. This also fits with the theory of competitive exclusion, where the presence and abundance of certain species actively excludes the presence of other weaker, competitors. It seems that the increased disturbance from divers may help to maintain a more diverse fish community, although this needs to be monitored carefully for early indications of phase shifts in the fish community, by the loss of one or two important species.

No immediate natural threats were observed during the period of this 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.

It is envisaged that future surveys will consist of teams of six divers trained in underwater working and identification of common organisms, working from a safari boat that will allow access to a much greater range of sites throughout the park. The use of quadrats placed at intervals along each transect will allow the monitoring of physical damage to corals by divers and snorkellers, and will also allow the monitoring of coral growth rates and recruitment of planulae larvae in the form of new coral recruits.

This preliminary data will be entered into a CVI database so that change can be monitored annually (or bi-annually), a copy of which will be provided upon completion.

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 volunteers 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.

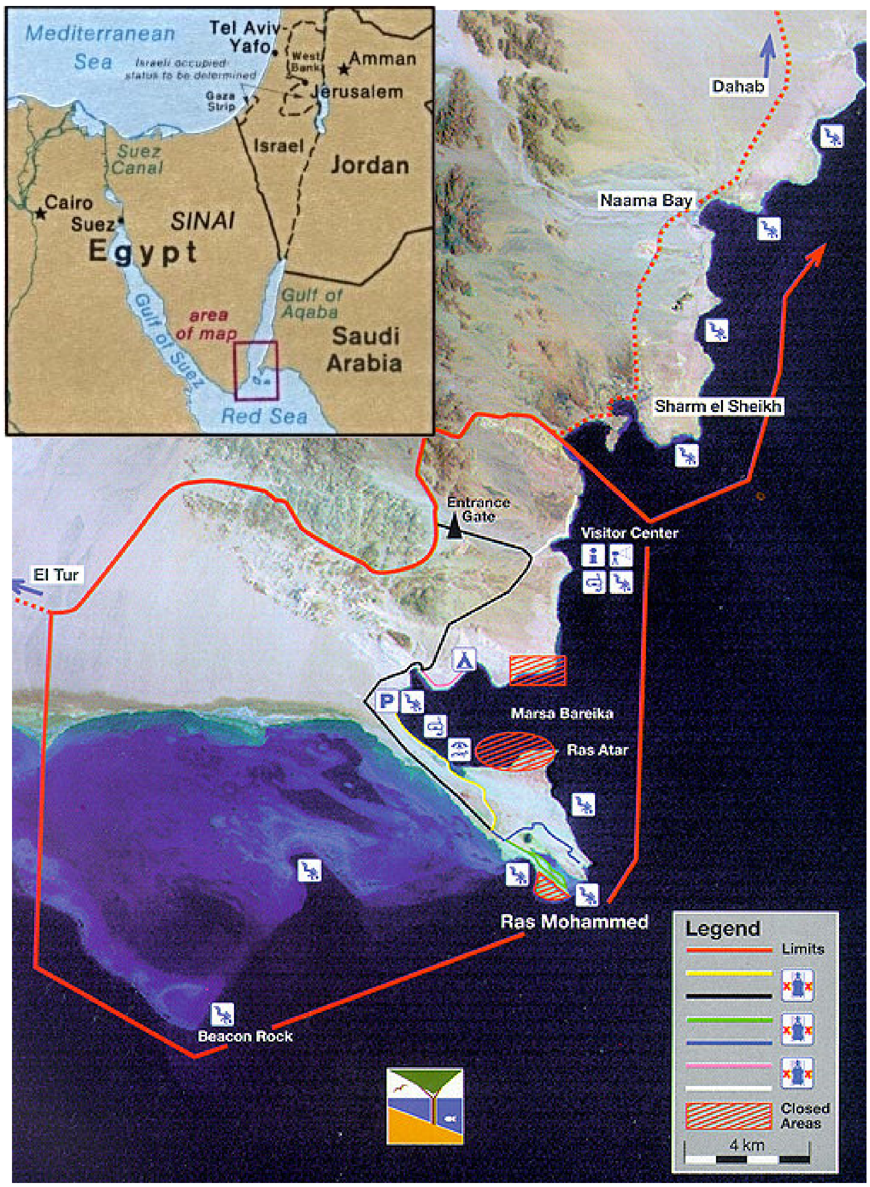

Figure 1. Map of the Ras Mohammed National Park (Source:EEAA)

1.3 Description of sites surveyed

Logistical limitations meant that the preliminary study in 2005 was restricted to four study sites;

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.

1.4 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 four study sites. Old Quay showed the lowest hard coral cover at 17.64(±2.00)%, with the highest cover found at South Bereika at 25.02(±2.93)%. Total live benthic cover showed a very highly significant difference ($F_{3,25}=9.73;p<0.001$) with the Old Quay site having the highest cover recorded at almost 50%. No difference was found between the other three 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 ($F_{3,25}=5.73;p<0.01$). 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. Significant differences were also found in the abundance of coral rubble between the sites ($F_{3,25}=9.92;p<0.001$). Rubble cover was lowest at the Shark Observatory site and highest at the heavily visited Old Quay site, which had significantly more rubble than all the other sites (Tukey p=0.001). The Old Quay site seems to show a slight improvement in hard coral cover since the end of the COTs outbreak, increasing from a mean value of 8.7% (after Saleh, unpubl.) to a current mean value of 17.6%. It also appears that the huge area of suitable substrata resulting from the COTs outbreak has been colonised by soft corals, which now dominate the reef.

The recovery of the hard coral communities shows a negative association to the number of divers visiting each site with the heaviest dived sites showing the smallest recovery rates. The dominant Scleractinian coral Genera included, *Acropora*, *Seriatopora*, *Pocillopora*, *Stylophora*, *Porites* and *Montipora*. There was also significant abundance of the Octocoral *Millepora*.

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 defined by a preliminary study, at three depths on the reef crest (2-6m), the upper reef slope (9-12m) and on the lower reef slope (14-18m). 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). Three 50 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
CCA	Crustose Coralline Algae
OTH	Other

The growth form of corals and sponges was recorded as one of according to the categories shown in Table 2.

Table 2. Hard coral growth form categories and abbreviations

Abbreviation	Coral growth Form
MAS	Massive
BR	Branching
TAB	Tabulate or Plate
SUB	Sub-massive
FOL	Foliose
ENC	Encrusting
MSH	Mushroom

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 tape and five metres above the substratum will be over swam to quantify the abundance of *A. planci* (COTs).

All transect data were log X+1 transformed to satisfy the distribution and variance assumptions of ANOVA. Data was analysed using the statistical computer packages SPSS and PRIMER.

2.4 Results

There was no significant difference between the percentage Scleractinian coral cover between the four study sites (Figure 2). The highest coral cover was found at South Bereika, with a mean value of 25.02 (±2.93)% HCC. The second highest mean coral cover was found at Marsa Ghozlani site, with a mean cover of 21.02 (±2.43)% HCC. Shark Observatory had a mean value of 19.40 (±2.06)% and the lowest hard coral cover was found at the Old Quay site with just 15.66 (±1.04)% cover. The ranges (Max and Min cover) and standard error of the mean can be seen in Table 3.

Table 3. Scleractinian coral cover at he four study sites (n=9)

Site	Percentage hard coral cover			
	Mean	±s.e.	Min	Max
South Bereika	25.02	2.93	14.98	37.62
Shark Observatory	19.40	2.06	12.14	29.10
Marsa Ghozlani	21.02	2.43	10.64	33.26
Old Quay	15.66	1.04	12.08	20.00

Although the hard coral cover did not vary significantly between sites, the total live cover did vary significantly ($F_{3,25}$=9.73;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.

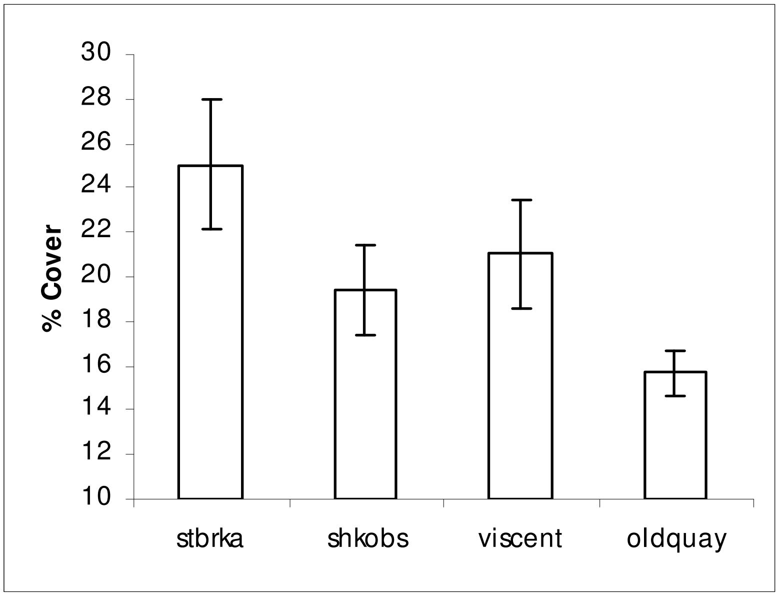

Figure 2. Mean (±s.e., n=9) hard (hermatypic) coral cover at the four study sites

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 ($F_{2,25}=45.87; p<0.001$). 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 sandy areas. The proportion of coral rubble varied very highly significantly between the four study sites ($F_{3,25}=9.92; p<0.001$) with the highest proportion of rubble, 16.27% found at the Old Quay site (Tukey; $p<0.001$). There was no significant difference in coral rubble cover between the other sites, with rubble cover values of 7.01% (Marsa Ghozlani), 4.82% (Shark Observatory) and 5.44% (South Bereika). Although the majority of the algae was recorded at the Marsa Ghozlani site, there was no significant difference in algal cover between all the sites.

