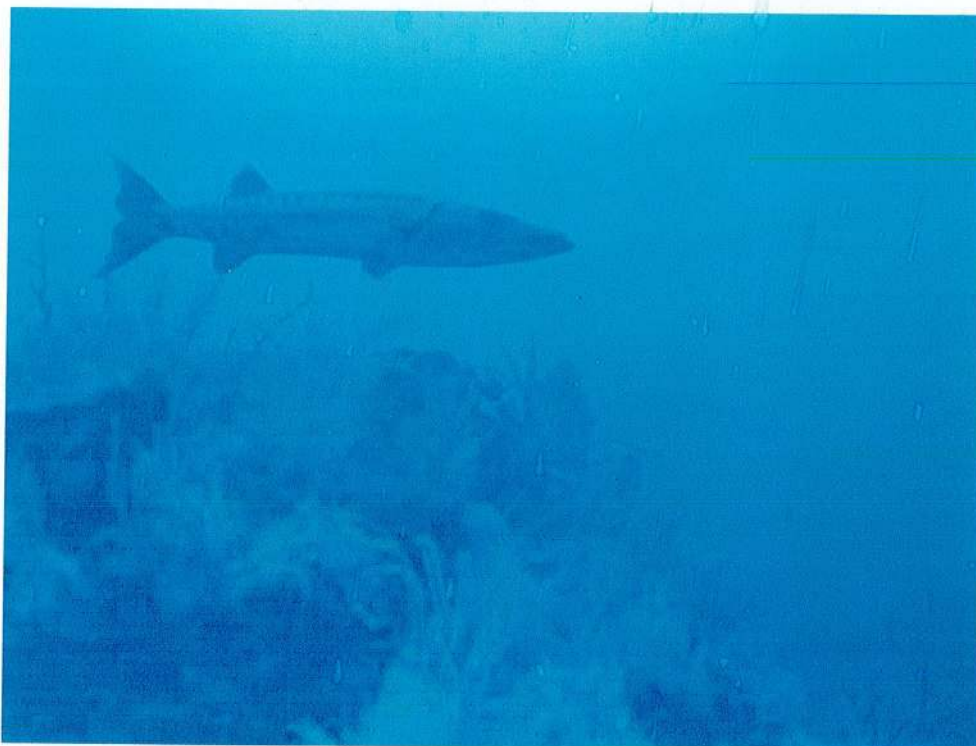


CCC
MEX 01

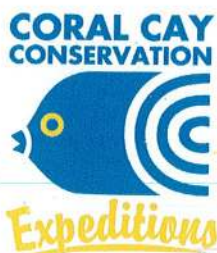
SIAN KA'AN CORAL REEF CONSERVATION PROJECT MEXICO 2003 – FINAL REPORT



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This report is available in both Spanish and English translations

TABLE OF CONTENTS

ACKNOWLEDGMENTS	3
ABBREVIATIONS	4
TABLES, FIGURES AND APPENDIX	5
SUMMARY	7
INTRODUCTION	9
PROJECT BACKGROUND	11
Mexican Reefs	11
The Mesoamerican Barrier Reef System (MBRS)	11
Sian Ka'an UNESCO Biosphere Reserve	12
METHODS	16
PROJECT TIMETABLE	16
VOLUNTEER TRAINING	16
SURVEY TECHNIQUES AND SITES	20
SYNOPTIC MONITORING PROGRAMME	21
Method 1: Surveys of corals, algae and other sessile organisms	21
Method 2: Belt Transect Counts for defined species lists	23
Species lists	24
DATA ANALYSIS	25
Benthic data	25
Fish and invertebrate data	25
Assessment of site Conservation Values	26
RESULTS	28
MULTIVARIATE ANALYSIS AND HABITAT DEFINITIONS	28
HABITAT DESCRIPTIONS	29
HABITAT DISTRIBUTIONS	29
CORAL DISEASE, BLEACHING AND MORTALITY	33
FISH POPULATIONS	37
STANDING STOCK BIOMASS	38
INVERTEBRATE POPULATIONS	44
MANAGEMENT VALUE	44
SPECIES LIST	46
ENVIRONMENTAL EDUCATION PROGRAMME	47
DISCUSSION	50
TRAINING	51
BENTHIC DATA	51
FISH DATA	52
INVERTEBRATE DATA	53
SITE DESCRIPTIONS	55
Sol	55
Chenchomac	56
Chenchomac 2	57
La Colonia	58
Punta Allen	59

<i>Mike's Reef</i>	60
<i>Dani's Buoy</i>	61
<i>Niccehabin</i>	62
<i>El Faro</i>	62
<i>El Barco</i>	63
<i>Mike's reef 2</i>	64
<i>Dani's Buoy 2</i>	65
MANAGEMENT RECOMMENDATIONS	66
CONCLUSION	69
REFERENCES	70
APPENDIX 1	74
APPENDIX 2	81
APPENDIX 3	84
APPENDIX 4	86
APPENDIX 5	88

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Abbreviations

CARICOMP	Caribbean Coastal Marine Productivity Program
CCC	Coral Cay Conservation
CIQRO	Centro de Investigaciones de Quintana Roo
GIS	Geographical Information System
MBRS	Mesoamerican Barrier Reef System
MPA	Marine Protected Area
NGO	Non Governmental Organisation
PRIMER	Plymouth Routines in Multivariate Ecological Research
PS	Project Scientist
PVC	Pescadores de Vigia Chico
SIMPER	Similarity Percentage Analysis
SKCRCP	Sian Ka'an Coral Reef Conservation Project
SMP	Synoptic Monitoring Program
SO	Science Officer
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WCMC	World Conservation Monitoring Centre
WWF	World Wide Fund for Nature

Tables, Figures and Appendix

Table 1	Summary of the 2001 Mesoamerican Caribbean Reef Eco-region Expedition
Table 2	Overall timetable for the scientific component of the three-month SKCRCP.
Table 3	Science training timetable for CCC volunteers during the SKCRCP.
Table 4	Name, buoy number and GPS point for each of the 12 SMP sites within Ascension Bay.
Table 5	Coral Disease Categories used in the MBRS-SMP.
Table 6	Fish species to be included in the SKCRCP
Table 7	Quantitative description of the 6 benthic classes defined from the SKCRCP.
Table 8	Total percentage cover of the 6 benthic classes defined by PRIMER.
Table 9	Percentage cover of the 6 benthic classes.
Table 10	Species of hard coral affected by disease, bleaching or parrotfish predation.
Table 11	Total abundance (m^2) of coral mortality.
Table 12	Abundance of coral mortality per $100 m^2$.
Table 13	Abundance per $100m^2$ of each target species of fish recorded during the SKCRCP.
Table 14	Biomass of each family of commercial fish.
Table 15	Total abundance per $100m^2$ of invertebrates recorded during the SKCRCP.
Table 16	Conservation management values.
Table 17	Number of species for different taxa reported by this and other studies from the UNESCO SKBR region of Quintana Roo.
Table 18	Summary of the SKCRCP schools environmental education program
Figure 1	Yucatan Peninsular and MBRS.
Figure 2	UNESCO- SKBR.
Figure 4	Diagrammatic representation of a diver conducting a belt transect for the MBRS-SMP.
Figure 5	Screen grab of the dendrogram derived from the cluster analysis of point intercept survey data collected during the SKCRCP.
Figure 6	Screen grab example of the SKCRCP data submitted to the WCMC global database for coral diseases.
Figure 7	Biomass structure of commercial fish families.
Figure 8	Standing stock biomass for Chenchomac in kg per family per $100m^2$
Figure 9	Standing stock biomass for Mike's reef in kg per family per $100m^2$
Figure 10	Standing stock biomass for Chenchomac 2 in kg per family per $100m^2$
Figure 11	Standing stock biomass for Punta Allen in kg per family per $100m^2$
Figure 12	Standing stock biomass for Dani's Bouy in kg per family per $100m^2$
Figure 13	Standing stock biomass for Sol in kg per family per $100m^2$
Figure 14	Standing stock biomass for Dani's Buoy 2 in kg per family per $100m^2$
Figure 15	Standing stock biomass for El Barco in kg per family per $100m^2$
Figure 16	Standing stock biomass for Mike's Reef 2 in kg per family per $100m^2$
Figure 17	Standing stock biomass for Niccehabim in kg per family per $100m^2$
Figure 18	Standing stock biomass for La Colonia in kg per family per $100m^2$
Figure 19	Standing stock biomass for El Faro in kg per family per $100m^2$

- Figure 20** GIS representing the relative conservation management values of the 12 sites surveyed by the SKCRCP.
- Figure 21** Creation of 'Marine Creature' with Parier Marche at Jardín de Infancia.
- Figure 22** Creating marine animals with geometric figures (colour paper), Jardín de Infancia.
- Figure 23a** Preparing for the day of snorkelling with Primaria.
- Figure 23b** Reef Environmental education poster designed for school children.
- Figure 24** Underwater images of the SKCRCP survey sites at Sol.
- Figure 25** Underwater images of the SKCRCP survey sites at Chenchomac.
- Figure 26** Underwater images of the SKCRCP survey sites at Chenchomac 2.
- Figure 27** Underwater images of the SKCRCP survey sites at La Colonia.
- Figure 28** Underwater images of the SKCRCP survey sites at Mikes Reef.
- Figure 29** Underwater images of the SKCRCP survey sites for Dani's bouy.
- Figure 30** Underwater images of the SKCRCP survey sites for El Barco.
- Figure 31** Underwater images of the SKCRCP survey sites for Mikes Reef 2.
- Figure 32** Underwater images of the SKCRCP survey sites for Dani's bouy 2.
- Figure 33** Model to show number of snorkellers and divers to visit Ho Chan Marine Park – Belize.
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- Appendix 1** Survey forms
- Appendix 2** Habitat cover
- Appendix 3** Standing stock biomass
- Appendix 4** Schools reef education lecture program
- Appendix 5** Species lists

Summary

- The coral reefs and coastal marine habitats of the Sian Ka'an Biosphere Reserve are of vital national and international importance, both ecologically and economically.
- During 2003 Coral Cay Conservation in collaboration with the Sian Ka'an Biosphere Reserve Management Team (the "*Sian Ka'an Coral Reef Conservation Project*") developed a program of surveys, and conservation education aimed at assessing the conservation management value of 12 patch reefs within the Ascension Bay area of the Reserve, the aim was to develop a community based environmental management strategy to accommodate snorkel based eco-tourism.
- Each patch reef was surveyed using methods developed by the Mesoamerican Barrier Reef System Synoptic Monitoring Program, but introducing an advanced species list for live substrate and invertebrates to allow for more powerful statistical analysis.
- The 12 patch reefs supported six statistically discrete benthic habitat classes, defined by PRIMER.
- The general health of the reefs surveyed was considered to be good in comparison to existing available data sets for the wider Caribbean.
- Other key reef health indicator species such as butterflyfish (Cheatodontidae) were in higher than regional abundances in 8 of the 12 sites. One site (*Dani's Buoy 2*) supported all 5 species of butterflyfish that are known to occur on shallow Caribbean reefs.
- Seven of the 12 sites supported snapper (Lujanidae) in greater numbers than regional mean abundance.
- Seven of the 12 sites supported Grouper (Serranidae) in greater numbers than regional mean abundance.
- The commercially harvested lobster (*Panulirus argus*), and regionally scarce tritons trumpet (*Charonia varietata*), were recorded in greater abundance than regional data would suggest for the wider Caribbean, in eight and five of the sites respectively.
- One hundred and one species of fish spanning 35 families, and 45 species of coral spanning 15 families, were positively identified for the reefs of Ascension Bay during the course of the project.
- A relative conservation management value was calculated for each site using variables of reef health such as total hard coral cover, live benthic and fish species diversity and richness, and abundance of coral mortality. A simple 'High' 'Medium' or 'Low' category was assigned to each of the 12 surveyed sites. A very simple colour coded GIS was produced to provide decision makers with a tool to identify areas of high relative conservation importance within the Ascension Bay.
- A structured community based reef awareness and environmental education program was conducted over a period of three months, within the four schools of Punta Allen. A "life on the coral reef" environmental education poster was produced for use in local schools.
- A simple environmental management strategy, with recommendations on the most sustainable way of operating the small-scale snorkel eco-tourism venture within Ascension Bay has been provided. Recommendations included creating

community managed Marine Protected Area's at the ecologically important Chenchomac and Mike's Reef 2. It was also suggested that CCC be invited back to the Reserve to implement a long term monitoring program of the reefs of Ascension Bay.

Introduction

Mexico covers an area of 1,964,375 km² (1,959,248 km² continental and 5,127 km² made up of islands). The mainland coastline stretches 11,122 km and its exclusive economic zone at sea amounts to 3,149,920 km². Mexico's main coral reef areas include the Pacific coast, Baja California and offshore islands, the underdeveloped reefs of the Revillagigedo Islands (restricted due to their cool water temperatures) and the extensive fringing off the Yucatan peninsula. These Yucatan reefs include offshore islands and the Banco Chinchorro atoll, continuing south as part of the Mesoamerican Barrier Reef System (MBRS). Reefs in the north of Yucatan (Quintana Roo) generally support low coral cover (17%), with expanding tourism in Quintana Roo considered a major threat. Coral diseases continue to be present in the Yucatan area, including both some of the highest and lowest infection rates found in the region (ranging from 0%-11%). In general, coral cover and juvenile density is higher but species richness is lower than in other parts of the MBRS.

Recent coral bleaching events and storm damage have exacerbated these effects by acting synergistically to reduce reef health further. Such impacts represent substantial long- and short-term threats to the ecological balance and health of reef ecosystems. If left unchecked they will ultimately lead to reduced income for coastal communities and other stakeholders relying on fishing and marine-based tourism. Furthermore, any natural or anthropogenic impacts on reef health will inevitably affect other countries in Mesoamerica, and *vice versa*, since the marine resources are linked via currents and the functioning of the system transcends geo-political boundaries.

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

Founded in 1986, CCC is dedicated to '*providing resources to protect livelihoods and alleviate poverty through the protection, restoration and sustainable use of coral reefs and tropical forests*' in collaboration with government and non-governmental organisations within a host country. CCC does not charge the host country for the services it provides and is primarily self-financed through a pioneering volunteer participatory scheme whereby international volunteers are given the opportunity to join a phase of each project in return for a financial contribution towards the project costs.

The Sian Ka'an UNESCO Biosphere Reserve (UNESCO-SKBR) developed collaborative links with CCC in mid 2003 in order for the development of the Sian Ka'an Coral Reef Conservation Project (SKCRCP). CCC agreed to apply the recently developed Mesoamerican Barrier Reef System Synoptic Monitoring Program (MBRS-SMP) to the shallow lagoonal and patch reef environment of the Ascension Bay region of the Reserve. Ascension Bay is facing the development of multiple

resource usage, including the long term artisanal exploitation of lobsters (*Panulirus argus*), by the local fisheries cooperative Pescadores de Vigia Chico (PVC). To maintain sustainability within the fishery, PVC has diversified with the development of alternative livelihoods, namely a snorkeling eco-tourism venture, running boat based snorkel tours to some of the patch reefs within the lagoon. The collaborative CCC / Sian Ka'an UNESCO Biosphere Reserve Management Team (Reserva de la Biosfera Sian Ka'an) three-month project was established in September 2003 with the following aims:

1. Implementing the regional MBRS SMP for selected sites within the Ascension Bay area of the UNESCO SKBR, to provide regional decision makers with up to date information on the biological condition of the local reefs.
2. Collecting data on the status of coral mortality and diseases to submit to the World Conservation Monitoring Centre (WCMC) – United Nations Environment Program (UNEP) Western Atlantic Coral Diseases Database. Plus submit baseline on the coral reefs of Sian Ka'an to the global web based interactive database – www.reefbase.org.
3. Use the collected data to develop a simple local environmental management plan for PVC's snorkeling eco-tourism venture.
4. Providing conservation and environmental education opportunities for the local community.