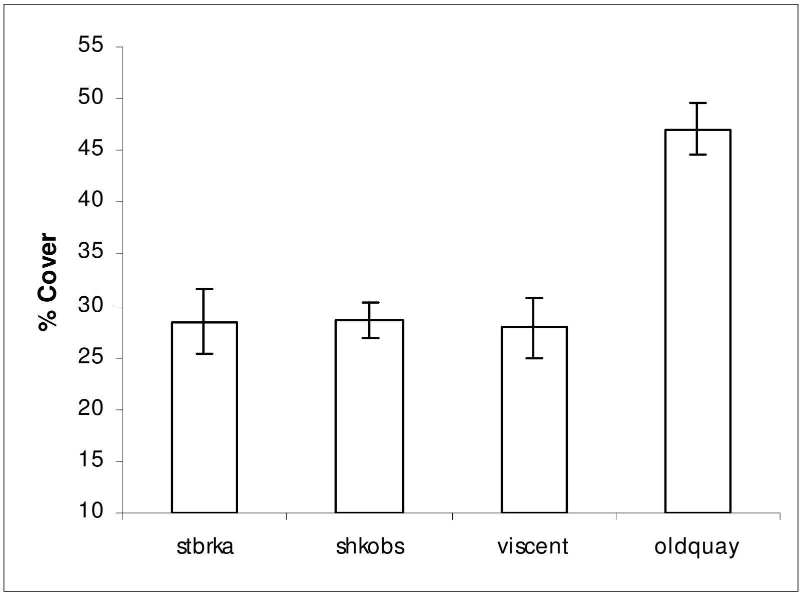

Figure 3. Variation in mean (±s.e.) live benthic cover between sites

The mean algal cover ranged from 3.34% at the Marsa Ghozlani site to negligible (<1%) at all the other sites. The proportion of sandy areas varied very significantly ($F_{3,25}$=19.98;p<0.001) with the highest sand cover found at the South Bereika site (Tukey p<0.001), followed by Marsa Ghozlani site (p<0.05), while there was no significant difference between the other sites. Three of the four sites were also shown to be dominated by bare rock substrata, as can be seen in Figure 4.

There was a very highly significant difference in the ratio of live to non-live cover between the four sites, which all showed negative(<1.00) ratios indicating the sites are dominated by abiotic cover. These ratios ranged from 0.17(±0.05) at South Bereika to 0.97(±0.09) at the Old Quay, with the other two sites at 0.41(±0.03) and 0.42(±0.05) at Shark Observatory and Marsa Ghozlani respectively.

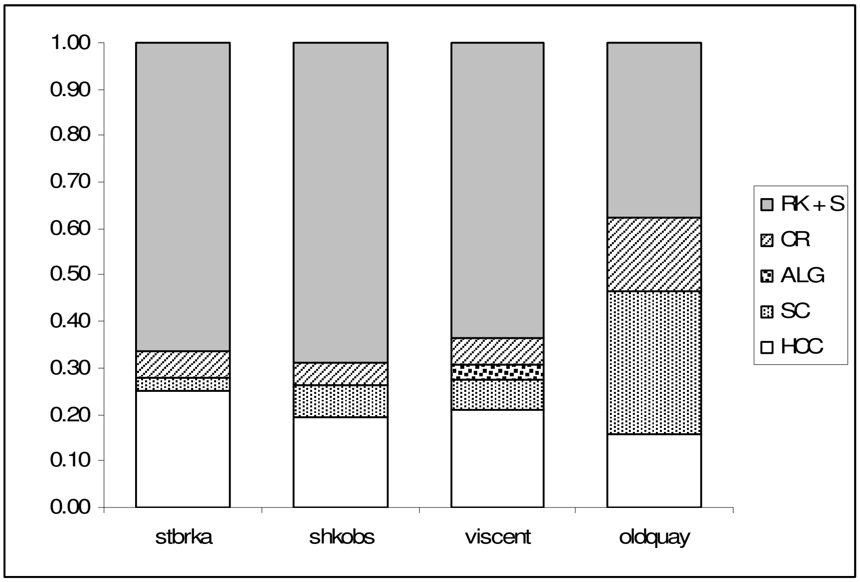

Figure 4. Breakdown of benthic cover by category [RK=Rock; S=Sand;CR=Coral Rubble;Alg=Macroalgae;SC=Soft Coral;HCC=Hard Coral Cover]

There was a significant difference ($F_{3,25}$=6.65;P<0.01) in the number of hard coral Genera found at the four study sites (Figure 5). South Bereika had the highest number of coral Genera (14), which was significantly higher than the number of Genera recorded at the Shark Observatory(10) site (Tukey p<0.001), whereas there was no significant difference in numbers between the other sites.

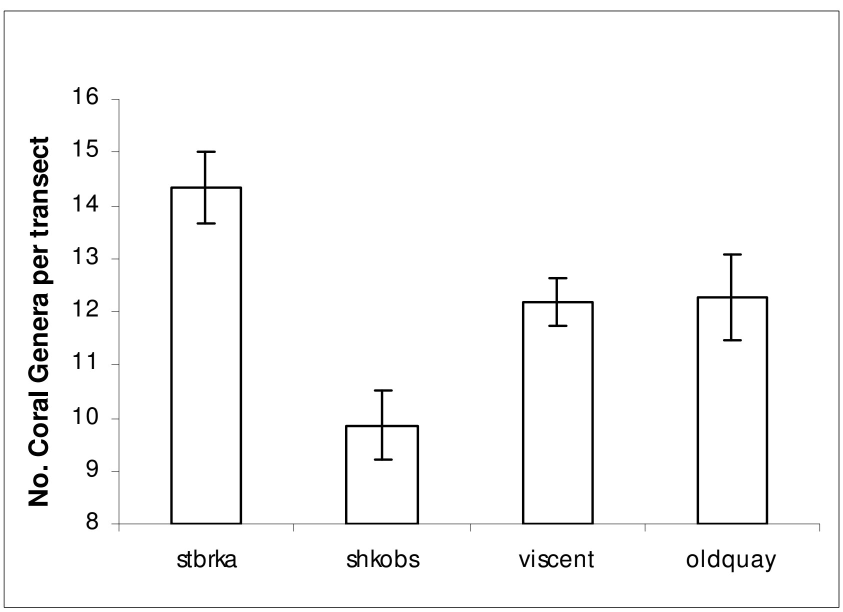

Figure 5. Mean(±s.e.) hard coral Generic richness

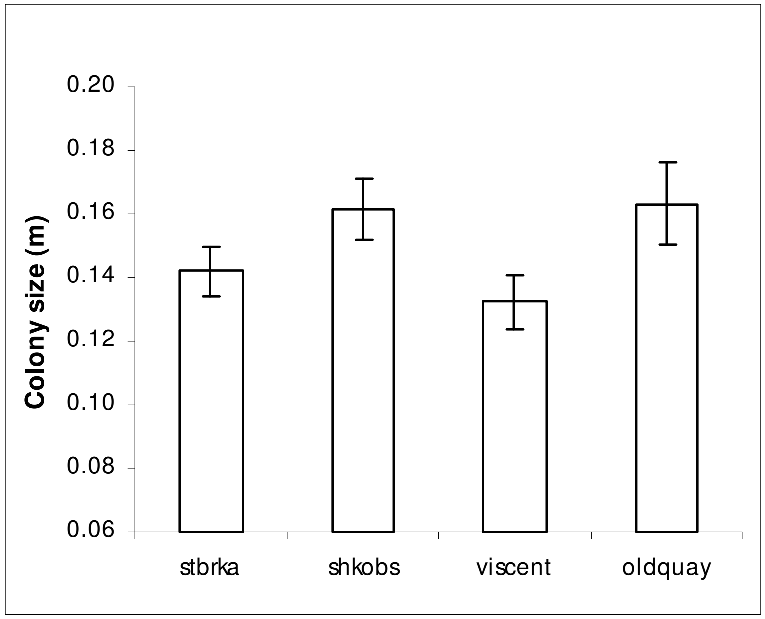

Figure 6. Mean (±s.e.) hard coral colony size

There was no significant difference in the mean size of the hard coral colonies between all the sites, with an overall average size of 0.15m (Range 0.13-0.17m). There was however a very significant difference in the number of coral colonies per transect area between the sites ($F_{3,25}=5.73; p<0.01$). 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.