This report provides the results and a summary of the work undertaken as part of the CCC / UNESCO SKBR Management Team collaborative *Sian Ka'an Coral Reef Conservation project (SKCRCP)*.

Project Background

Mexican Reefs

There are 346 reef-associated fishes in Mexico, of which at least 245 reef fish are found on the Atlantic coast of Mexico; 68% of these in the Gulf of Mexico and 92% along the Yucatan Peninsula. Herbivores are dominant on the Gulf of Mexico reefs, carnivores are more abundant in the Caribbean, important families include Scaridae, Pomacentridae, Labridae, Acanthuridae, Lutjanidae, Haemulidae and Serranidae (Amada-Villela, *et al.* 2002).

Reefs on the Pacific and Atlantic coasts are under pressure from tourism activities, which including boat groundings, alteration to the coastal fringe, potential loss of mangrove and the resulting loss of protection from storms. Mexican reefs have received considerable attention and researchers from government and NGOs conduct coral reef research and monitoring in the country. Recently, the Comisión Nacional de Areas Naturales Protegidas (CONANP) organised a workshop to develop a Mexican Monitoring Protocol, which was presented to the MBRS Initiative as the Mexican contribution to the regional monitoring effort (Amada-Villela, *et al.* 2002). These new activities should greatly enhance the existing knowledge of the reefs, including the work undertaken by the SKCRCP.

The Mesoamerican Barrier Reef System (MBRS)

The Mesoamerican Barrier Reef System (MBRS), extending from Isla Contoy on the north of the Yucatan Peninsula to the Bay Islands of Honduras (Figure 1), includes the second longest barrier reef in the world (Amada-Villela, *et al.* 2003). The coral reefs in this region clearly show the effects of severe recent disturbances; Hurricanes Keith (2000) and Iris (2001) damaged reefs along Belize and Hurricane Isidore hit the northern part of the Yucatan Peninsula in September 2002. There have also been recurrent bouts of coral bleaching throughout the 1980s and 90s, resulting in major changes in the coral populations on both sides of Central America. These climate related events have also resulted in major impacts to the agricultural industries in the State of Yucatan, which is among the five main national producers of pork, chickens and eggs. The losses in these agro-industries are estimated to be up to 80%. The full impact of Hurricane Isidore on the marine resources has as yet not been evaluated. The combined effects of this event and the resulting flooding and sedimentation in the region, along with white band and bleaching events are expected to have long-term ecological consequences for the coral reefs. The MBRS has a long-term monitoring program to assess the health of the coral reefs and associated ecosystems (mangroves, seagrass beds and other coastal wetlands).

During 2001, the *Mesoamerican Caribbean Reef Eco-region Expedition* was organised by The World wide Fund for Nature (WWF) along with researchers from Amigos de Sian Ka'an and SEMARNAP (Mexico), Coastal Zone Management Institute and Belize Audubon Society (Belize), Honduras Coral Reef Fund and DIGEPESCA (Honduras). The overall aim was to assess the reefs from Mexico to Honduras (Table 1). This expedition was the first time regional scientists had

collaborated on coral reef surveys of the entire Mesoamerican Reef System from Mexico to Honduras. The main goals were to determine the ecological status of reefs throughout the region, monitor recovery from 1998 disturbances, give local researchers ecoregional perspective and training and gather information to refine an Ecoregional Conservation Plan. They examined 36 sites in 4 subregions. It was discovered that most fore-reefs (15-17m depth) still show the impacts of the severe disturbances of 1998, with little recovery apparent. Average live coral cover for the region was 15% (range 2.6% to 39.7%), substantially lower than pre-1998 values. The density of recruits or juvenile corals was 7.5 per m² (range 1.0 to 14.6 per m²). There were 26.7 (range 18 to 33) hard coral species on average per site, and 3.3% of 3,692 corals showed active disease infections (range 0-11.5%). The most common were 'white plague' and 'dark spot' diseases, with 'dark spot' and 'white band' more common in the two northern sub-regions, and 'black band' and 'white plague' more common in the south.

The average recent mortality for the region (including parts of colonies that died in the last year) was 1.7% (range 0.2 to 4.4%). The expedition discovered some interesting trends e.g. coral diversity is highest in the south, while coral abundance (adults and juveniles) is higher in the north. Of particular concern was the relatively low coral cover in many sites, particularly in the Honduras and Belize sub-regions. Coral cover of 25-30% would be considered good for the Caribbean (Amada-Villela, et al. 2002), and recent patterns of coral diseases and coral mortality are very complex. Diseases were highest in the North Honduran Coast sub-region, and lowest in Belize, and the Sian-Ka'an / Ambergris region had high variability in disease levels, potentially indicating that some local stresses and not regional problems are the major influences e.g. possibly local development. In Honduras widespread stresses such as agricultural run-off may explain the consistently high disease levels. While Belize had the lowest average disease rate, there was relatively high recent mortality, suggesting other causes of mortality such as bleaching and hurricane damage. (Amada-Villela, et al. 2002).

Table 1. Summary of the 2001 *Mesoamerican Caribbean Reef Eco-region Expedition* averaging coral data from 36 sites in 4 regions (developed from Amada-Villela, et al. 2002).

Sub-Region	Coral Species	% Coral Cover	% Juveniles per m ²	% Coral Disease	% Recent mortality
North Quintana Roo	24.5	24.5	12.2	3.0	2.7
Sian Ka'an/Ambergris	26.4	20.3	7.0	3.7	1.1
Belize	26.5	12.9	7.6	2.3	1.9
North Honduras	27.6	10.1	6.9	4.4	1.8
Overall	26.7	15.2	7.5	3.4	1.6

Sian Ka'an UNESCO Biosphere Reserve

The Sian Ka'an UNESCO Biosphere Reserve located between 19°05'20"-20°06'N and 87°30'-87°58'W, off the east coast of the Yucatan Peninsula, Quintana Roo (Figure 2) was declared a Biosphere Reserve in 1986 and inscribed as a World Heritage Site in 1987 (Salvat, et al. 2002). The reserve covers approximately 6,808 km² and is Mexico's third largest protected area. Sian Ka'an is described as the largest effective

nature reserve in Mexico and protects one of the most pristine expanses of wetland in Mesoamerica (Salvat, et al. 2002). Sian Ka'an lies on a partially emerged coastal limestone plane which forms part of the extensive barrier reef system.



Figure 1. Yucatan Peninsular and MBRS – reefs illustrated in orange.



Figure 2. UNESCO- SKBR - reefs illustrated in orange

Flora and fauna

The site is a transition zone where both Mesoamerican and Antillean species are represented. An estimated 1,200 species of vascular plants can be found in Sian Ka'an's nine vegetation types, including old growth, medium, and seasonally inundated lowland forests, as well as grasslands. The wetlands are home to the endangered marsh crocodile (*Crocodylus moreletii*) and the river crocodile (*Crocodylus acutus*). The Reserve's beaches are prime breeding areas for the hawksbill (*Eretmochelys imbricata*), loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), and green turtle (*Chelonia mydas*). A total of 85 species of fish have been recorded on the reefs, of which 14 are classed as commercially important (Jordan et al, 1994). Padilla et al (1992) found 37 scleractinian and 27 gorgonian species in the northern part of Sian Ka'an. Jordan-Dahlgren et al (1994) distinguishes two main coral community types: a shallow water community colonizing raised features dominated by scleractinians; and a deeper water community colonizing raised features or a shallow environment within raised features. Here scleractinian corals are the least important component and the community is dominated by gorgonians. Well-developed coral reef structures are mostly restricted to shallow *Aporosa palmata* reefs with some *Millepora complanata* forming a fringing barrier reef bordering the shoreline (Jordan-Dahlgren et al., 1994).

In deeper waters, a rich and diverse coral community colonises isolated raised karstic features. However, most of the bottom of the shallow shelf consists of hard grounds with sparse coral cover. Massive *M. annularis* and other massive coral species, such as *Diploria ciosa*, *D. strigosa* and *Colpophyllia natans*, and encrusting corals (mostly forms of *Agaricia agarrites*) are more abundant in well-developed reef structures and are rather scarce on hard ground (Jordan-Dahlgren et al., 1994). Gorgonians form a very conspicuous component of the coral community. Coral community composition and relative degree of development seem to be influenced principally by the magnitude of the submarine topographical relief and depth (Jordan-Dahlgren et al., 1994). According to Padilla (1992) *Plexaura sp* and *Gorgonia sp.* were the most important gorgonian species and *Monstastrea annularis*, *A. palmata* and *D. ciosa* the most important hard coral species in the lagoon of the northern area.

Resource use and major threats

Approximately 1,000 people live in the reserve, in either small family ranches along the coast or in the reserve's two fishing settlements, Javier Rojo Gómez (Punta Allen) and Punta Herrero. At present the main economic activities are fishing of lobster and finfish, small-scale agriculture and ranching. Sian Ka'an is located south of Cancún, the area's most popular tourist destination. Tourism began in the 1970s when the beaches of Tulum to the north began to attract foreign visitors (Salvat, et al. 2002). The development of tourist based activities, such as sport fishing and eco-tourism, especially in the northern part of the reserve, is increasing, despite the basic lack of services (CIQRO, 1983).

Use of the coastal zone for tourism purposes is the main motivating factor for long-term conservation plans for the reserve. Major threats to the area include:

- Uncontrolled growth of tourism development
- Inadequate waste disposal

- Oceanic waste and ship dumping
- Use of unconventional fishing gear with associated negative impacts
- Over-fishing of commercial marine species
- Illegal hunting
- Forest fires
- Soil erosion

Scientific research and management

Centro de Investigaciones de Quintana Roo (CIQRO) has conducted extensive surveys on wildlife, ecology, geology and hydrology (CIQRO, 1983). There is one scientific station situated within the biosphere reserve and two climatological stations. Espejel (1983) wrote a general description of the shallow marine zone. Zlatarski and Wells made some general observations and described the general conservation status and coral cover (UNEP/IUCN, 1988). Jordan (1990) published a scleractinian and gorgonian list. Padilla *et al* (1992) wrote a detailed description of the reefs of the northern part of Sian Ka'an. Much research has centered around the exceptionally well managed community based lobster fishing cooperative (PVC) operating out of Punta Allen (Lonzano-Alvarez, 1996., Sosa-Cordero, 1995., Eggleston, *et al.*, 1990, Eggleston, *et al.*, 1992., Boudreau, *et al.*, 1993.). Restrictions on fishing net use in Ascension Bay have been put in place (Bezaury *et al.*, 1998). Since 1992, the NGO, the Amigos de Sian Ka'an, has been implementing a coral reef monitoring program (Salvat, *et al.*, 2002).

A revised management plan came into force in 1995, identifying 16 management zones. Its objectives include protection, resource management, monitoring, environmental restoration, archaeological and cultural protection and management, social development, public use (tourism), and infrastructure (Salvat, *et al.*, 2002). The management plan has been used to control tree felling, reduce commercial hunting and indiscriminate use of forest products, removal of exotic casahuate trees, establish ecological regulations for the relocation of an area damaged by hurricanes, and contract local inhabitants as reserve workers (Salvat, *et al.*, 2002).

The MBRS Synoptic Monitoring Program

The MBRS Synoptic Monitoring Program (SMP) has been developed to try to answer some of the questions on the health of the reef and its associated ecosystems, in order to assist in the management of this unique and shared resource. The SMP evolved through a consultative process in which nationals from Belize, Guatemala, Honduras and Mexico, as well as regional and international scientists and field biologists were involved. The main consultations included Technical Working Groups with specialists from each MBRS participating country, an Expert Meeting and specialist consultations. In addition, there were three key regional consultancies: Coral Reef Ecology and Associated Ecosystems; Marine Pollution and Physical Oceanography/Models, which were supported by National Consultancies (except for the section of Coral Reef Ecology for Mexico). Finally, there have been numerous consultations with scientists and coral reef workers in the four countries, the Caribbean region and elsewhere (Almada-Villela, *et al.* 2003).

Methods

Project Timetable

Table 2 shows the overall timetable for the scientific component of the three-month *SKCRCP*. Details of the training programme and survey techniques are provided in subsequent sections.

Table 2. Overall timetable for the scientific component of the three month *SKCRCP*. RW= Ryan Walker (CCC Marine Science Co-ordinator), JT = Jacqui Taylor (CCC Chief Technical officer for Mesoamerica), HW= Hannelore Waska (Project Scientist) and DPT= Daniel Ponce-Taylor (Science Officer).

Week	1	2	3	4	5	6	7	8	9	10	11	12	13 & 14
	Phase 1						Phase 2						Data analysis and report production and dissemination to SKBR and SMP
RW ¹	Scientific and analytical support. Project supervision, data analysis and dissemination (UK)												
JT ¹	Project supervision and data analysis (on site)												
HW ²	Training of Volunteers, project supervision and data analysis												
DPT ²	Training of Volunteers project supervision and data analysis												
Volunteer training	Science training						Science training						
Volunteer surveys ³			SMP transects and data collection										

¹ RW and JT present in Sian Ka'an for the start of the project.

² HW and DPT arrived in Sian Ka'an between the 1st and 12th of September respectively.

Volunteer Training

Efficient and effective training is a vital component of any volunteer programme in order that participants quickly gain the required identification and survey skills that allow them to collect accurate and useful data. During the *SKCRCP*, CCC used an intensive 14-day training programme, outlined in Table 3. The programme was designed to provide volunteers, who may have no biological knowledge, with the skills necessary to collect useful and reliable data. The primary aim of the lecture programme was to give volunteers the ability to discern the specific identification characteristics and relevant biological attributes of the species that they would encounter during their diving surveys employing the MBRS SMP¹ methods. The training programme was coordinated by the Project Scientist (PS) and Science Officer (SO) and involved two lectures and two dives/snorkels, to include species identification and commercial fish size estimation (using a specially designed training rope) each day. This was complimented with debriefings and evening audio-visual presentations. Volunteers were also encouraged to snorkel and utilise identification guides to ensure a thorough understanding of the information provided in the lectures.

¹ Methods are standard SMP methods as set out by the MBRS project. Due to the intensive level of training received by CCC volunteers additional data was collected, for example hard corals were identified to species level, sponges to life form and additional species of fish recorded and used for CCC reporting purposes. Only standard SMP data requested by the MBRS project has been submitted to the organizing committee.

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

Since it is impossible to compare volunteer fish data to a reference, validation of fish surveys were conducted by measuring the consistency between pairs of surveyors. It was then assumed that if surveyors are consistent they are also accurate. Therefore, both divers within a buddy pair independently surveyed the whole fish list and each surveyor filled out their own survey form and entered it onto a spreadsheet. As with the benthic validation, the pairs of results were compared using the Bray-Curtis similarity coefficient. These assessments were similar to the critical assessment conducted by CCC in 1993 to test the accuracy of volunteer divers conducting baseline transect surveys (Mumby *et al.*, 1995).