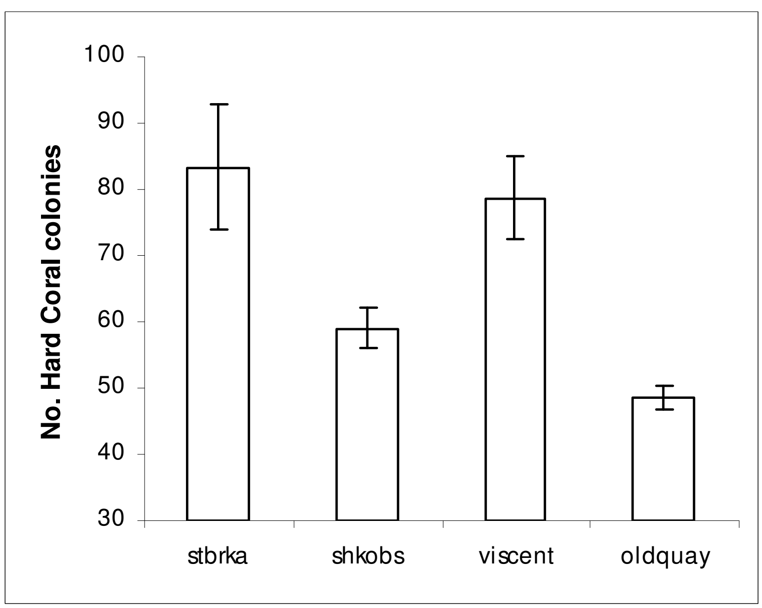

Figure 7. Mean(±s.e.) number of hard coral colonies at each site

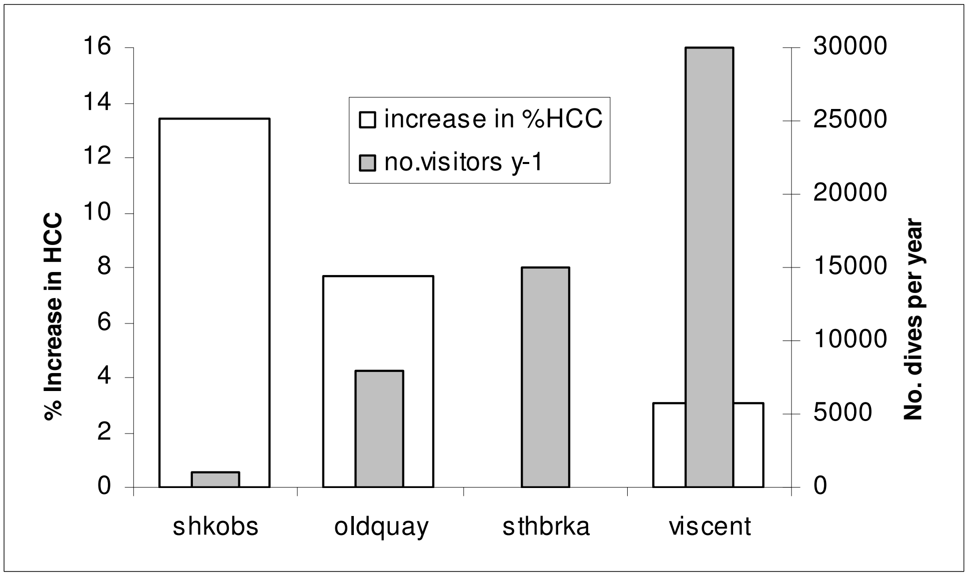

Figure 8. Negative association between hard coral recovery since COTs outbreak and number of divers visiting each site

The recovery of coral cover since the 1998-2003 COTs outbreak shows a significant negative correlation (r_p=0.94;p<0.01) with the number of visitors to the site, when comparing results from this study with data from Saleh (unpubl.), recorded immediately after the outbreak, almost two years ago. The sites with the fewest visitors appear to have recovered more than those with high visitor numbers. The South Bereika site is the only one of the four to show a further decline in benthic cover since the COTs outbreak.

2.5 Discussion

The uniformity of coral cover at the four 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 was some 5% higher than that reported by PERSGA (2005). The Old Quay site also showed the highest levels of coral rubble, which may be attributable to the number of snorkellers and shore divers observed at this site during the course of this study. It may be that for this popular site, more visitors are entering the water from shore as the number of visiting dive boats is one of the lowest in the park. 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. Soft corals are also understood to out-compete hard corals by the use of allelopathy. There was no evidence of predator impacts, although an unconfirmed report from a Dive guide (Anemone divers – Na'ama Bay) suggested that there were infestations of COTs appearing on reefs further up the Gulf of Suez.

The Shark Observatory site had the second lowest hard coral cover of the four 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 50% 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 observed at this site than at any other. 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 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.

This study was limited to only four sites by logistical difficulties. It is foreseen that Operation Wallacea will provide a day boat for the 2006 survey, which will allow access to a much larger number of sites throughout the whole Ras Mohammed park. It is currently estimated that 15-20 sites will be surveyed in 2006.

Again due to logistical reasons, data from fixed quadrats was not gathered this year and will be included at all sites in 2006 to allow the calculation of coral growth rates and recruitment. Use of a light chain of fixed length will also be used to measure rugosity of the sites to allow for an estimate habitat complexity.

A number of $1m^2$ quadrats will be placed randomly along each LIT to allow for monitoring of coral growth rates and coral recruitment rate.

In summary, the benthic communities of the Ras Mohammed national park appear to be starting 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. Further monitoring over the coming years is vital to monitor this recovery and identify further problems. It is also worth noting that the rate of recovery of coral cover appears to be negatively correlated to the number of visitors to each site. Increasing the number of survey sites in 2006 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. The total number of different species observed did not vary significantly between the four sites with 96 species observed at the Shark Observatory, 102 at the Old Quay site, 100 at Marsa Ghozlani and 93 at South Bereika. The three diversity measures calculated all showed significant differences between the study sites. With regard to Shannon-Weiner index of diversity ($F_{3,22}$=13.24;p<0.001), both South Bereika and Marsa Ghozlani had significantly higher fish diversity than Shark Observatory (p<0.05) and Old Quay(p<0.001). A definitive negative correlation was also found between the abundance and diversity of the fish population (r_p=-0.63;p=0.001). Two sites (Old Quay and Shark Observatory) had high abundance, but relatively low diversity, whereas the other two sites (Marsa Ghozlani and South Bereika) were characterised by lower abundance, but higher diversity.

Cluster analysis suggested that the fish communities at all four sites shared a similarity in composition of around 87%. 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.

For the 50 metre by 5 metre transects the observer identifies an object estimated to be 2.5 metres perpendicular to the centre line of the transect.

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 four survey sites showed significant variation in all of the fish survey metrics used apart from species richness, which showed no significant difference (Table 4).

The species richness varied between 37.0 (±2.08) fish species per transect at Shark Observatory to 45.5 (±1.12) at the Old Quay site. The total number of species recorded at each site also showed no significant difference between sites, which ranged from 93 to 102 species (Figure 9).

Table 4. One-way ANOVA of fish assessment measures between sites

One-Way ANOVA	F	df	p
Fish spp. Richness	2.26	3,22	>0.05
Mean fish abundance	4.80	3,22	0.01
Margalefs richness	4.34	3,22	<0.05
Pielous equitability	15.54	3,22	<0.001
Shannon-Weiner Index of diversity	13.24	3,22	<0.001
Simpsons Index of diversity	13.89	3,22	<0.001

With regard to abundance of fishes at the four sites (Figure 10), there was a very significant difference ($F_{3,22}$=4.80;p=0.01) between the Old Quay site (Tukey p<0.05) and the Marsa Ghozlani (Visitor Centre) site. There was no significant difference in the mean fish abundance between all other sites. The Old Quay site had a mean (±s.e.;n=9) abundance of 6278.7(±1113.8), Shark Observatory had 5365.3(±1736.1), South Bereika had 2877.5(±450.4), while the lowest abundance was found at the Marsa Ghozlani site, with 1414.7(±249.9). The abundance values varied quite considerably between individual samples with a minimum value of 764 at the Marsa Ghozlani site to a maximum value of 13060 at the Shark Observatory (Table 5).