Table 3. Science training timetable for CCC volunteers during the Sian Ka'an Coral Reef Conservation Project - Mexico 2003.

WEEK ONE		Day +1 Sat	Day +2 Sun – no diving	Day +3 Mon	Day +4 Tues	Day +5 Wed	Day +6 Thur	Day +7 Fri
EVE	↕	Transfer New vols (i.e. trained scuba divers) to Project site Fri. PM. Orientation ► Welcome & tour of facilities ► Expedition life & duties ► General health & safety ► CCC rules & regulations Lecture 2 ► Dangerous Animals	Safety briefs ► Radio use ► Emergency procedures ► Boat safety ► Use of boat safety kit Lecture 3 ► Introduction and Background to Coral Reefs Lecture 4 ► CCC's Mexican Partners ► Scuba kit allocation	Lecture 6 ► Intro to Phylum <i>Cnidaria</i> Practical 2 ► Reef intro –different algae - <i>Cnidaria</i> spp. (Scuba)	Lecture 8 ► Intro to hard corals – biology and life-forms Practical 4 ► Hard Coral ID (SCUBA) ► Specimen ID – reference (books)	Lecture 10 ► Hard coral spp. ID and Black Corals Practical 6 ► Hard coral targets ID (SCUBA / snorkel)	Lecture 11a ► Invert. ID –part I ► Sponge – basic biology and intro to different lifeforms Practical 8 ► Invert. ID/ Coral review (SCUBA)	Lecture 12 ► Intro to fish ID and out line of major groups Practical 10 ► Fish ID (SCUBA / snorkel)
		Safety briefs ► PADI EFR: Ac mods 1+2 ► O ₂ therapy ► PADI tables & quiz (OW mods 4+5) ► CCC dive standards Lecture 1 ► Country Brief, Local culture and customs, Mexico and Sian Ka'an.	Lecture 5 ► Intro to the biology and ID of marine plants and algae Practical 1 ► Algae ID (snorkel) ► Size estimation exercise Review ► Algae ID – target species	Lecture 7 ► Intro to Coral Biology, taxonomy and ID of Soft Corals Practical 3 ► ID – Cnidaria groups and soft coral life-forms (SCUBA / snorkel) Revision ► Algae ID – target species	Lecture 9 ► Hard coral ID targets Practical 5 ► Hard & soft Coral ID ► Sponge lifeforms (SCUBA) ► Specimen ID – reference (books)	Review ► Hard & soft Coral ID – target spp. Practical 7 ► Hard coral targets ID – coral trail (SCUBA / snorkel) Revision ► Hard and soft corals	Review ► Algae/ Invert. ID/ Coral ID (slides) Practical 9 Practical Exam ► Hard and soft coral validation (SCUBA / snorkel)	Lecture 13 ► Fish ID sp 1 Lecture 14 ► Fish ID sp 2 Practical 11 ► Fish ID (SCUBA / snorkel) Review ► Fish ID – target species 1
		Review ► Expedition Skills Development Programme schedule	Review quiz ► CCC health & safety regulations ► CCC dive standards ► Emergency procedures ► Local culture & customs	Examination ► Algae ID	Review ► Cnidaria & hard coral life forms ► Soft Corals (spot samples/slides)	Examination Hard and soft Coral ID	Lecture 11b ► Invert. ID –part II	Review ► Invert spp Examination ► Invert ID

		Day +8 Sat	Day +9 Sun	Day +10 Mon	Day +11 Tues	Day +12 Wed	Day +13 Thur	Day +14 Fri	Day +15 Sat end of training
WEEK TWO	AM	Lecture 15 ▶ Fish ID spp 3 Revision ▶ Fish families/ spp Practical 12 ▶ Fish ID – Families/ sp (SCUBA / snorkel)	Camp maintenance Revision ▶ Fish families/ spp (slides)	Practical 15 Skills validation ▶ Benthic Validation ▶ Size estimation (snorkel)	Lecture 16i ▶ The synoptic monitoring programme (SMP) technique (technique 1) Lecture 16ii ▶ The synoptic monitoring programme (SMP) technique (technique 2) Practical 17 ▶ SMP monitoring methods (dry run) ▶ Practice SMP survey techniques (snorkel)	Review ▶ Data entry on to forms/ computer ▶ Navigation and GPS Practical 17 ▶ SMP Practice Survey-technique 3 ▶ Size estimation (snorkel)	Lecture 19 ▶ Reef Check Intro & Survey Method (dry run of method)* Practical 19 ▶ Practice Reef Check Survey 1 – Fish/ Inverts (SCUBA)* ▶ Size estimation (snorkel) ▶ Reef check survey forms and data entry*	▶ Size estimation (snorkel) Survey dive + data collation Recreational Dive	▶ Size estimation (snorkel) Recreational Dive
	PM	Revision ▶ Fish families /spp Practical 13 ▶ Fish ID – Families/ spp (SCUBA / snorkel)	Practical 14 ▶ Size estimation exercise - snorkel Examination ▶ Fish ID	Review ▶ Fish ID – target species 1 Practical 16 Skills validation ▶ Fish Validation	Lecture 16iii ▶ Intro to SMP Survey forms, ▶ SMP Reef Survey technique 1 (review) Practical 16 ▶ SMP Practice Survey-technique 2	Review ▶ Sessions available to catch up on missed lectures Practical 18 ▶ SMP Practice Survey-technique 4	PADI EFR* ▶ Mods Review ▶ Sessions available to catch up on missed lectures Practical 20 ▶ Practice Reef Check Survey 2 – Fish/ Inverts (SCUBA)*	PADI EFR* ▶ Mods Survey dive + data collation	Recreational Dive Graduation! Congratulations on completing the CCC Skills Development Programme Safety brief ▶ Night-diving procedures
	EVE		ID skills evaluation ▶ Re-takes if required	Review Benthic and fish validation results	Lecture 17 ▶ Navigation and GPS:	Lecture 18 ▶ Conservation of coastal and marine habitats (mangrove / seagrass / reefs)	Lecture 20 ▶ Threats to Reefs 1 Data entry – Reef Check Practices	Lecture 21 ▶ Global and regional coral reef initiatives Data entry - database	Data entry – database Optional night dive Party night

* Due to unforeseen circumstances it was not possible to perform any Reef Check surveys

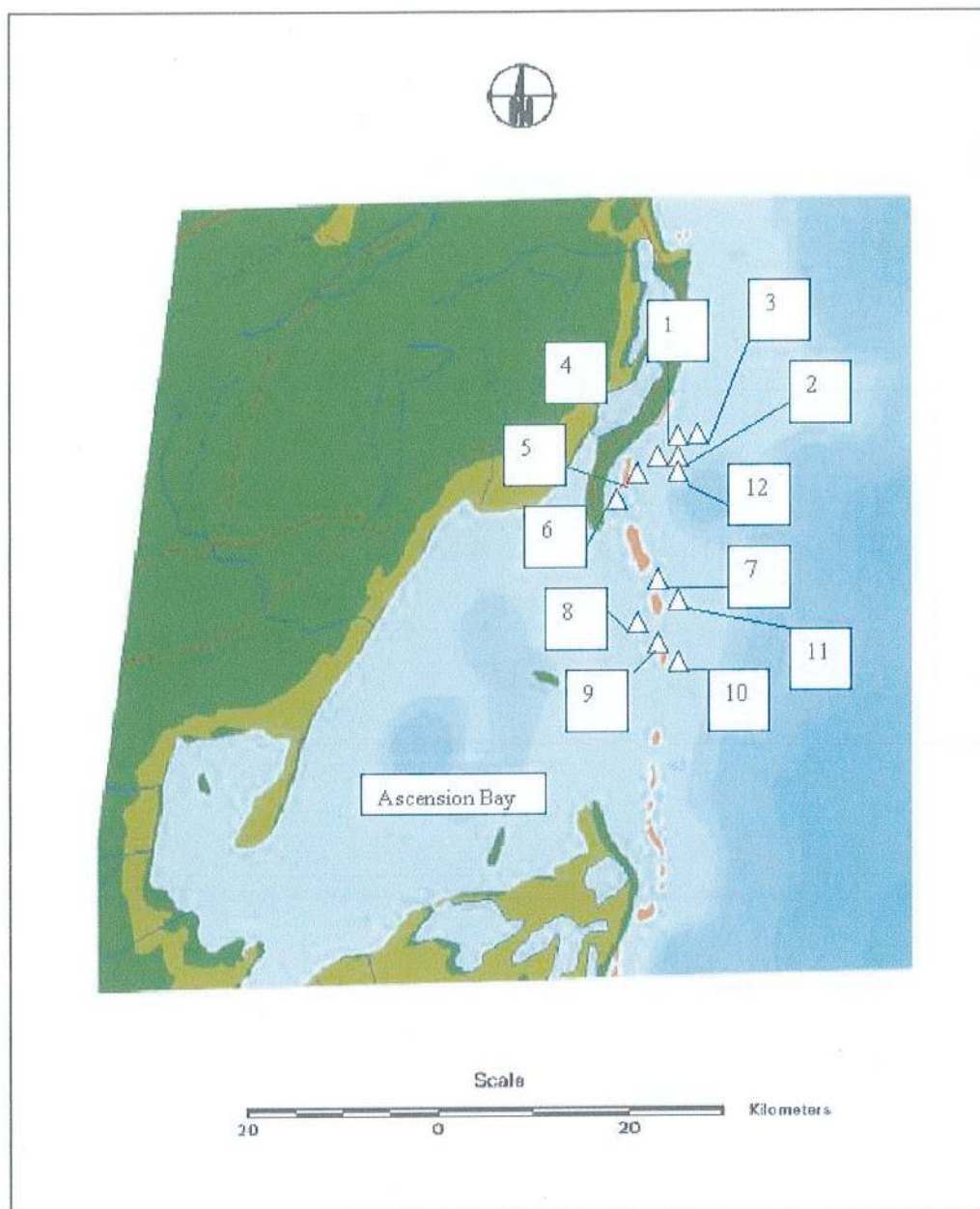


Figure 3. Twelve sites surveyed by SKCRCP – Ascension Bay UNESCO SKBR.

Survey Techniques and Sites

From discussions with the Sian Ka'an Management Team, 12 sites were identified for surveying by CCC volunteers during the three month SKCRCP. These sites consisted mainly of general patch reef environments. The shallow and sheltered nature of each of the 12 sites have meant that the community of Punta Allen have developed small scale snorkel tours for tourists, in an effort to create an alternative livelihood and relieve the complete dependence on the lobster fishery as a sole source of local revenue. Each of the 12 sites within Ascension Bay are indicated in Figure 3.

For the 12 sites volunteers performed point intercept surveys of hard coral, macro algae and other sessile invertebrates, as well as belt transects to monitor adult fish and *Diadema* urchin populations, in accordance with the SMP methodology (Almada-Villela *et al.*, 2003). For each of the 12 designated survey sites (Table 4), six replicates of the point intercept survey and eight replicates of the belt transect survey were undertaken, resulting in a total of 14 transects at each site.

Table 4. Name, buoy number and GPS point for each of the 12 SMP sites within Ascension Bay – most of the names are abbreviations of corresponding named areas on the coast adjacent to the sites.

Buoy Number	Location	GPS Point Long Lat / UTM	Mean Depth m
1	Sol	N19°50'53.2 W87°26'27.9 / 453813.52 2193864.5	2.7
2	Chenchomac	N19°50'41.1 W 87°25'55.3 / 454763.16 2194359.39	15.9
3	Chenchomac 2	N19°50'34.8 W 87° 26'40.1 / 453459.6 2194169.12	1.2
4	La Colonia	N19°50'24.1 W 87°26'12.4 / 454264.44 2193838.11	14.3
5	Punta Allen	N19°48'37.4 W87°27'33.4 / 451899.48 2190564.5	2.5
6	Mikes Reef	N19°47'57.1 W 87°26'53.2 / 453065.71 2189322.58	5.1
7	Dani's Buoy	N19°46'52.0 W 87°26'20.0 / 454026.452187318.95	1.6
8	Niccehabim	N19°44'15.4 W 87°25'18.5 / 455803.97 2182500.72	4.4
9	El Faro	N19°43'46.8 W 87°25'10.2 / 456043.38 2181621.0	3.6
10	El Barco	N19°42'03.1 W 87°25'03.4 / 456233.472178432.92	3.4
11	Dani's Buoy 2	N19°46'54.9 87°25'52.7 / 456197.39 2185883.79	10.8
12	Mike's Reef 2	N19°50'19.7 W87°26'13.9 / 454582.94 2193157.03	8.9

Synoptic Monitoring Programme⁴

The MBRS SMP programme includes the surveying and monitoring of the three most abundant tropical coastal ecosystems; coral reef, seagrass beds and mangroves. CCC was asked to undertake survey work by UNESCO SKBR management team on only coral reefs. Of this CCC was asked to apply *Method 1: Survey of corals, algae and other sessile organisms* and *Method 2: Belt transect counts of defined species lists*.

Method 1: Surveys of corals, algae and other sessile organisms

At each monitoring site, replicate 30m line transects were surveyed by one buddy pair of divers for sessile organisms. Transects were deployed randomly. The 30-m transect line was laid just above the reef surface in a direction perpendicular to the reef slope. Six classes of algae were targeted, 8 sponge life forms, 6 gorgonians and 30 species of scleractinian corals (Appendix 1). Diver 1 measured the percentage cover of sessile organisms and substrate along the 30 m transect, recording the nature of the substrate or organism directly below every 25 cm point along the transect. Divers avoided being selective. Organisms were classified into one of the following groups:

1. *Coralline algae*: crusts or finely branched algae that are hard (calcareous) and extend no more than 2cm above the substratum

⁴ SMP methods have been taken from Almada-Villela *et al* (2003) and adapted slightly for CCC's use.

2. *Turf algae*: may look fleshy and/or filamentous but do not rise more than 1 cm above the substrate.
3. *Macro algae*: include fleshy algae whose fronds are projected more than 1 cm above the substrate.
4. *Sponges*: specific life forms
5. *Gorgonians*: specific life forms and species
6. *Stony corals*: Specific species

Diver 2 was responsible for collecting data on the characterisation of the coral community under the transect. Diver 2 swam along the transect and stopped at the first coral head, cluster, or thicket (or a portion) that was located directly beneath the transect line. These colonies were all at least 10 cm average diameter, and in original growth position. For colonies that had fallen or been knocked over, only colonies were assessed that had become reattached to the substratum or were too large to move. Colonies that were loose and rolling around were ignored. The SMP required a sample of at least 50 coral colonies from each site. For each coral colony surveyed, diver 2 record each of the following:

1. Name to species level.
2. Water depth at the top of the colony at the beginning and end of each transect. In cases where bottom topography was very irregular, or the size of the individual corals vary, water depth was recorded at the top of each coral beneath the transect line at any major change in depth (>1m).
3. The colonies boundaries were identified based on connective or common skeleton. Using a measuring device, the colonie's projected diameter (live + dead areas) in plan view and maximum height (live + dead areas) from the base of the colony's substratum (not from the base of the reef), were measured. The diameter was measured perpendicular to the axis of growth. The height should was measured parallel to the axis of growth. Plan view was assessed from an angle that is parallel to the axis of growth.
4. Diver 2 estimated the percentage of coral that was recently dead and long dead as viewed from above in plan view.