Table 5. Mean(±s.e.) fish abundance per 1000m^2 with minimum and maximum counts for each study site

	sthbereika	viscent	shkobs	oldquay
Mean	2877.5	1414.7	5365.3	6278.7
s.e.	450.4	249.9	1736.1	1113.8
Min	1544	764	2000	3524
Max	5260	2200	13060	11212

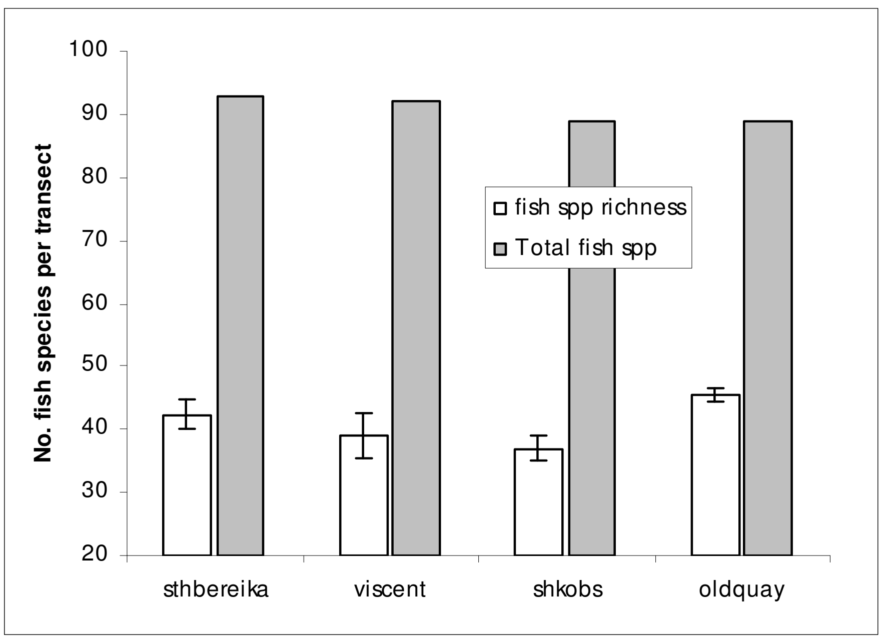

Figure 9. Mean(±s.e.) fish species richness at each site (light bars) with total fish species observed at each site (shaded bars)

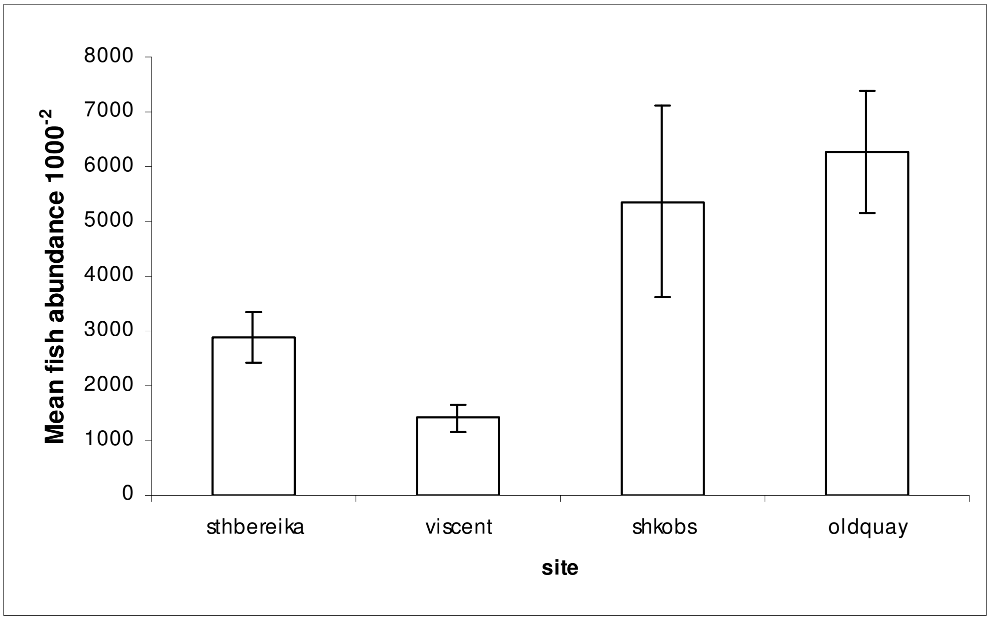

Figure 10. Total mean (± s.e.) fish abundance per 1000m^2 at each study site

Of the four measures of diversity calculated, Pielous equitability measure ($F_{3,22}$=15.54;p<0.001), Shannons index of diversity ($F_{3,22}$=13.28;p<0.001) and Simpsons index of diversity ($F_{3,22}$=13.89;p<0.001), all showed very highly significant differences between the sites (Table 4), while the final measure, Margalefs species richness showed a significant difference between the sites ($F_{3,22}$=4.34;p<0.05). The values for Margalefs richness ranged from 5.15(±0.14) at Shark Observatory to 6.53(±0.45) at Marsa Ghozlani. Tukey post-hoc tests identified that Margalefs richness at both South Bereika (p<0.05) and Marsa Ghozlani (p<0.05) having higher values than those found at Shark Observatory. There were no other significant differences between the other sites. Pielou's equitability measurements showed a range from 0.37 (±0.04) at Old Quay to 0.50 (±0.14) at Shark Observatory. Both South Bereika (p<0.001) and Marsa Ghozlani (p<0.001) had significantly higher equitability values than did the Old Quay site. Marsa Ghozlani also showed a significantly higher equitability value than did the Shark Observatory site (p<0.05).

Calculated values for the Shannon-Weiner index of diversity ranged from 1.42 at the Old Quay site to 2.42 at the South Bereika site. Tukey post hoc tests identified that both the South Bereika (p<0.001) and Marsa Ghozlani (p<0.001) sites had significantly higher values than found at the Old Quay site, while the same two sites also showed significant differences in Shannons measure of diversity as South Bereika ($p<0.05$) and Marsa Ghozlani ($p<0.05$) were both significantly higher than values for the Shark Observatory.

Simpsons index of diversity values ranged from 0.53(±0.05) at the Old Quay site to 0.82(±0.03) at the South Bereika site. Post hoc tests identified that three of the sites, South Bereika ($p<0.001$), Marsa Ghozlani ($p<0.001$) and Shark Observatory $p<0.05$), all showed significantly higher values than did the Old Quay site. No other significant differences between sites were identified.

It can be seen in Figure 11 that the four measures of fish community diversity that were used, all show the same patterns between sites, with all measures identifying the Marsa Ghozlani site as the most diverse, and the Old Quay site showing the lowest values of diversity.

It is also worth noting the identified relationship between fish community diversity and abundance (Figure 12). The two factors are negatively correlated with each other ($r_p=0.63;n=3;p=0.001$). Two sites (Old Quay and Shark Observatory) had high abundance, but relatively low diversity, whereas the other two sites (Marsa Ghozlani and South Bereika) were characterised by lower abundance, but higher diversity. This relationship can also be seen in Figure 15. An MDS plot of the abundance data, overlaid with one of the diversity measures (Pielou’s equitability) shows a clear linear pattern between abundance and diversity.

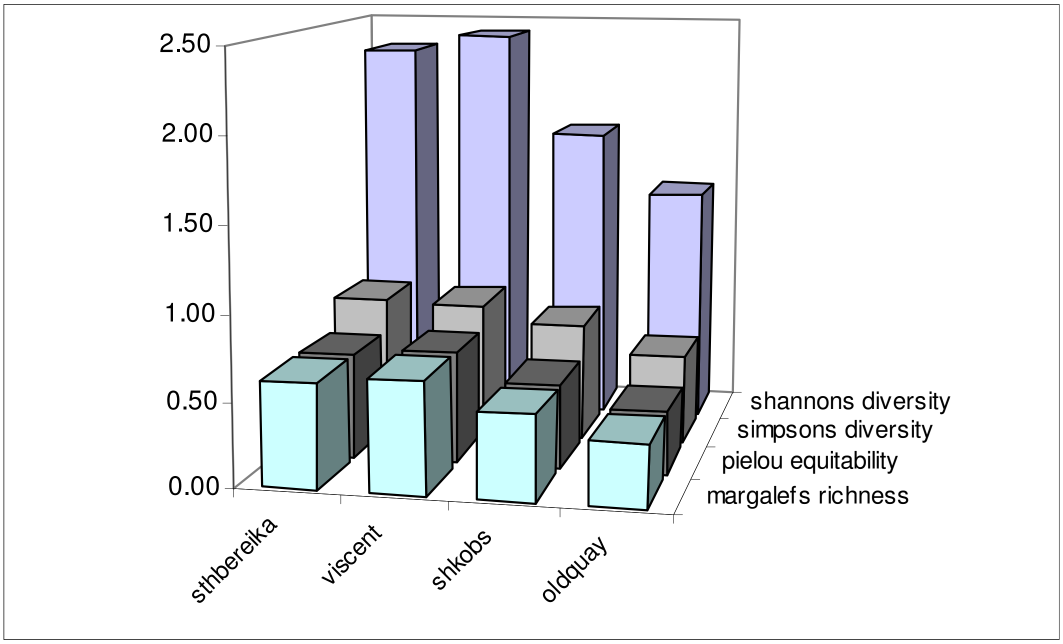

Figure 11. Relationship between the various diversity measures calculated across all sites

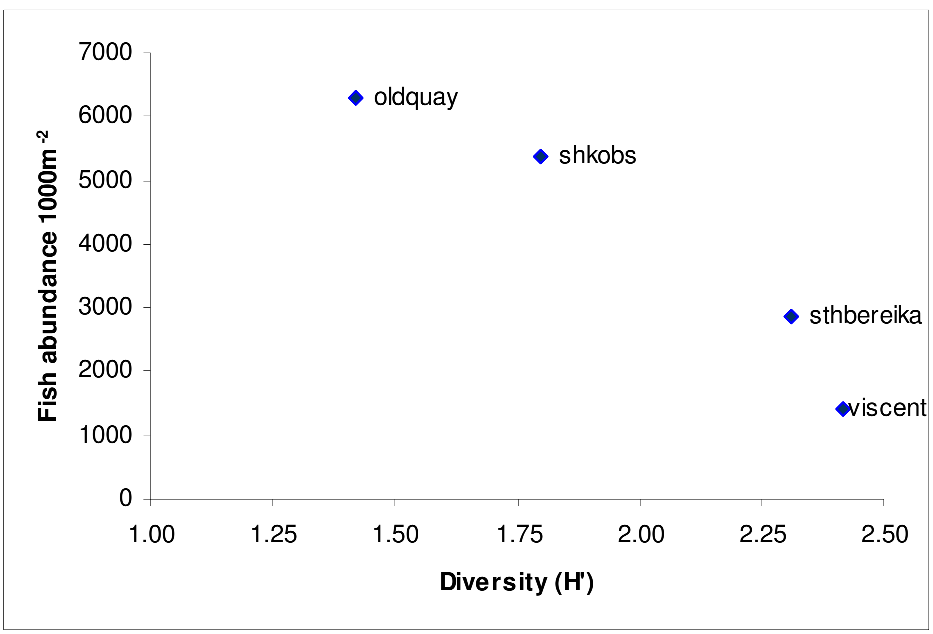

Figure 12. Negative correlation between fish abundance and fish community diversity (Shannons H')

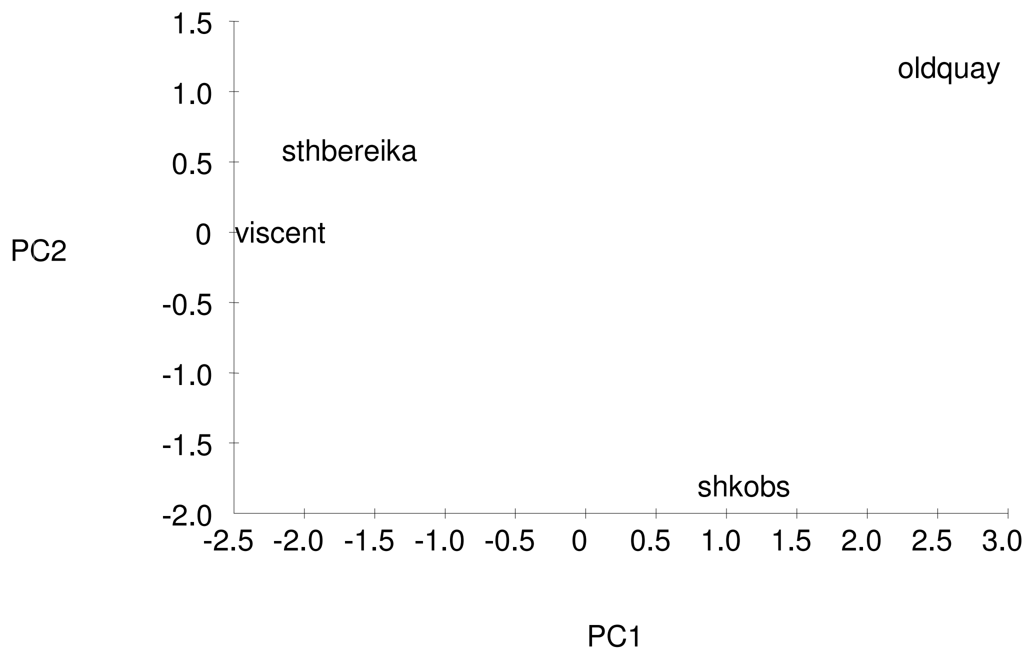

Figure 13. PCA plot of fish assessment metrics (PC1 +PC2 explain 97.2% variance)

Both Principle Component Analysis (Figure 13) and Bray Curtis (Group average) cluster analysis (Figure 14) identified the similarity between the South Bereika and Marsa Ghozlani sites as well as the difference of these sites to the other two, which PCA also identified as different from one another. However, the cluster analysis suggested that the fish communities at all four sites shared a similarity in composition of around 87%.

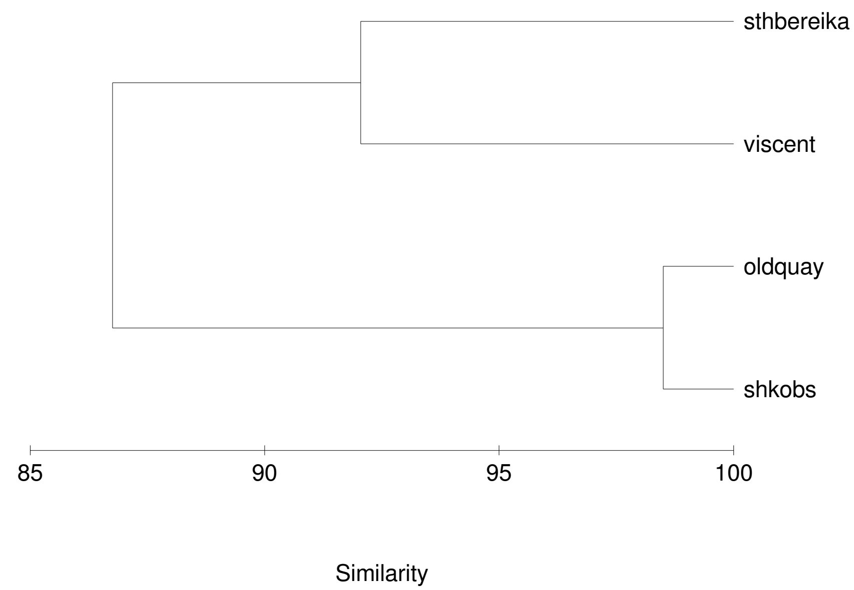

Figure 14. Dendrogram of cluster analysis (Bray-Curtis, group average linkage) of fish assessment metrics

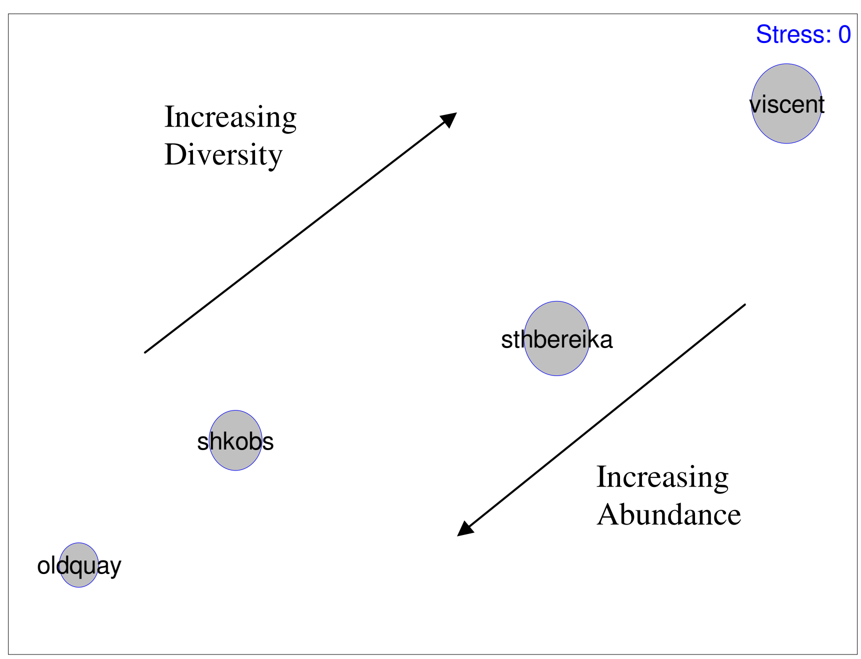

Figure 15. MDS plot of fish summary metrics overlaid (bubbles) with Pielou's equitability measure

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*). At the South Bereika site, these three species account for 53.0 (±5.0)% of the fish population. Similarly, these species account for 55.0 (±9.1)% at Shark Observatory, 49.4 (±8.8)% of the Marsa Ghozlani community and at the Old Quay site these three dominant species account for 81.5 (± 4.0)% of the fish density observed.

The functional redundancy of the four sites, i.e. the number of different species present within a Family, (Figure 16), shows that there were very limited differences between the different sites in the number of species representing each of the dominant seven Families. Only a larger number of wrasse (Labridae) species at the Old Quay site and the reduced numbers of Grouper (Serranidae) and Damselfishes (Pomacentridae) at the Shark Observatory site were noticeable.