"*Recently dead*" was defined as any non-living parts of the coral in which the corallite structures were white and either still intact or covered over by a layer of algae or fine mud. For recent mortality, there are several stages; *Very recent* showing white intact skeleton still visible (dead within 1 month or less); *Recent* with corallite covered by thin turf algae or sediment (up to 6 months); *Older recent* with corallite structure slightly eroded or covered but can still be identified to genus (< 1-2 yrs), unless covered by clionid sponge. *Long dead* was defined as any non-living parts of the coral in which the corallite structures are either gone or covered over by organisms that are not easily removed (certain algae and invertebrates).

Diver 2 was also responsible for noting down bleaching and disease related impacts to colonies on the transect. Bleached tissue was characterised as the following:

1. *Pale* (discoloration of coral tissues)
2. *Partly Bleached* (patches of fully bleached or white tissue)
3. *Bleached* (tissue is totally white, no zooxanthallae visible)

Disease was recorded using the following nine categories taken from CARICOMP⁵ (Table 5).

Table 5: Coral Disease Categories used in the MBRS-SMP adapted from Almada-Villela *et al* (2003)

Disease	Description
Black Band Disease	Multispecific
White Band Disease	Types I and II (only known in <i>acroporids</i> so far)
White Plague-II	Multispecific
Yellow Blotch Disease	Only described in species of <i>Montastraea</i> but also reported in many other species
Dark Spots Disease I	Small dark areas with no apparent tissue mortality. This disease is common in <i>Siderastrea</i> spp.
Dark Spots Disease II	Large dark areas, larger than DS-I, common in <i>M. annularis</i> and <i>S. intersepta</i>
Red Band Disease	BBD has been seen as red bands too. RBD has been reported for <i>Gorgonia</i> spp. And <i>Agaricids</i> in the Caribbean
Aspergillosis	In <i>Gorgonia ventalina</i> , <i>G. flabellum</i> , <i>P. Americana</i> and other octocoral species as well (<i>Plexaura flexuosa</i>)
Other	This category includes all other “unconfirmed-pathogen-produced” diseases (tumors, hyperplasia, white pox, and all the ‘blotches’)

Method 2: Belt Transect Counts for defined species lists

In a buddy pair, a 30 m transect line was laid out by first placing the weighted end of the line on the bottom (Fig. 4) at a point selected haphazardly within the general confines of the site. The divers swam in a straight line along depth contours so as to minimize changes in depth while releasing the tape from the reel. Eight replicate transects were repeated for each site.

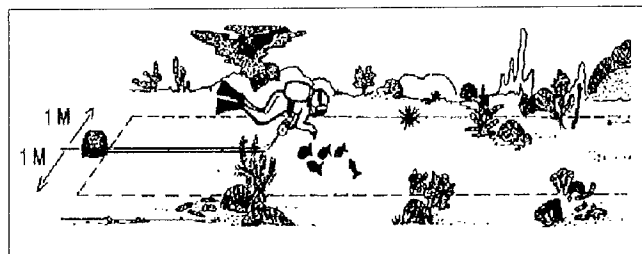


Figure 4: Diagrammatic representation of a diver conducting a belt transect for the MBRS-SMP. From Almada-Villela *et al* (2003).

Diver 1 of the pair was responsible for identifying and counting specific fish species (Table 6), recording those those fish found within a 2 m wide visually estimated belt transect. Only those species listed in Table 6 were counted and juvenile parrotfishes or grunts less than 5 cm in total length were not recorded. This list of species was chosen by the SMP to provide coverage of a number of the species most likely to be affected by anthropogenic impacts, while preserving a relatively consistent search image. Diver 1 also estimated the size of each fish and assigned them to the following size categories: (<5 cm, 5-10, 10-20, 20-30, 30-40, >40 cm).

⁵ <http://www.ccde.org.jm/>

Table 6. Fish species to be included in counts along the 2m wide MBRS SMP belt transects, adapted from Almada-Villela *et al* (2003)

Every species of the following families are included in the survey	
Acanthuridae	surgeonfishes
Chaetodontidae	butterflyfishes
Haemulidae >5cm	grunts
The following species were included in the survey	
<i>Mycteroperca bonaci</i>	black grouper
<i>Epinephelus guttatus</i>	red hind
<i>E. fulvus</i>	coney
<i>E. striatus</i>	nassau grouper
<i>E. itajara</i>	jewfish
<i>E. morio</i>	red grouper
<i>E. adscensions</i>	rock hind
<i>Balistes vetula</i>	queen triggerfish
<i>B. capricus</i>	gray triggerfish
<i>Melichthys niger</i>	black durgon
<i>Aluterus scriptus</i>	scrawled filefish
<i>Catherhines pulles</i>	orangespotted filefish
<i>C. macrocerus</i>	whitespotted filefish
<i>Bodianus rufus</i>	spanish hogfish
<i>Caranx ruber</i>	bar jack
<i>Lachnolaimus maximus</i>	hogfish
<i>Microspathodon chrysurus</i>	yellowtail damselfish
<i>Sphyraena barracuda</i>	barracuda

Diver 2 of the buddy pair was responsible for recording the presence of the following groups, within a 1m belt along the 30m transect.

- *Diadema* spp.
- Pencil urchin *Eucidaris tribuloides*
- Banded coral shrimp *Stenopus hispidus*
- Lobster *Panulirus argus*
- Caribbean spiny lobster *Panulirus argus*
- Triton shell *Caronia variegata*
- Flamingo tongue *Cyphoma gibbosum*

Species lists

Many of the reefs that CCC survey are poorly explored and comprehensive species lists are rarely available. Indeed, species lists for the entire country are often incomplete. Although CCC volunteers and science staff do not usually have the expertise to document the total biodiversity, it is possible to produce species lists of fish and corals observed during survey work. These lists assist the aims of the overall project by providing additional reasons for conservation initiatives, such as the presence of rare species, and may lead to documenting the presence of species not previously recorded from the area or country.

Species lists were compiled during the course of the SKCRCP during survey dives by CCC science staff, who are trained tropical marine biologists, and experienced volunteers. Species were only added when CCC staff had either seen the fish themselves or trusted the sighting of an experienced volunteer. 'Possible' sightings are not included in the lists given in this report. The fish, coral and invertebrate species lists (Appendix 5) were prepared by compiling species records from all areas surveyed in the Ascension Bay area of the UNESCO SKBR. These areas covered mainly seagrass beds, patch reef and shallow outer reef slope environments.

Data analysis

Benthic data

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

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

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

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

Fish and invertebrate data

Fish and invertebrate data were summarised graphically and via descriptive statistics, along with more detailed examination of the data through calculating the total

abundance of each species / life form per 100m² of reef for each of the 12 sites. Standing stock biomass was calculated for fish species recorded by using data obtained from fish base⁶ to calculate a standard weight for each record using the length weight calculation, where length (a)-weight (b) (log a vs b) is calculated then displayed graphically enabling a calculation of weight to be made from a length estimation. The data collected and the subsequent calculation of biomass can only be considered a relative indication to the potential standing stock biomass of the site, due to size estimations being taken within 10cm, and the subsequent size of the fish rounded up to a mean for the purposes of data analysis (i.e. a fish recorded in the 20-30cm size class will have a length of 25cm assigned to it for L-W calculation). The most accurate estimates of standing stock biomass can only be obtained from physically handled specimens to accurately measure them, and not through under water visual census.

Assessment of site Conservation Values

Assigning conservation values to areas of reef within the Ascension Bay area is important in order to select priority areas for marine protected areas (MPAs). 'Conservation value' is a complex term that can be related to biodiversity, fisheries potential, aesthetic value, naturalness, representativeness, uniqueness and tourist potential.

The concept of the establishment of MPAs or areas of special management as in the case of Ascension Bay, is based on the need for environmental stability as well as the influence of socio-economic demands placed on the natural resources of an area. Ideally, MPAs or managed areas should represent the best and most ecologically important areas. This idea is related to the theory that certain reef areas are source reefs that have a net export of larvae whilst other areas are sink reefs that have a net import of larvae (Harding *et al.*, 2003). The concept behind this source and sink reef management is that if the source reefs are protected, they will repopulate the denuded sink reef areas.

Source reefs are reefal areas of good health. The concept of a healthy coral reef community is a complex one and one that relies on a number of variables. In this study, the relative health and therefore the relative management potential of each surveyed area of reef is defined using a range of univariate health indicators, as described in the conservation management value rating technique developed by Comley *et al.* (2003). Each of these indicators is calculated for each transect, which is in itself, a geographically defined data set. The factors used were; mean hard coral cover, Shannon-Weiner Diversity Index of benthic species associated with the site, the Marglef species richness recorded, Shannon-Weiner Diversity Index of fish associated with the site in question, Marglef species richness recorded, and hard coral cover mortality each site.

Mean values of each of these reef health indicators were calculated across all transects. Transect were then assessed in turn to determine how many of its calculated reef health variables were above average. Finally, each site was given a rating using

⁶ <http://fishbase.org>

the number of univariate reef health indicators on which it scored above average. A score of zero on this rating scale equates to the site where none of the six univariate reef health indicator variables were above average across all the transects analysed. By contrast, a site with a score of six belongs to a benthic class where all six variables were above the average value calculated. Each site surveyed during the SKCRCP is comprised of a composite of more than one Habitat Record, each of which may belong to different benthic classes and therefore have differing degrees of reef health.

To facilitate easy interpretation of these values, the following scale was used; where sites scored an overall rating >4 they were classified as of high management potential, from 3-4 as moderate management potential and finally <3 of low management potential. With each of these sites being spatially locatable data sets, a map to show the relative management potential of each site surveyed thus far has been constructed.

Results

A total of 167 transects covering 10,020 m² were undertaken by the SKCRCP between September and December 2003. This comprised of six point intercept transects and 8 belt transects at each of the 12 sites within Ascension Bay. A total of 14,294 individual species, substrate or coral mortality records were recorded.

All maps reproduced in this report have been sourced from Reef base (<http://reefbase.org>) and enhanced using MapInfo or ERDAS imagine.

Multivariate Analysis and Habitat Definitions

The following section presents the dendrogram produced by agglomerative hierarchal cluster analysis as outlined in the methods section (Figure 5). Secondly, using the characteristics of the benthic classes as defined by SIMPER and univariate analysis; a full and quantitative description of each habitat identified is presented in Table 7.

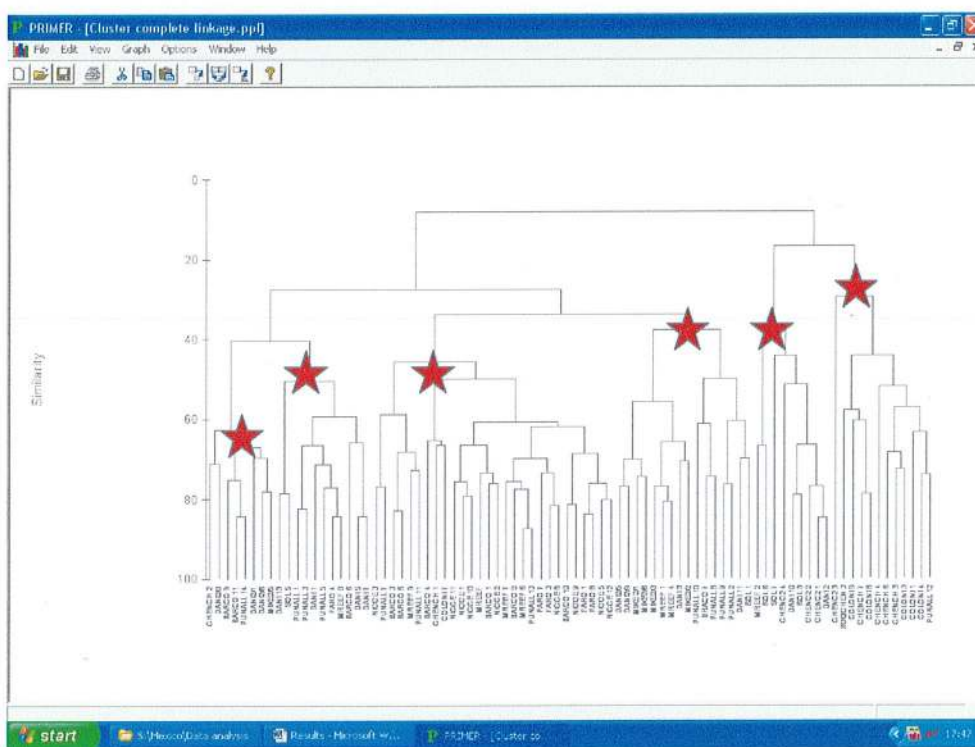


Figure 5.

Screen grab of the dendrogram derived from the cluster analysis of point intercept survey data collected during the SKCRCP. Each line represents benthic and substratum data from each transect. The red stars highlight the major clusters representing the six habitat classes discriminated. Horizontal axis represents similarity as calculated with the Bray- Curtis coefficient (%).

Habitat Descriptions

A total of six statistically discreet habitat groups were defined from the data set collected during the SKCRCP across the 12 sites. Table 7 summarises the main biological and substratum characteristics of each habitat type and provides a quantitative description of each benthic group. The values in the table represent the mean percentage make up of characteristic species or benthic types within each group.

The most abundant habitat was habitat number 3; *Shallow sandy lagoonal environment with sparse mixed gorgonians and Montastraea* (Table 8). This habitat label has was assigned to 33.3% of the transects undertaken across the study site, and occurs in six of the 12 survey sites. The habitat described as *Deep mixed reef dominated by Montastraea and Prorites astreoides with sponge cover* supported the highest mean hard coral abundance; 17.8% (Appendix 2). This habitat label was assigned to 14.3% of the transects, and occurred in four different sites. Hard coral cover was generally quite low across all of the habitats, with algal abundance considered to be reasonably high across most. Habitats 4, 5 and 6 supported mean algal coverage of 37.1%, 54.4% and 38.6% respectively. Gorgonians were highest in habitat 6, supporting a mean coverage of 23.4% (Appendix 2). The six habitats are generally quite shallow, as one would expect in a shallow lagoonal environment with small patch reefs. Habitat 6 recorded the deepest mean depth of 11.6m.

Habitat distributions

Table 9 describes the distribution of habitats across each of the 12 survey sites. Three of the sites, Punta Allen, Mikes Reef and El Barco have four or greater habitats within the site, with Punta Allen supporting five of the six habitats classified. However, 58% of these habitats are described as *Shallow lagoonal environment with exposed substrate / sparse Halimeda and Dictyota* or *Shallow sandy Halimeda and Dictyota dominated substrate with sparse gorgonians and sponges*, so hard coral cover is low with only 8% made up of *Deep mixed reef dominated by Montastraea and Porites astreoides with sponge cover*. Niccehabin supports only one habitat, with a complete habitat made up of *Shallow sandy lagoonal environment with sparse mixed gorgonians and Montastraea*.