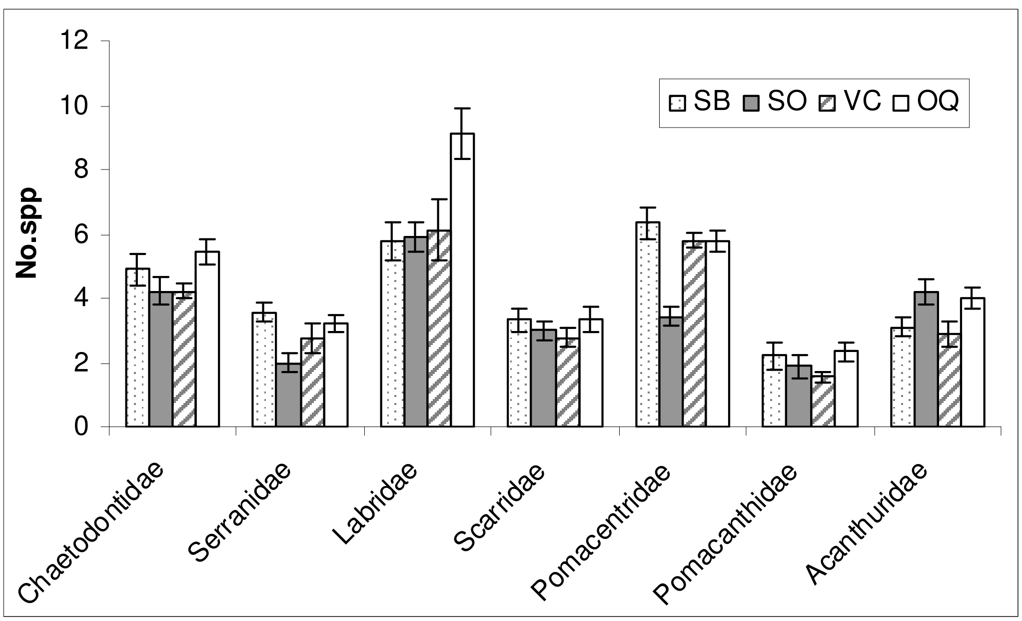

Figure 16. Functional redundancy of the seven main fish Families

When looking at the actual trophic composition of the four fish communities, three of the sites (South Bereika, Marsa Ghozlani and Old Quay) all showed similar proportions of herbivore, carnivore, corallivore etc. (Figure 17). The exception was the Shark Observatory site where the proportion of carnivores was much greater than at the other three sites, while the proportion of invertivores is slightly lower at the Shark Observatory site. The proportion of herbivores seems steady at 15% across all sites, while the proportion of corallivores is also steady across the sites at 4%.

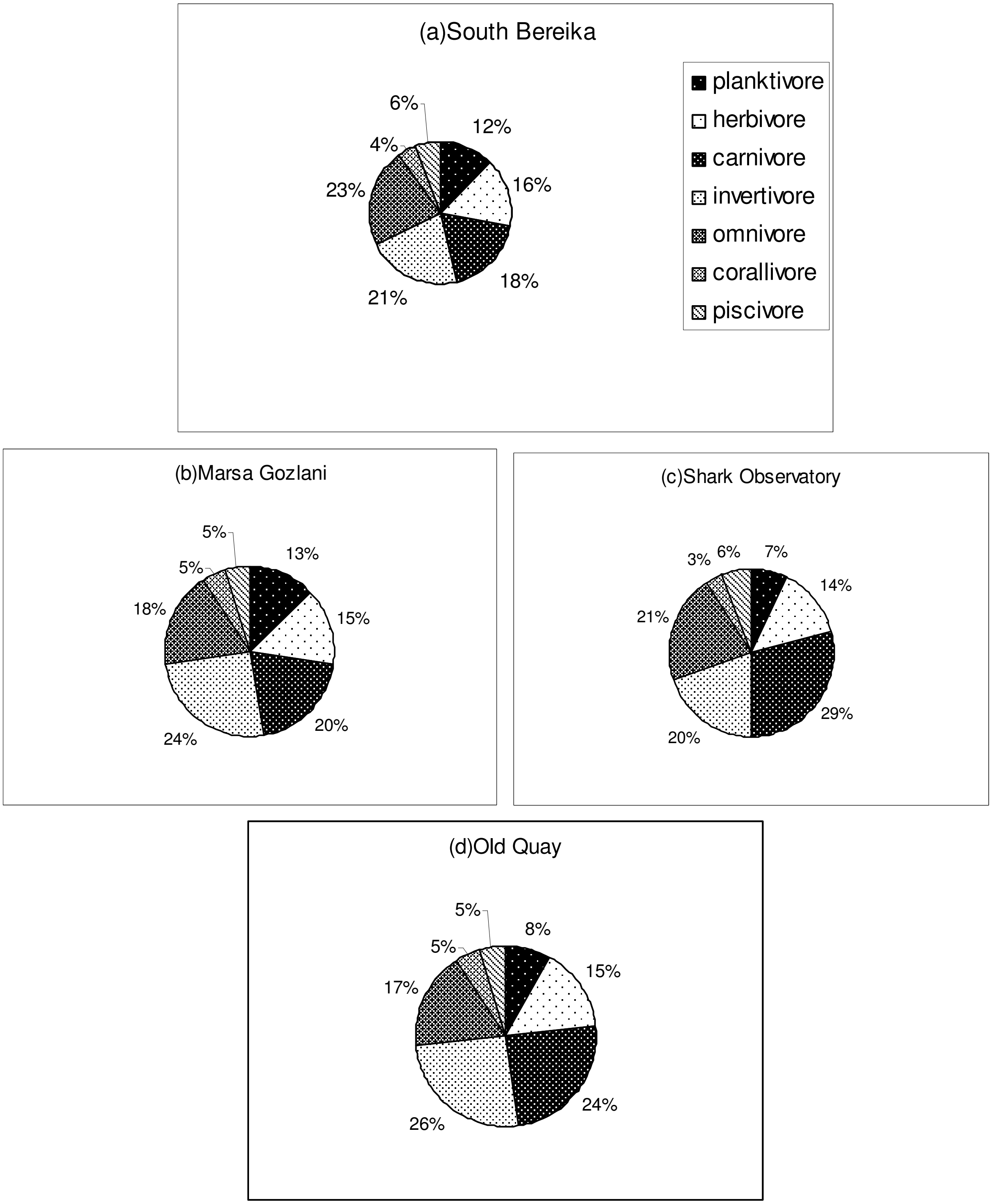

Figure 17. Functional composition of the fish communities at the four study sites

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 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) site, 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 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 Marsa Ghozlani site which had the most stable, sheltered conditions, but the lowest overall abundance of fishes. This site receives the highest number of visitors with hundreds of snorkellers often to be found in the water simultaneously. This may be impacting the fish population along with the noise levels in the bay due to the near constant coming and going of dive boats.

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.

The diversity measures used all followed the same pattern, though at different scales and so only a single diversity measure need be reported in future. Again only data from the South Bereika site was available from previous studies in the literature. The values of Shannon-Weiner diversity index were slightly lower for this study than for that of Leujak (2005), and while again the vales are not directly comparable due to different methodologies, it is worth noting that the South Bereika area was closed to the public during the earlier study and has recently been opened again for boat access.

The two sites with the highest diversity values, South Bereika and Marsa Ghozlani were also the two sites with the lowest overall abundance of fishes. The negative correlation between abundance and diversity can be explained in part by the schooling behaviour of many fishes. Those sites with high abundance tended to have lower diversity as they were dominated by vast numbers of several common species, such as the Anthiases (*Pseudoanthias squamipinnis*), which were found in great numbers at the Shark Observatory site, this is supported by the equitability values calculated for each site. The two low abundance sites did not appear to be dominated by a few species and hence showed greater diversity. The Principle Component Analysis also highlights that these two low abundance sites (Marsa Ghozlani and South Bereika) showed great similarities to each other. They are both in semi enclosed fairly sheltered bays, with both consisting of a gently sloping topography, with minimal prevailing current. The two sights even have the same aspect, being roughly north facing, and as such receive similar light levels, which may influence the benthic productivity which in turn supports the fish population. The PCA plot also identifies the Old Quay site as different to all the others, as is the Shark Observatory site. These sites receive differing light levels, have different topographies and varied currents. However, this contradicts the cluster analysis (Bray Curtis- group average linkage), which identifies the fish communities at the Old Quay and Shark Observatory sites as around 98% similar composition. The cluster analysis also shows a high degree of similarity between the South Bereika and Marsa Ghozlani sites as did the PCA. 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 Labrid species richness at the Old Quay site and lower richness of both Pomacentrids and Serranids 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 grouper species, along with increased interspecific competition with 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 the Old Quay site.

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.

There were very limited differences in the trophic composition of the fish communities at the four study sites. It is very useful to note the proportion of corallivores and herbivores appears constant across all of the sites. This will aid in the early detection of shifts in community structure (Belwood *et al*., 2004; McClanahan *et al*., 2002; McCook, 1999) and further testing of these proportions at more sites in future studies would be useful. Lirman (2001) showed that removal or exclusion of herbivores led to increased algal abundance and increased spatial competition with corals. This in turn leads to shifts in community structure to algal dominated systems. The presence of larger proportions of predators at the Shark Observatory site ties in with factors already mentioned such as currents and topography, while the increased proportion of carnivores at both the Shark Observatory and Old Quay sites relates to the higher overall abundance of the fish populations at these sites. A lack of fishing pressure within the park means that with standardised sampling, these proportions can be monitored for stability and alterations in proportions will suggest some sort of impact, which can be investigated further, before shifts in community structure occur.