Benthic class	Average depth	Substratum	Hard corals	Gorgonians	Sponges	Algae
1	8.2	Bare Rock (43.5%) Sand (31.4%), Bare Rock (30.9%)	<i>Montastraea annularis</i> (5.3%)	Sea rods (6.0%), Sea Plume (5.9%), Sea rods (2.4%)	encrusting sponge (1.0%)	<i>Halimeda</i> (8.5%) <i>dictyota</i> (10.4%) <i>Halimeda</i> (12.1%)
2	2.8	Sand (45.4%)	<i>Montastraea annularis</i> (8.7%) <i>Solenastrea bournoni</i> (2.5%), <i>Montastraea annularis</i> (1.4%) <i>Porites astreoides</i> (3.2%) <i>Acropora palmata</i> (2.8%) <i>Porites furcata</i> (1.6%)	Sea rods (4.2%), sea plume (3.7%) Sea rods (3.9%), sea plume (4.6%)	-	Turf algae (6.6%), <i>Dictyota</i> (6.9%) <i>Halimeda</i> (10.9%) <i>Dictyota</i> (16.9%) <i>Halimeda</i> (18.0%)
3	4.7	Sand (24.1%)	<i>Montastraea annularis</i> (8.4%), <i>Porites astreoides</i> (3.0%)	Encrusting gorgonian (5.1%) Sea rods (4.5%), sea plume (11.6%), sea fan (3.3%)	Encrusting sponge (1.5%)	Turf algae (14.5%) <i>Dictyota</i> (13.8%) <i>Halimeda</i> (23.1%) <i>Dictyota</i> (19.4%) <i>Halimeda</i> (14.0%)
4	5.4	Sand (20.5%)				
5	2.1	Sand (13.6%)				
6	11.6					

Table 7

Quantitative description of the 6 benthic classes defined from the data collected from the 12 sites during the SKRCRP. Figures in parenthesis indicate mean percentage abundances.

Table 8

Total percentage cover of the 6 benthic classes across the 12 sites surveyed during the SKRCRP.

Benthic class	Total % cover	Habitat label
1	9.5	Moderate depth bedrock with sparse gorgonians and hard corals
2	13.0	Shallow lagoonal environment with exposed substrate / sparse <i>Halimeda</i> and <i>Dictyota</i>
3	33.3	Shallow sandy lagoonal environment with sparse mixed gorgonians and <i>Montastraea</i>
4	19.0	Shallow sandy <i>Halimeda</i> and <i>Dictyota</i> dominated substrate with sparse 'gorgonians and sponges.'
5	10.7	Shallow dominated with algae
6	14.3	Deep mixed reef dominated by <i>Montastraea</i> and <i>Porites astreoides</i> with high sponge coverage

Table 9 Percentage cover of the 6 benthic classes across each of the 12 sites surveyed during the SKCRCP

Site	% cover	Habitat label
1. Sol	20	2. Shallow lagoonal environment with exposed substrate / sparse <i>Halimeda</i> and <i>Dictyota</i>
	20	4. Shallow sandy <i>Halimeda</i> and <i>Dictyota</i> dominated substrate with sparse gorgonians and sponges.
	60	5. Shallow dominated with algae
2. Chenchomac	17	1. Moderate depth bedrock with sparse gorgonians and hard corals
	17	4. Shallow sandy <i>Halimeda</i> and <i>Dictyota</i> dominated substrate with sparse gorgonians and sponges.
	66	6. Deep mixed reef dominated by <i>Montastraea</i> and <i>Porites astreoides</i> with sponge coverage
3. Chenchomac 2	13	1 Moderate depth bedrock with sparse gorgonians and hard corals
	37	5. Shallow dominated with algae
	50	6. Deep mixed reef dominated by <i>Montastraea</i> and <i>Porites astreoides</i> with sponge coverage
4. La Colonia	17	3. Shallow sandy lagoonal environment with sparse mixed gorgonians and <i>Montastraea</i>
	83	6. Deep mixed reef dominated by <i>Montastraea</i> and <i>Porites astreoides</i> with sponge coverage
5. Punta Allen	8	1. Moderate depth bedrock with sparse gorgonians and hard corals
	25	2. Shallow lagoonal environment with exposed substrate / sparse <i>Halimeda</i> and <i>Dictyota</i>
	25	3. Shallow sandy lagoonal environment with sparse mixed gorgonians and <i>Montastraea</i>
	33	4. Shallow sandy <i>Halimeda</i> and <i>Dictyota</i> dominated substrate with sparse gorgonians and sponges.
	8	6. Deep mixed reef dominated by <i>Montastraea</i> and <i>Porites astreoides</i> with sponge coverage
6. Mike's Reef	12.5	2. Shallow lagoonal environment with exposed substrate / sparse <i>Halimeda</i> and <i>Dictyota</i>
	50	3. Shallow sandy lagoonal environment with sparse mixed gorgonians and <i>Montastraea</i>
	25	4. Shallow sandy <i>Halimeda</i> and <i>Dictyota</i> dominated substrate with sparse gorgonians and sponges
	12.5	5. Shallow dominated with algae
7. Dani's Buoy	50	2. Shallow lagoonal environment with exposed substrate / sparse <i>Halimeda</i> and <i>Dictyota</i>
	25	4. Shallow sandy <i>Halimeda</i> and <i>Dictyota</i> dominated substrate with sparse gorgonians and sponges.
	25	5. Shallow dominated with algae
8. Niccchabin	100	3. Shallow sandy lagoonal environment with sparse mixed gorgonians and <i>Montastraea</i>
9. El Faro	20	2. Shallow lagoonal environment with exposed substrate / sparse <i>Halimeda</i> and <i>Dictyota</i>
	80	3. Shallow sandy lagoonal environment with sparse mixed gorgonians and <i>Montastraea</i>
10. El Barco	20	1. Moderate depth bedrock with sparse gorgonians and hard corals
	10	2. Shallow lagoonal environment with exposed substrate / sparse <i>Halimeda</i> and <i>Dictyota</i>
	60	3. Shallow sandy lagoonal environment with sparse mixed gorgonians and <i>Montastraea</i>
	10	4. Shallow sandy <i>Halimeda</i> and <i>Dictyota</i> dominated substrate with sparse gorgonians and sponges.
11. Mike's reef 2	25	1. Moderate depth bedrock with sparse gorgonians and hard corals
	75	4. Shallow sandy <i>Halimeda</i> and <i>Dictyota</i> dominated substrate with sparse gorgonians and sponges.
12. Dani's Buoy 2	60	1. Moderate depth bedrock with sparse gorgonians and hard corals
	40	4. Shallow sandy <i>Halimeda</i> and <i>Dictyota</i> dominated substrate with sparse gorgonians and sponges.

Coral disease, bleaching and mortality.

Across the 12 sites, a total of seven species of hard coral were affected by seven diseases, a further seven were effected by coral bleaching and one species; *Diporia strigosa*, was recorded to have been predated by parrotfish (Table 10). Mike's reef had the greatest number of species affected, with black band disease having been recorded on *Montastraea annularis*, bleached *Agaricia agaricetes*, *M. annularis*, *Porites furcata* and *Solenastrea bournoni*, yellow band disease on *M. annularis* and *S. bournoni* showing signs of patchy necrosis/white pox (Table 10). Mike's reef 2 showed only *S. bournoni* to be effected by bleaching, bleaching too had also only effected *M. annularis* on El Faro.

Table 10 Species of hard coral affected by disease, bleaching or parrotfish predation a cross the 12 sites surveyed by the SKCRCP.

		Black band disease										Bleaching										Yellow band disease		Yellow Bloch disease	Parrotfish predation	Red band disease II	White band diseases	Dark spot disease	Patchy necrosis/white pox
		<i>Montastraea annularis</i>	<i>Porites astreoides</i>	<i>Solenastrea bournoni</i>	<i>Agaricia agaricites</i>	<i>Diploria labyrinthiformis</i>	<i>Madracis mirabilis</i>	<i>Millepora alcicornis</i>	<i>Montastraea annularis</i>	<i>Porites astreoides</i>	<i>Porites furcata</i>	<i>Siderastrea radians</i>	<i>Solenastrea bournoni</i>	<i>Montastraea annularis</i>	<i>Siderastrea radians</i>	<i>Diporia strigosa</i>	<i>Porites astreoides</i>	<i>Montastraea annularis</i>	<i>Acropora prolifera</i>	<i>Solenastrea bournoni</i>	<i>Acropora palmata</i>								
1. Sol		■	■																		■								
2. Chenchomac					■				■	■		■																	
3. Chenchomac 2						■	■	■																					
4. La Coloni			■	■					■	■																			
5. Punta Allen												■	■							■									
6. Mike's Reef	■			■					■		■		■	■						■									
7. Dani's Buoy 2											■			■			■	■	■										
8. Niccehabin	■								■				■	■		■													
9. El Faro									■																				
10. El Barco									■				■	■															
11. Dani's Buoy 2					■					■			■		■														
12. Mikes Reef 2												■																	

Bleaching is by far the greatest cause of hard coral mortality across the 12 sites, with all but Sol affected. In total 7.4 m² of hard coral colony mortality was recorded as a result of bleaching across the 12 sites. Yellow band and black band disease were the commonest form of disease, 2.4 m² and 2.1 m² of dead coral colonies were recorded respectively across the 12 sites during the SKCRCP (Table 11). The highest mean

percentage cover of mortality occurred on Mike's Reef with 0.854m² of hard coral colony mortality as a result of diseases or bleaching (Table 11).

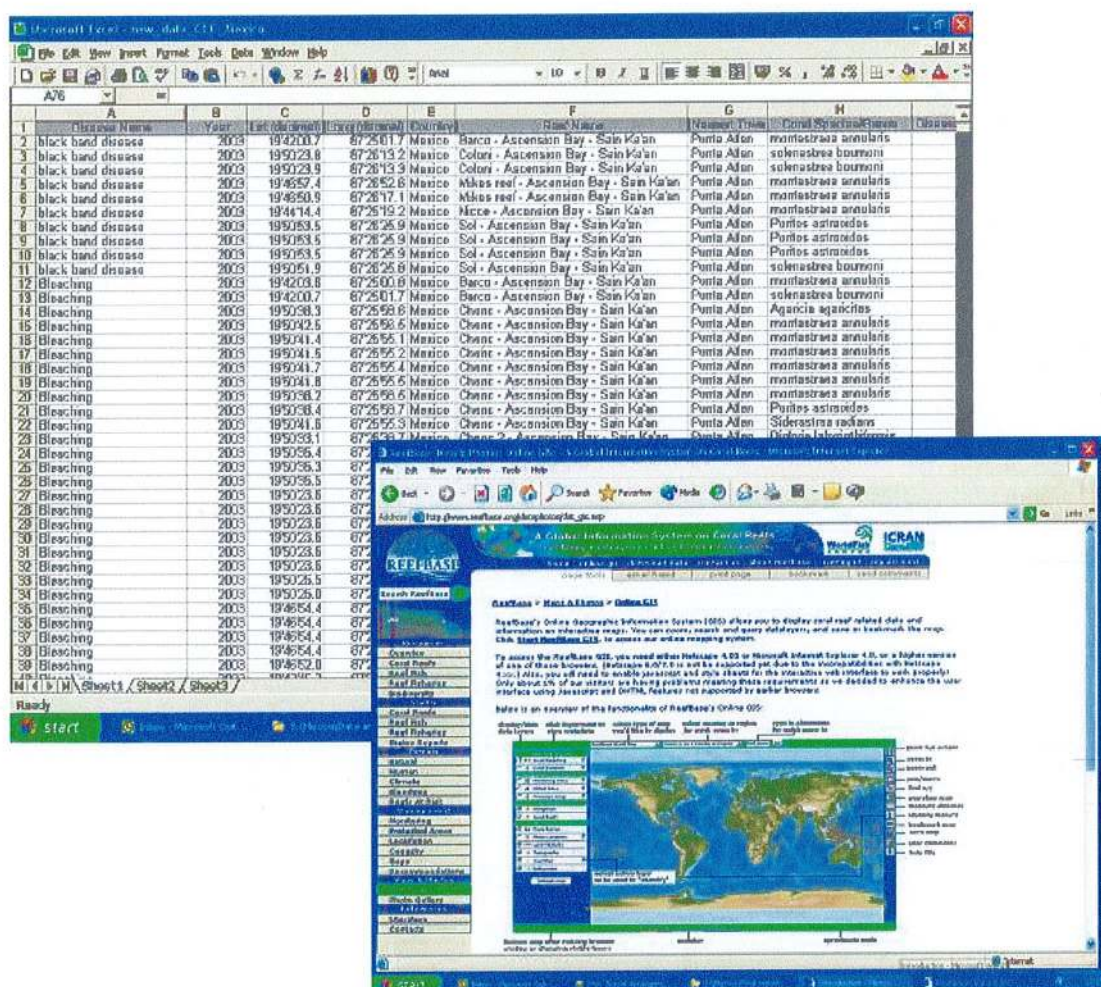


Figure 6

Screen grab example of the SKCRCP data submitted to the WCMC global database for coral diseases and the interactive global database on coral reef health – <http://www.reefbase.org>.

In addition the data collected for coral mortality was entered into the above excel spreadsheet and submitted to the World Conservation Monitoring Centre (WCMC), to contribute to their web based database for global coral disease and mortality. Data was also submitted to the global database on reef health hosted by reefbase - <http://www.reefbase.org>

Table 11. Total abundance (m^{-2}) of coral mortality due to disease or bleaching across the 12 SKCRCP survey sites

Site	Black band Disease		Bleaching		Yellow band disease		Parrotfish predation		Red band disease II		White band disease		Dark spot disease		Patchy necrosis/white pox	
	#	Diseased colonies (m^{-2})	#	Diseased colonies (m^{-2})	#	Diseased colonies (m^{-2})	#	Diseased colonies (m^{-2})	#	Diseased colonies (m^{-2})	#	Diseased colonies (m^{-2})	#	Diseased colonies (m^{-2})	#	Diseased colonies (m^{-2})
1. Sol	0.1	0.4					0.2	0.2							2	2
2. Chenomac			0.4	0.4												
3. Chenomac 2			0.6	0.6												
4. La Coloni	0.1	0.2	0.2	0.2												
5. Punta Allen			0.01	0.01	0.8	0.8							0.3	0.3		
6. Mike's Reef	0.1	1.1	2.6	2.6	0.4	0.4							0	0		
7. Dani's Buoy			0.01	0.01					0.02	0.02	0.2	0.2				
8. Niccehabin	0	0.1	1.9	1.9	1	1	0.005	0.005								
9. El Faro			0.1	0.1												
10. El Barco			1.1	1.1	0.1	0.1										
11. Dani's Buoy 2	0	0.2			0.2	0.2										
12. Mike's Reef 2			0.4	0.4												
Total	0.3	2.1	7.4	7.4	2.4	2.4	0.2	0.2	0.02	0.02	0.2	0.2	0.3	0.3	2	2

Table 12 Abundance of coral mortality due to disease or bleaching per 100 m² of reef at each site.

Site	Black band Disease (m ²)	Bleaching (m ²)	Yellow band disease (m ²)	Parrotfish predation (m ²)	Red band disease II (m ²)	White band disease (m ²)	Dark spot disease (m ²)	Patchy necrosis/white pox (m ²)	Total (m ²)
1. Sol	0.133			0.067				0.667	0.800
2. Chenchonac		0.111							0.111
3. Chenchonac 2		0.25							0.25
4. La Colonia	0.056	0.056					0.042		0.111
5. Punta Allen		0.001	0.111						0.154
6. Mike's Reef	0.229	0.542	0.083						0.854
7. Dani's Buoy		0.002		0.001	0.004	0.042			0.049
8. Nicchabin	0.002	0.352	0.185						0.539
9. El Faro		0.02							0.02
10. El Barco	0.033	0.183	0.017						0.233
11. Dani's Buoy 2			0.067						0.067
12. Mikes Reef 2		0.133							0.133

Fish populations

Of the 66 species listed as target species for the SKCRCP survey programme 48 were recorded across the 12 sites during survey dives. Surveys failed to record queen angelfish (*Holacanthus ciliaris*), four species of Scaridae, five Serranidae and five Balistidae and Monacanthidae. Encouragingly all five species of butterflyfish (Cheatodontidae) were recorded at Dani's Buoy 2. Despite the absence of banded (*Cheatodon striatus*) and longsnout butterflyfish (*C. aculeatus*) Chenchomac recorded an abundance of 9.3 individual butterflyfish per 100m² (Table 13).

Consistently common species recorded across the 12 sites include blue tang (*Acanthurus coeruleus*), yellowtail snapper (*Ocyurus chrysurus*) and bar jack (*Caranx ruber*), as one would expect on most Caribbean reefs. Surveys at Sol recorded individual abundance of 572.9 Acanthuridae per 100m². Fish abundance at this site was generally high, with 222.9 Lutjanidae and 193.8 Haemulidae abundance per 100m² (Table 13).

Species	2. Chenchomac	4. La Colonia	3. Chenchomac 2	5. Punta Allen	6. Mike's Reef	7. Dani's Reef	8. Niccehabin	1. Sol	11. Dani's Reef 2	9. El Faro	10. El Barco	12. Mikes Reef 2
Cheatodontidae												
Reef Butterflyfish	0.5	0.4	0.0	0.1	0.5	0.5	0.4	0.0	1.1	0.0	1.0	0.0
Longsnout Butterflyfish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Four-eye Butterflyfish	6.7	3.0	0.0	4.2	5.2	1.7	1.1	0.0	2.4	1.9	0.5	1.7
Banded Butterflyfish	0.0	0.0	0.0	0.5	0.0	0.9	0.2	0.0	0.9	0.0	0.2	1.2
Spotfin Butterflyfish	2.1	0.2	0.0	0.4	0.7	0.3	0.4	0.0	0.2	2.9	0.7	0.2
Total	9.3	3.5	0.0	5.3	6.4	3.3	2.0	0.0	4.8	4.8	2.4	3.1
Scaridae												
Stoplight Parrotfish	2.6	0.7	0.0	1.8	1.7	0.2	1.9	12.5	1.5	4.3	1.4	1.4
Redband Parrotfish	0.7	2.0	0.0	1.0	1.2	0.0	0.4	0.0	1.3	1.0	0.7	1.7
Redtail Parrotfish	0.5	0.2	0.0	0.3	0.7	0.2	0.7	2.1	0.7	0.2	0.7	0.7
Princess Parrotfish	1.0	1.5	0.0	0.6	1.9	0.0	0.7	4.2	2.8	1.4	0.0	1.2
Striped Parrotfish	0.5	0.6	0.0	0.4	0.0	0.6	1.3	2.1	2.6	4.3	0.5	1.7
Blue Parrotfish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2
Total	5.2	5.0	0.0	4.1	5.5	0.9	5.0	20.8	8.9	11.4	3.3	6.9
Lutjanidae												
Cubera Snapper	0.0	0.0	0.3	0.0	0.0	0.0	0.0	20.8	0.0	0.0	0.0	0.2
Mahogany Snapper	0.2	0.0	0.3	0.6	0.7	0.0	0.4	6.3	0.6	1.0	0.0	0.7
Mutton Snapper	0.0	0.0	0.3	0.8	1.2	0.0	0.2	2.1	0.6	0.0	0.0	0.0
Dog Snapper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.2	0.0	0.0	0.0
Lane Snapper	0.0	0.0	0.0	0.0	0.0	0.2	0.0	14.6	0.6	0.2	0.0	0.0
Red Snapper	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.2	0.0	0.0
Grey Snapper	0.0	0.0	0.3	1.7	0.0	0.0	0.9	2.1	0.2	0.5	0.0	0.0
Schoolmaster	1.2	0.2	17.0	20.8	1.4	8.2	1.1	97.9	0.4	0.5	0.0	0.7
Yellowtail Snapper	9.5	7.8	16.3	3.2	2.9	3.2	3.1	72.9	8.9	1.9	11.4	7.4
Total	11.0	8.0	34.7	27.1	6.2	11.5	5.7	222.9	11.3	4.3	11.4	9.0
Acanthuridae												
Doctorfish	0.7	0.9	1.7	2.9	0.2	8.9	12.0	158.3	1.9	1.4	2.4	1.9

Blue Tang	9.3	11.9	12.7	11.8	4.5	30.2	21.7	387.5	14.8	13.3	2.1	8.1
Ocean Surgeonfish	3.8	5.4	0.7	4.4	3.3	7.6	1.5	27.1	5.7	1.2	2.4	5.7
Total	13.8	18.1	15.0	19.1	8.1	46.7	35.2	572.9	22.4	16.0	6.9	15.7
Serranidae												
Tiger Grouper	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nassau Grouper	0.2	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.5	0.0
Red Hind	0.0	0.0	0.0	0.1	0.2	0.3	0.9	2.1	0.2	0.0	0.2	0.2
Rock Hind	0.5	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.5	0.0	0.0
Yellowfin grouper	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1.2	0.0	0.0	0.1	0.5	0.3	1.1	4.2	0.2	0.5	0.7	0.2
Haemulidae												
French Grunt	1.7	0.7	3.7	54.7	8.8	3.0	3.9	45.8	4.3	2.9	1.9	1.2
Bluestriped Grunt	0.2	0.6	2.3	70.9	11.2	2.1	4.1	20.8	2.0	0.5	1.9	0.7
Smallmouth Grunt	0.0	0.0	0.0	1.5	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.0
Caesar Grunt	1.0	0.0	9.7	47.8	9.5	7.9	2.8	110.4	2.6	1.2	2.9	0.2
Spanish Grunt	0.5	0.0	0.3	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.5
Striped Grunt	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Sailors Choice	0.0	0.0	0.7	2.6	0.2	0.0	0.4	2.1	0.0	3.3	29.5	0.0
Tomtate	0.0	0.0	0.0	0.9	1.2	0.0	0.6	0.0	0.0	2.6	0.2	0.0
White Margate	0.0	0.0	0.3	0.0	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.0
Porkfish	1.9	0.4	0.0	0.3	3.8	0.3	0.4	8.3	0.4	0.2	0.7	0.2
Black Margate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.2	0.0	0.0
Total	5.2	1.7	17.0	178.7	35.0	13.5	12.4	193.8	9.3	11.2	37.1	2.9
Other												
Bar Jack	6.7	2.8	6.7	2.1	6.4	12.4	13.1	20.8	2.0	2.9	6.4	1.7
Barracuda	1.0	0.0	0.3	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.2	0.2
Spanish Hogfish	1.7	0.7	0.7	0.6	2.4	0.3	0.2	0.0	0.9	0.5	0.2	0.5
spotted trunkfish	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Queen Triggerfish	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Hogfish	0.2	0.2	0.0	0.0	0.5	0.3	0.0	0.0	0.0	0.0	0.2	0.2
Rock Beauty	3.8	2.0	0.3	0.0	0.2	0.2	0.4	0.0	1.9	0.2	0.0	0.7
Grey Angelfish	1.4	0.0	0.3	1.0	0.7	1.1	0.9	0.0	0.9	1.4	0.2	0.5
French Angelfish	0.0	0.0	0.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	15.5	6.1	8.3	4.9	10.7	14.2	16.5	20.8	5.7	5.0	7.4	4.0

Table 13 Abundance per 100m² of each target species of fish recorded across the 12 sites during the SKCRCP. Totals marked bold indicate total mean abundances greater than the regional mean abundance for Atlantic and Caribbean reefs according to Hodgson and Liebeler (2002).

Standing stock biomass

Figure 7 shows the relative percent biomass structure for commercially exploited fish families across each site. Although no general trend can be observed, some families were recorded at all sites, namely Lutjanidae, Haemulidae and Acanthuridae.

Figures 8-19 show the biomass of the commercial fish families per 100 m² at every surveyed site. Chenchomac (Fig. 8) proved to be the only site where all nine families were recorded. It is interesting to note that the deeper sites (La Colonia, Fig. 18, Chenchomac, Fig. 8, Dani's Buoy 2, Fig. 14 and Mike's Reef 2, Fig. 16) showed a

wider diversity of these commercial fish species. The shallower sites generally had fewer of these families.

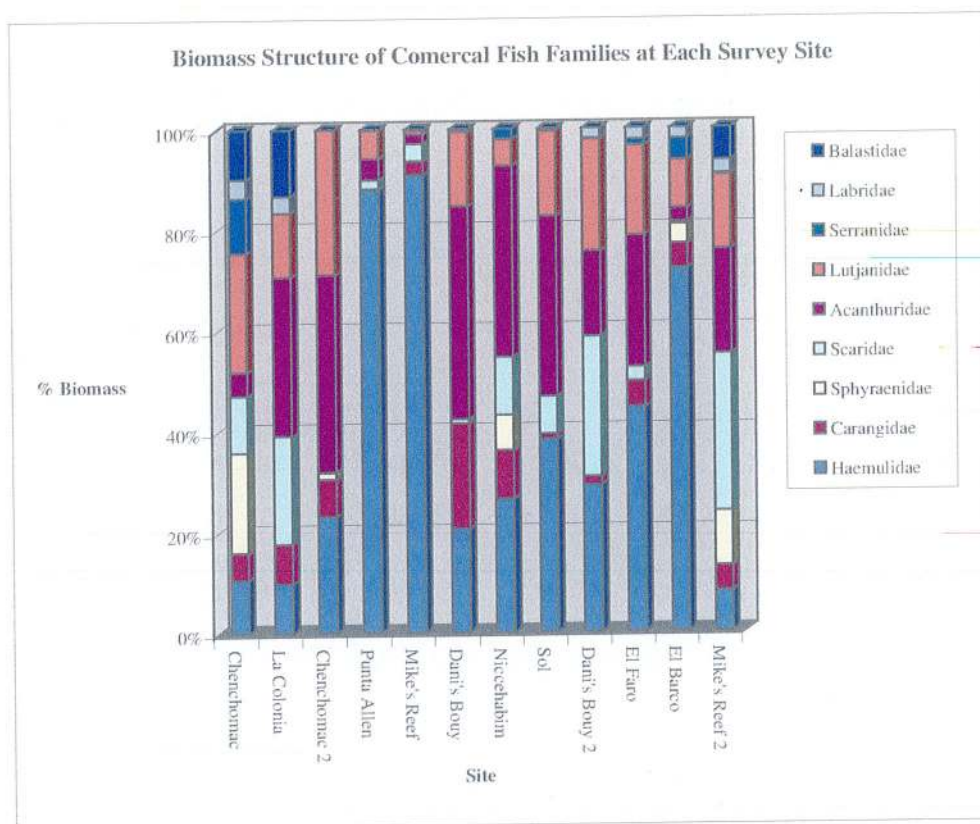


Figure 7 Biomass structure of commercial fish families at each site

Another interesting point to note is the extremely high values of Haemulidae biomass calculated at Mike Reef and Punta Allen (Fig 9 & 11). These values are in the region of 10-fold higher than the rest of the surveyed sites (50 Kg at Mike's Reef vs. 2.51 Kg at El Faro). Grunts were therefore clearly dominant in these two sites.

Serranidae, Sphyrnidae and Balastidae were the fish families with smaller biomass and also fewer occurrences. Balastidae were only recorded at La Colonia and Chenchomac; Serranidae were seen in Barco, Faro, Chenchomac and Sol, all of them in values lower than 0.50 kg; Sphyrnidae were recorded at Chenchomac, Chenchomac 2 and Barco.