In summary, all of the sites in this study have similar fish populations, although the exposed Shark Observatory and Old Quay sites are characterised by low species diversity but high abundance, while the sheltered Marsa Ghozlani 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 site was rated highest with index scores of 44 and 62 for benthic and fishery health respectively, giving a CVI score of B2. The South Bereika site scored 35 and 63 for benthic and fishery respectively giving an overall CVI value of C2. The Marsa Ghozlani site also scored C2 overall, with a benthic score of 39 and a fishery value of 55. The lowest scoring site was the Shark Observatory, with a benthic score of 33 and a fishery value of 47, 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 within the CVI database 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

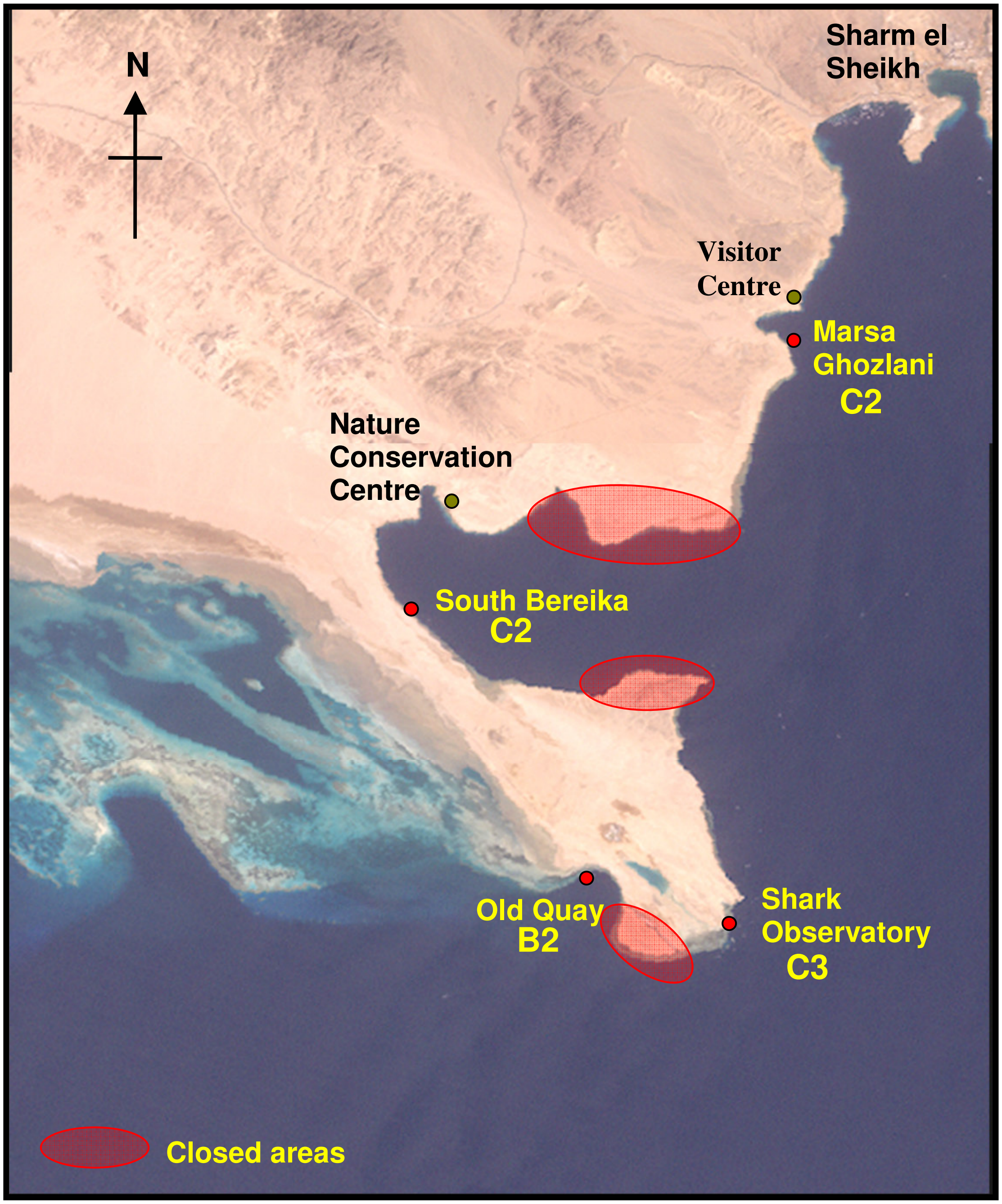

Figure 18. Satellite image of Ras Mohammed National Park with overlaid CVI values for the study sites
(Source: Landsat millennium coral reef archive)

Table 6: CVI benthic and fish values with final CVI codes

Site	CVI Benthic score	CVI Fishery score	CVI code
South Bereika	35	63	C2
Shark Observatory	33	47	C3
Marsa Ghozlani	39	55	C2
Old Quay	44	62	B2

The CVI scores for the four sites are displayed in Table 6 and can also be seen in Figure 18, 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 Old Quay site scored the highest with a score of 45 out of a maximum of 65 points. The second highest benthic score was found at the Marsa Ghozlani site at 39. South Bereika had a score of 35, with the Shark Observatory showing the lowest benthic score at 33. This meant that 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 South Bereika site scored highest with 63 (out of 85), closely followed by the Old Quay site at 62. The Marsa Ghozlani site scored 55, while the Shark Observatory site scored just 47. This low score meant that the Shark Observatory was ranked as a CVI value of ‘3’, while the other three sites were all ranked as ‘2’.

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 establishment of these baseline CVI values will allow the monitoring of these four sites 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.

As mentioned in previous chapters, the inclusion of metrics to monitor coral growth rate and recruitment, as well as reef complexity (rugosity), will further increase the usefulness of this index.

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 – SOME OBSERVATIONS

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 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 0.58% and 1.01% of coral colonies at Marsa Ghozlani and South Bereika sites respectively. They were generally observed on *Acropora* spp. colonies.

As it was regularly observed that there were a number of broken live coral fragments on the study reefs, in future studies the volume of physical damage from divers and snorkellers will be included from quadrat data.

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 50m long LIT at each depth at each site (nine 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.

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 small patches of dead coral in the immediate vicinity.

The corallivorous gastropod *Drupella* spp.(Figure 19) was present on several coral colonies at the Marsa Ghozlani and South Bereika sites, while none were observed at the Shark Observatory and Old Quay 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.

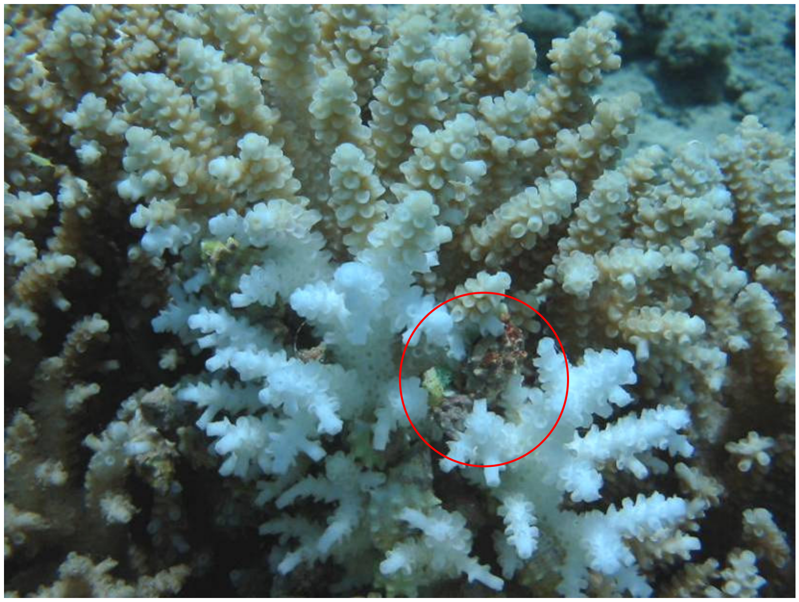

Figure 19. *Drupella* spp. Gastropods feeding on *Acropora* spp. (S.McMellor)

No incidence of coral bleaching or coral disease were observed either on the transects or in the park in general during the period of this study.

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 (Figure 20). 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.

Figure 20. Examples of extensive littering at the Marsa Ghozlani/ Visitor Centre site include water bottles, food waste and disposable nappies

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, nor 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 inclusion in future surveys of coral fragmentation data from quadrats will allow the quantification of physical damage being caused by some careless divers. 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.

With regard to the volume of litter at the Marsa Ghozlani site, patrols at these busy sites by uniformed rangers may dissuade tourists from littering which coupled with fines for the tourist operators could quite easily alleviate this problem.

5.6 References

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CHAPTER 6. RAS MOHAMMED CONSERVATION SWOT ANALYSIS

Strengths and Opportunities;

The Ras Mohammed Park is already well established in the area and there appears to be a general agreement of compliance from the local dive tourism industry.