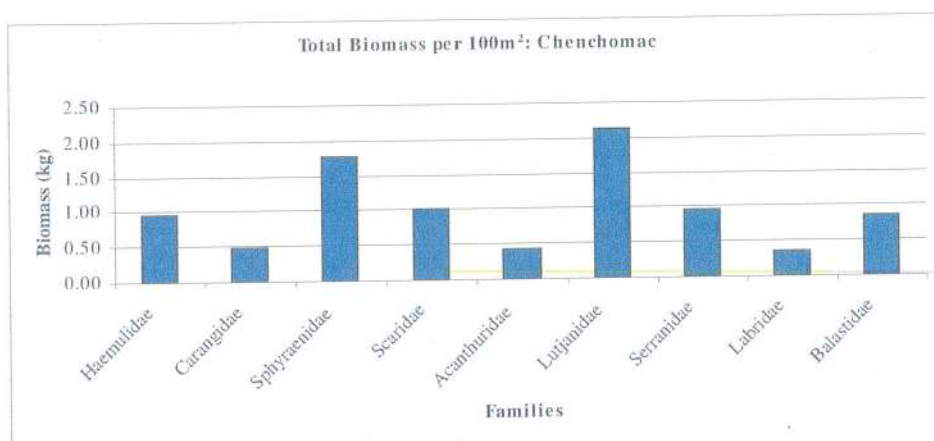


Figure 8 Standing stock biomass for Chenchomac in kg per family per 100m2

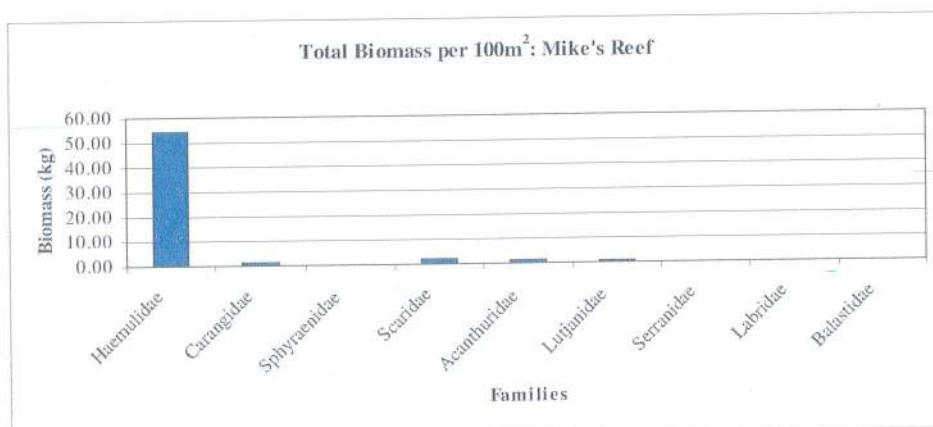


Figure 9 Standing stock biomass for Mike's reef in kg per family per 100m2

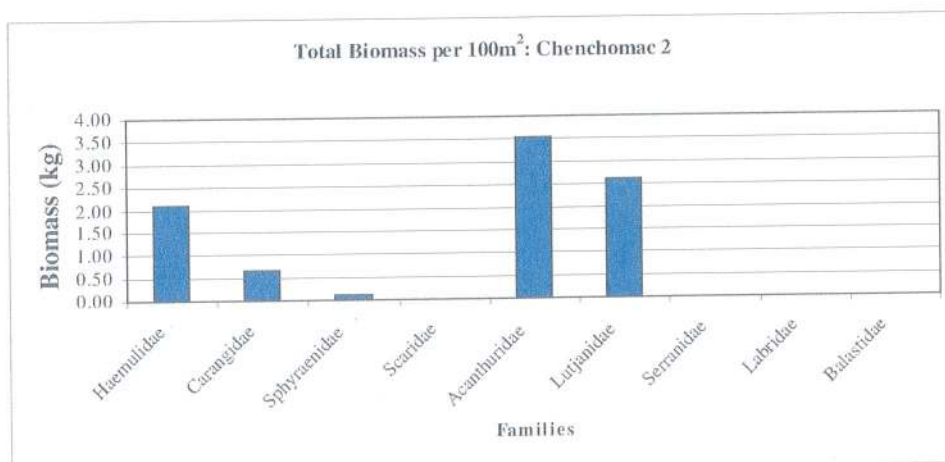


Figure 10 Standing stock biomass for Chenchomac 2 in kg per family per 100m2

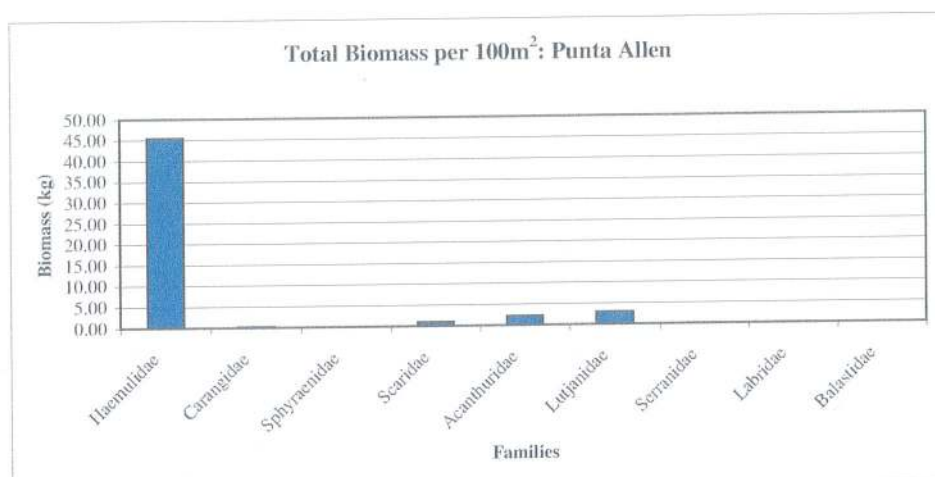


Figure 11 Standing stock biomass for Punta Allen in kg per family per 100m²

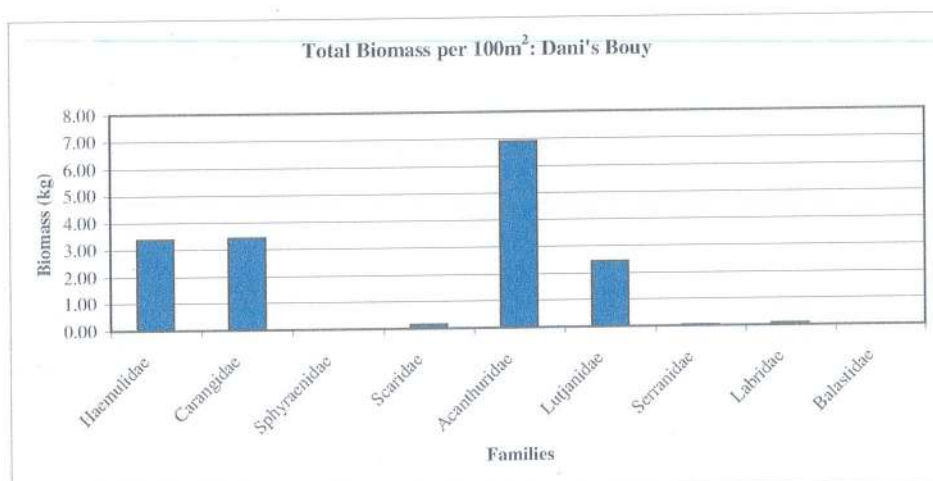


Figure 12 Standing stock biomass for Dani's Bouy in kg per family per 100m²

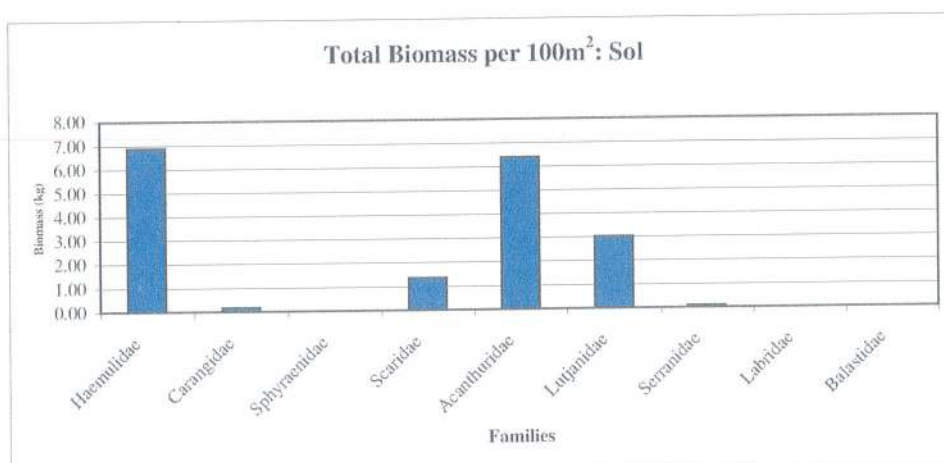


Figure 13 Standing stock biomass for Sol in kg per family per 100m²

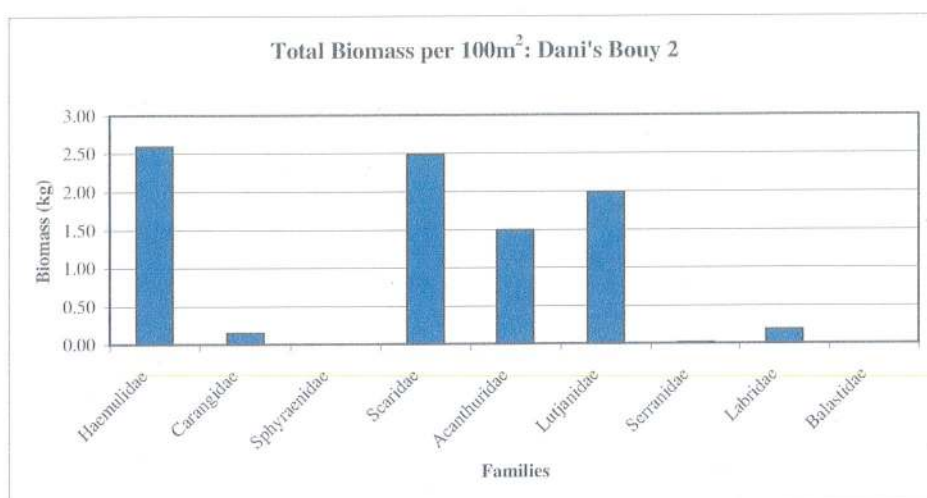


Figure 14 Standing stock biomass for Dani's Bouy 2 in kg per family per 100m²

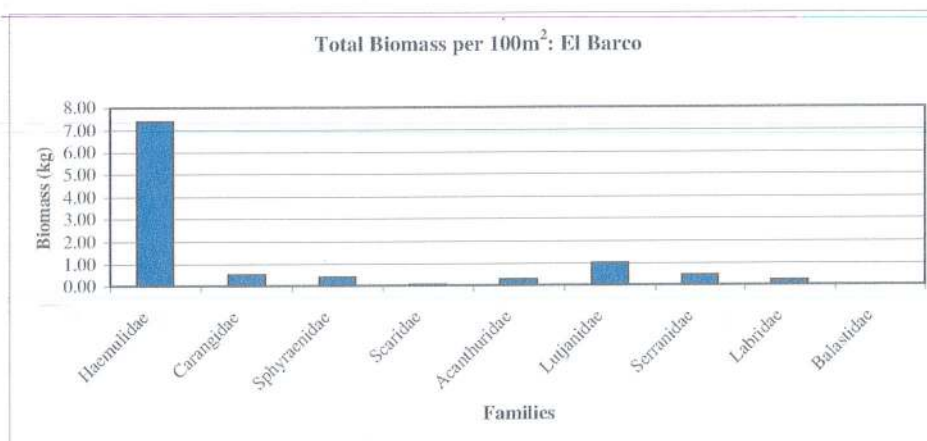


Figure 15 Standing stock biomass for El Barco in kg per family per 100m²

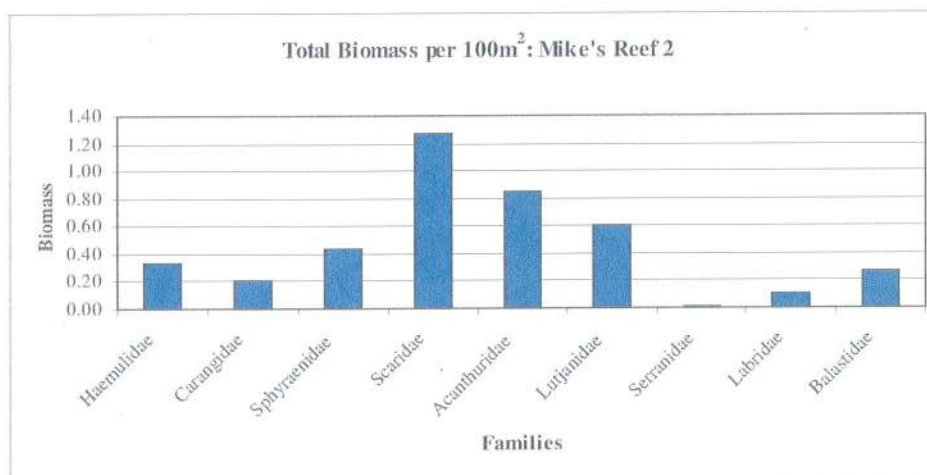


Figure 16 Standing stock biomass for Mike's Reef 2 in kg per family per 100m²

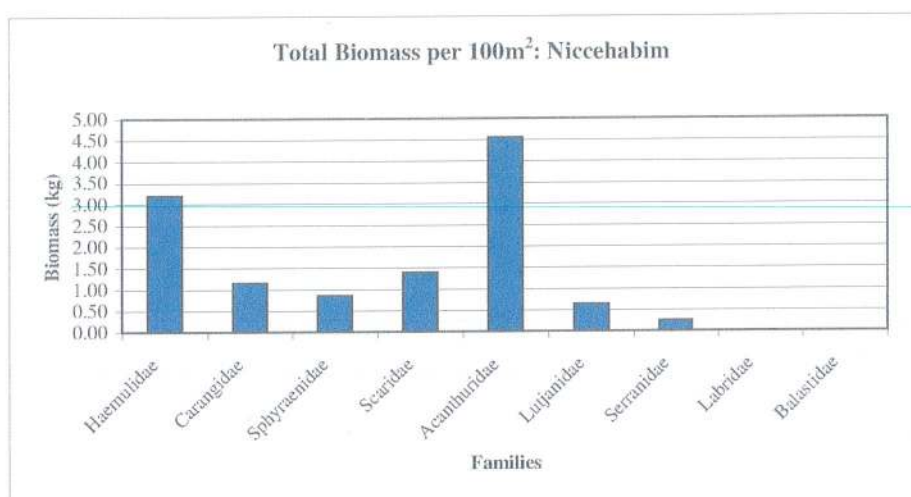


Figure 17 Standing stock biomass for Niccehabim in kg per family per 100m²

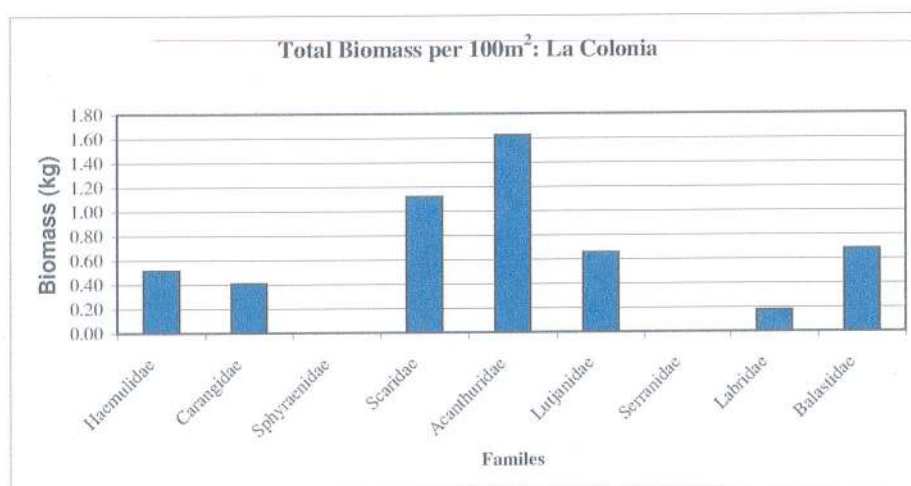


Figure 18 Standing stock biomass for La Colonia in kg per family per 100m²

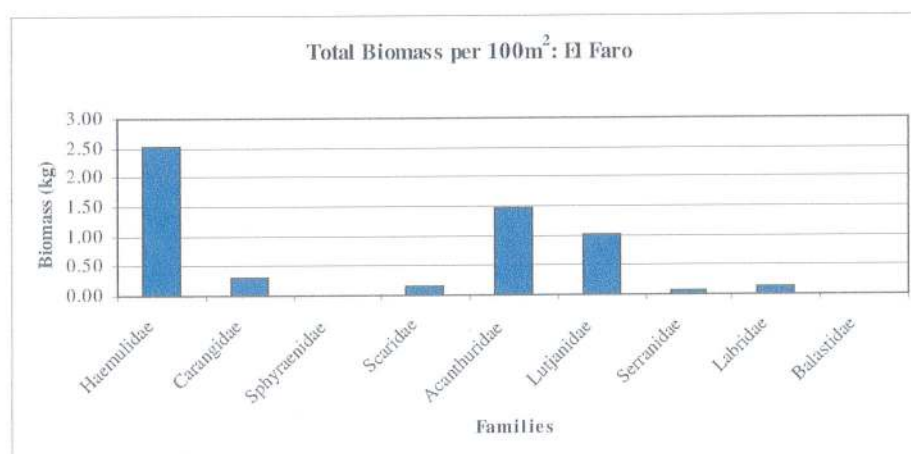


Figure 19 Standing stock biomass for El Faro in kg per family per 100m²

Invertebrate Populations

Of the six target groups or species of invertebrate surveyed, urchins were the most abundant and common, pencil urchins or *Diadema* spp occurring at every site. Sol recorded a mean abundance of 3.5 urchins per 100m². Chenchomac recorded a mean average abundance of 2.4 coral shrimp per 100m² and encouragingly the regionally scarce tritons trumpet (*Charonia variegata*) was recorded at Punta Allen, Mike's reef, Niccehabim, Sol and Mike's reef 2 (Table 14). Lobster (*Panulirus argus*) were also recorded at 9 of the 12 sites.