The Multi-zoned management which is in place should prove a suitable framework for the long-term management and recovery of the park, particularly after the COTS problems of previous years. Use of ‘Closed’ areas as control sites will allow the study of rates of reef recovery as well as acting as a benchmark to identify levels of damage caused by visitors to the park.

The majority of the visitors to the park do not seem to object to the fee for park entry and there may be the possibility to increase this fee as it has not varied since its introduction in the 1990’s. This would provide increased funding for the EEAA park rangers to invest in vehicles and patrol craft so long as the extra monies could be retained by the park authorities.

If successful over the next year or two, there is the potential to expand the monitoring program to all dive sites within the park, with involvement of the park rangers and possibly also representatives from the local dive tourism industry.

Weaknesses and Threats;

The immediate weakness of any park management is a lack of enforcement of existing regulation. Appropriate funding is necessary to maintain regular patrolling of the park by the EEAA rangers.

The main threat to the Ras Mohammed reefs is quite clearly the number of divers/ snorkellers visiting them. Several studies have estimated the carrying capacity of Red Sea reefs in this area, with the most prominent suggesting a carrying capacity of around six to eight thousand dives per year. Even the sites receiving the lowest numbers of visitors exceed this by almost 100%, while the heavily dived sites exceed the recommended levels by over ten times. This is clearly not sustainable and more efforts need to be made to implement awareness programs and buoyancy training to further reduce the impacts caused by divers and snorkellers.

Large amounts of litter were regularly observed at popular shore sites such as Marsa Ghozlani, even though litter bins are provided. The implementation of on the spot fines for tourists and more importantly the tour companies could help reduce this problem.

A lack of maintenance/ repair for moorings has been observed over the course of this study with moorings regularly breaking due to the number and size of boats using them. This in turn is leading to anchor/ reef damage from direct mooring.

Due to previous problems it makes sense to monitor the COTS population within the park. It would also be prudent to monitor the Drupella population as observed during this study

Evidence of illegal fishing was observed at all sites in the form of nets and monofilament lines tangled around the reef benthos, some form of patrol, especially at night would help to alleviate this problem as again boats were often sighted in Marsa Bereika bay in the early hours of the morning, presumably fishing. One of the obstacles here and to patrolling in general seems to be the attitude of the military stationed in Bereika Bay whom control the movement of the rangers patrol boat, prohibiting movement after 1800hrs.

Appendices

I – Scleractinian Coral genera surveyed in Ras Mohammed

Acropora
Astreopora
Blastomussa
Coscinaraea
Ctenactis
Diploastrea
Echinopora
Favia
Favites
Fungia
Galaxea
Goniopora
Goniastrea
Herpolitha
Lobophyllia
Millepora (Octocoral)
Montastrea
Monitpora
Oxypora
Pachyseris
Pocillopora
Porites
Platygyra
Plerogyra
Seriatopora
Stylophora
Symphillia
Tubastrea
Turbinaria

II- Fish species surveyed in Ras Mohammed

Abudefduf vaigiensis
Acanthurus nigrofuscus
Acanthurus sohal
Aethaloperca rogaa
Aethaloperca rogaa
Aluterus scriptus
Amblyeleotris sungami
Amblyglyphidodon flavilatus
Amblyglyphidodon leucogaster
Amphiprion bicinctus
Anampses lineatus
Anampses twistii
Anyperodon leucogrammicus
Arothron diadematus
Arothron stellatus
Aspidontus taeniatus
Balistapus undulatus
Balistoides viridescens
Bodianus anthoides
Bodianus diana
Bolbometapon muricatum
Bryaninops natans
Caesio chrysozona
Caesio lunaris
Caesio striata
Caesio suevica
Carangoides bajad
Carangoides fulvoguttatus
Caranx ignoblis
Caranx melampygus
Centropyge multispinus
Cephalopholis argus
Cephalopholis hemistiktos
Cephalopholis miniata
Cetoscarus bicolor
Chaetodon auriga
Chaetodon austriacus
Chaetodon fasciatus
Chaetodon lineolatus
Chaetodon melannotus
Chaetodon paucifasciatus
Chaetodon semilarvatus
Chaetodon trifascialis
Cheilinus lunulatus
Cheilinus quinquecinctus
Cheilinus undulatus
Cheilodipteris quinquelineatus
Chelio inermis
Chlororus gibbus
Chrois pembae
Chromis dimidiata
Chromis flavaxilla
Chromis pelloura
Chromis viridis
Chromis weberi
Cirripectes castaneus
Coris aygula
Coris formosa
Corythoichthyes sp.
Ctenochaetus striatus
Dascyllus aruanus
Dascyllus marginatus
Dascyllus trimaculatus
Diodon hystrix
Ecsenius aroni
Ecsenius gravieri
Ecsenius midas
Epibulus insidiator
Epinephelus fasciatus
Epinephelus gabrielle
Epinphelus tukula
Genicanthus caudovittatus
Gomphosus caeruleus
Gymnothorax javanicus
Halichoeres hortulanus
Halichoeres marginatus
Hemigymnus melapterus
Hemigymnus sexfasciatus
Heniochus diphreutes
Heniochus intermedius
Hipposcarus harid
Istigobius decoratus
Labroides dimidiatus
Lethrinus borbonicus
Lotilia graciliosa
Lutjanus ehrenbergi
Lutjanus monostigma
Macolor niger
Monotaxis grandoculis
Mulloidichthys vanicolensis

Myripristis murdjan
Naso elegans
Naso unicornis
Neoniphon sammara
Neopomacentrus miryae
Novaculichthys taeniourus
Ostracion cubicus
Ostracion cyanurus
Oxycheilinus mentalis
Para cheilinus octotaenia
Paracirrhites forsteri
Parapercis hexophthalma
Parupeneus barberinus
Parupeneus cyclstomus
Pempheris vanicolensis
Plagiotremus rhinorhynchus
Plagiotremus tapeinosoma
Platax teira
Plectorhinchus gaterinus
Plectropomus areolatus
Plectropomus pessuliferus
Pomacanthus imperator
Pomacanthus maculosus
Pomacentrus sulfureus
Pomacentrus trichourus
Pomacentrus trilineatus
Priacanthus hamrur
Pseudoanthias squamipinnis
Pseudobalistes flavimarginatus
Pseudobalistes fuscus
Pseudocheilinus evanidis
Pseudocheilinus hexataenia
Pseudochromis fridmani
Pseudochromis springeri
Ptereleotris evides
Pterois miles
Pterois radiata
Pygoplites diacanthus
Rhinecanthus assai
Sargocenton caudimaculatum
Sargocenton spiniferum
Saurida gracilis
Scarus ferrugineus
Scarus fuscopurpureus
Scarus niger
Scarus sordidus
Scorpaenopsis oxycephala
Siganus argenteus
Siganus luridus
Siganus rivulatus
Siganus stellatus
Sphyraena barracuda
Sufflamen albicaudatus
Synodus dermatogenys
Synodus variegatus
Taeniura lymma
Thalassoma lunare
Thalassoma purpureum
Thalassoma rueppellii
Thalassoma urpureum
Trachinotus blochii
Triaendon obesus
Variola louti
Zebrasoma desjardinii
Zebrasoma xanthurum

Appendix III - CVI metric values for Ras Mohammed (Benthic and fishery)

Benthic metrics	**SthBreika**	**VisCentre**	**OldQuay**	**SharkObs**
Hard CoralCover	25.02	20.33	17.64	19.22
Soft Coral Cover	2.76	8.30	30.31	7.97
Coral Rubble	5.44	7.01	16.27	4.82
Total Live Cover	28.42	29.04	48.39	29.35
Algal cover	0.20	3.36	0.00	0.07
Biotic/abiotic	0.17	0.42	0.97	0.42
HC Generic richness	14.33	11.56	12.22	9.67
HC colony mean size	0.14	0.13	0.17	0.17
No. HC colonies	83.33	76.33	50.67	57.00
p(bleached)	0.00	0.00	0.00	0.15
p(diseased)	0.00	0.00	0.00	0.00
C.O.T.S. abundance	0.00	0.00	0.00	0.00
Bioeroder abundance	1.01	0.39	0.00	0.00
Fish metrics				
Chaetodont richness	4.9	4.2	5.4	4.2
Serranid richness	3.6	2.8	3.2	2.0
Labridae richness	5.8	6.1	9.1	5.9
Scarid richness	3.3	2.8	3.3	3.0
Pomacentrid richness	6.3	5.8	5.8	3.4
Pomacanthid richness	2.2	1.6	2.3	1.9
Acanthurid richness	3.1	2.9	0.16	4.2
p(Omnivore)	0.24	0.19	0.18	0.22
p(Invertivore)	0.23	0.27	0.27	0.21
p(Herbivore)	0.17	0.16	0.16	0.15
p(Planktivore)	0.13	0.13	0.09	0.07
p(Carnivore)	0.19	0.20	0.26	0.31
p(Corallivore)	0.05	0.05	0.05	0.04
Total abundance	689.2	534.0	1595.8	1142.7
Shannons H'	2.289	2.203	1.367	1.883
Total No. spp.	93	100	102	96
Spp.richness	40.4	39.0	45.9	37.2