Table 14 Total abundance per 100m² of each target species of invertebrate recorded across the 12 sites during the SKCRCP. Totals marked in bold indicate total mean abundances greater than the regional mean abundance for Atlantic and Caribbean reefs between 1997-2001 (Hodgson and Liebel 2002).

species	Chenchomac	La Coloni	Chenchomac 2	Punta Allen	Mikes Reef	Dani 's Bouy	Niccehabim	Sol	Dani Buoy 2	El Faro	El Barco	Mike's Reef 2
Banded coral shrimp	2.4	0.9	0.0	0.5	1.0	0.6	0.6	0.0	0.4	2.1	0.2	0.0
Diadema spp.	0.5	0.4	1.3	0.3	0.0	0.3	1.1	3.5	0.4	0.5	0.2	0.0
Flamingo tongue	0.0	0.0	0.0	0.0	0.7	0.0	0.7	0.0	0.0	0.0	0.0	0.0
Lobster	0.0	0.6	0.0	1.2	1.9	0.5	1.1	0.0	0.4	0.5	0.2	0.7
Pencil urchins	0.7	0.2	3.3	0.8	1.4	0.2	0.6	0.2	0.2	0.2	0.2	0.2
Triton shell	0.0	0.0	0.0	0.1	0.7	0.0	0.2	0.8	0.0	0.0	0.0	0.2

Management Value

Harding et al (2003) and Harding et al (in press) have developed a simple, unique and effective method of assigning a relative conservation management value to areas of reef within a region using certain biological variables. Results based on these methods of data analysis have been developed for the 12 sites included in the SKCRCP. Table 16 briefly summarises the major biological characteristics (reef health indicators) of each of the 12 survey sites and gives each site a 'score' in terms of the number of occasions a site's biological attributes exceed the mean values (except in the case of disease/bleaching where a >average value is scored with a 0).

Table 15

Calculated values for six reef health indicators: four for benthic sessile organisms and 2 for fish assemblages associated with each of the 12 survey sites. Values in bold exceed the calculated average value for that variable at that site (except for the case of disease /bleaching where a value >average was assigned a 0). The final column describes the relative conservation management value for each of the 12 sites.

Site	Live substrate				Fish		Number of variables >average	Conservation management value
	Disease/bleaching total mean	% Hard coral cover	abundance per 100m ²	Marglef species richness	Log _e Shannon-Weiner index	Marglef species richness	Log _e Shannon-Weiner index	
Sol	17.51	0.80	1.60	1.55	2.51	1.66	1	Low
Chenchomac	26.46	0.11	3.01	2.19	3.33	2.29	6	High
Chenchomac 2	8.13	0.25	1.28	1.31	2.01	1.72	1	Low
La Colonia	17.89	0.11	3.21	2.19	2.31	1.67	4	Medium
Punta Allen	5.05	0.15	1.95	1.65	1.99	1.51	1	Low
Mike's Reef	11.42	0.85	2.43	1.96	2.74	1.98	4	Medium
Dani's Buoy	5.77	0.05	1.65	1.43	1.68	1.40	1	Low
Niccehabim	12.28	0.54	2.10	1.85	2.73	1.88	4	Medium
El Faro	10.69	0.02	2.54	2.01	3.31	2.13	4	Medium
El Barco	6.18	0.23	1.94	1.76	2.35	1.70	1	Low
Dani's Buoy 2	11.98	0.07	3.23	2.05	2.88	2.09	5	High
Mike's Reef 2	11.74	0.13	2.87	2.02	2.64	1.92	5	High
Mean	12.12	0.29	2.27	1.81	2.53	1.82		

Using this ranking system, three sites, Chenchomac, Dani's Buoy 2 and Mike's Reef 2 all have >5 reef indicators greater than the calculated averages across all sites. Chenchomac has all six of the reef indicators greater than the calculated averages across all habitats, and is therefore arguably of the greatest conservation management value. Hard coral cover was the highest at this site at 26.46%, with 66% of the surveys undertaken at Chenchomac classified as, and assigned the habitat label of *Deep mixed reef dominated by Montastraea and Porites astreoides with sponge*. Chenchomac 2, Sol Punta Allen, Dani's Buoy and El Baco all score low in this management-rating scheme. These results are represented by a simple colour coded GIS (Fig. 20). This tool allows a visual reference to be made to the location of each survey site and its relative conservation management value.

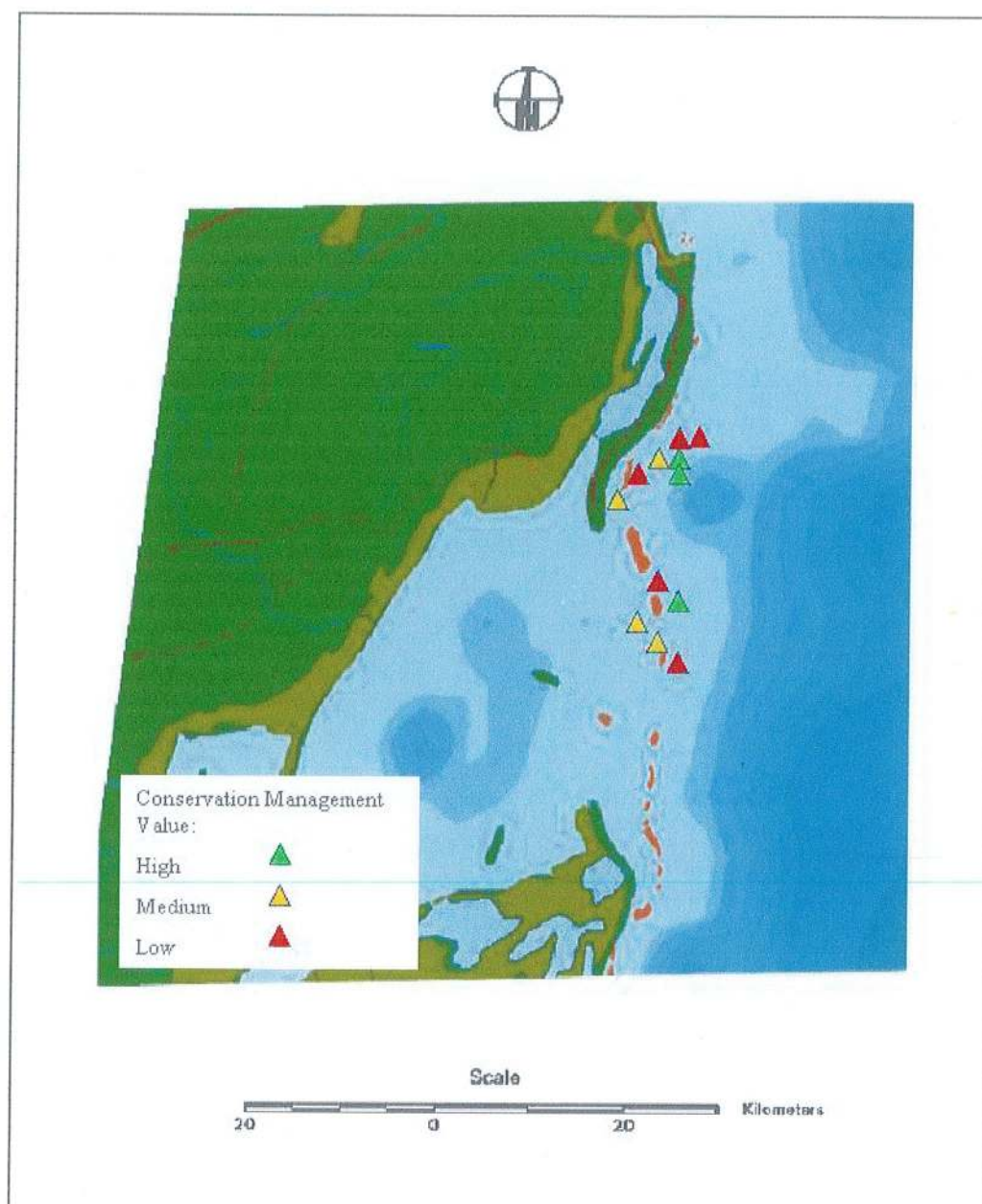


Figure 20 Basic geographical information system (GIS) representing the relative conservation management values of the 12 sites surveyed by the SKCRCP. Green represents a High conservation management value, yellow a Medium and red a Low in accordance with the methods described by Harding et al 2003.

Species List

A total of 101 species of fish were recorded by the SKCRCP from 35 families during survey and non-survey diving (Appendix 4). Fish species diversity was high considering all surveys and nearly all diving was confined to reefs shallower than 20m, with the vast majority shallower than 10m. From a conservation point of view, three species of sharks (lemon shark - *Negaprion brevirostris*, bull shark –

Carcharhinus leucas and nurse shark *Ginglymostoma cirratum*) were recorded as present in Ascension Bay. Other commercially targeted species such as Grouper (*Epinephelus morio*, *Myceteroperca tigris*, *Epinephelus guttatus*, *Epinephelus adscensionis* and *Cephalopholis fulva*), snook (*Centropomus underdecimalis*) and tarpon (*Megalaops atlanticus*) were in reasonable abundance, indicating medium to low levels of fishing pressure, probably a result of lobster (*panulirus argus*) being the main target species of the local fishery. Five of the six species of butterflyfish (Chaetodontidae) were recorded, with only bank butterflyfish (*Cheatodon aya*) absent, but unsurprising as the species has a preference for deep-water reefs >30m. Interestingly longsnout seahorses (*Hippocampus reidi*) were recorded, a species belonging to a family that is becoming increasingly rare due collection for the aquarium trade and traditional Chinese remedies.

The total number of fish species recorded was greater than that of Salat *et al* (2002), but less than the 128 species recorded by Nunez-lara *et al* (2003) in the northern reaches of the Reserve (Table 16). Forty-five species of coral were recorded by the SKCRCP, a number comparable to results from Ruiz-Zarate *et al.*, (2003) and Beltran-Torres & Carricart-Ganivet, (1999) where species were encountered in the Reserve and southern Quintana Roo respectively.

Table 16 Number of species for different taxa reported by this and other studies from the UNESCO SKBR region of Quintana Roo – full species lists for SKCRCP are listed in Appendix 5.

Reference	Area	Taxa	Number of species
Sian Ka'an Coral Reef Conservation Project 2003	Ascension Bay area	Reef fish	101 (35 families)
Salvat <i>et al.</i> , 2002	UNESCO SKBR	Reef fish	85
Nunez-lara <i>et al.</i> , 2003	Northern area of UNESCO SKBR	Reef fish	128 (43 families)
Sian Ka'an Coral Reef Conservation Project 2003	Ascension Bay area	Coral	45 (15 families)
Padilla <i>et al.</i> , 1992	Northern area of UNESCO SKBR	Coral	64 (37 scleractinian, 27 gorgonian)
Gutierrez <i>et al.</i> , 1993	Northern area of UNESCO SKBR	Coral	42 (scleractinian)
Ruiz-Zarate, <i>et al.</i> , 2003	Southern area of UNESCO SKBR	Coral	41(scleractinian)
Ruiz-Zarate, <i>et al.</i> , 2003	Mahahual region south of UNESCO SKBR	Coral	46 (scleractinian)
Beltran-Torres & Carricart-Ganivet, 1999	Central-southern Quintana Roo	Coral	47(scleractinian)
Sian Ka'an Coral Reef Conservation Project 2003	Ascension Bay area	Algae	31
Sian Ka'an Coral Reef Conservation Project 2003	Ascension Bay area	Marine invertebrates	23

Environmental Education Programme

A formal open day was undertaken to introduce CCC and the work programme to the local community of Punta Allen. This was followed by approaching the four schools within the community and offering a structured, marine based environmental education programme. CCC was welcomed into the community, and the local schools

accepted the offer of a fun based, marine awareness education program as detailed in Table 17 below.

Table 17 Summary of the SKCRCP schools environmental education program

Date	School	Activity/ education program
15/10/03	Jardin de Infancia (JI)	What is a coral Started building a 3-D coral reef, explaining characteristics of different reef creatures.
20/10/03	Primaria (PR)	Introduction to Coral Reefs. what kind of organisms are they? Coral Reefs around the world, with a little quiz Associated habitats to coral reefs (Mangroves and sea grass beds) and their importance.
22/10/03	Guarderia (GR)	Introduction to key spp with pictures, and painting activities.
29/10/03	JI	Finish 3-D reef. Introduction to 'where different animals live in the reef' and relate it with the 3-D model
30/10/03	PR	Reef Biodiversity - Important Spp - Food chains - Spp I.D. games
5/11/03	GR	Painting activities on 'Marine creatures'
7/11/03	Tele-Secundaria (TS)	Introduction to Coral Reefs, what kind of organisms are they? Coral Reefs around the world, with a little quiz Associated habitats to coral reefs (Mangroves and seagrass beds) and their importance.
12/11/03	JI	Creation of 'Marine Creature' with <i>Papier Macher</i>
12/11/03	PR	Threats and problems of the reef - Natural - Anthropogenic - Sustainable use of resources - Reserve of the Biosphere Sian Ka'an.
18/11/03	PR	Day out on the Reef
20/11/03	TS	Reef Biodiversity - Important Spp - Food chains - Spp I.D. games
02/12/03	JI	Creating marine animals with geometric figures (colour paper). Last day at JI
04/12/03	PR	Evolution and adaptation on the reef. followed by a slide show. Last day in the PR

Guarderia (2-4 years old)

Jardin de Infancia (4-6 years old)

Primaria (6-12 years old)

Tele-secundaria (12-16 years old)

A specially designed poster entitled "Life on the Coral Reef" was produced in Spanish through a grant from the British Foreign and Commonwealth Office (Fig. 23a). The poster was designed to be used as an education tool by school children. The poster illustrates the main species to be found within a Mesoamerican reef environment, and highlights the main threats facing coral reefs within the region. Copies of the poster can be obtained free of charge for educational purposes by applying the first author at the address on the front of this report.



Figure 21 Creating marine animals with geometric figures (colour paper), Jardín de Infancia.



Figure 22 Preparing for the day of snorkelling with Primaria.



Figure 23a Creation of 'Marine Creature' with Papier Marche at Jardín de Infancia.



Figure 23b Reef Environmental education poster designed for school children. Funded with a grant by the Foreign and Commonwealth office of the UK government.

Discussion

Training

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

Benthic data

A total of six benthic habitats have been defined from the data derived from advanced MBRS SMP methods undertaken during the SKCRCP. These six statistically, discreetly different habitats are likely to be a fair representation of all the reef habitats that can be found in the shallow patch reef environment of Ascension Bay, based on the geographic spread and quantity of data collected. The total 45 species of coral, (spanning 15 families) recorded during the SKCRCP, lower than any other published species list for the Reserve. This is possibly attributed to the relatively small geographical area surveyed, and habitat constraints of the shallow sites only allowing for colonisation of certain species. Thirty-one species of algae were recorded, of approximately 600 described for the Caribbean (Litter et al, 1989). Positive algae identification will always prove difficult for the non specialist taxonomist to undertake.

Those habitats occurring at slightly greater depth; (habitat 1 and 6), support slightly higher coral cover of 17.8 and 12.7% respectively, than the shallower habitats 2, 3, 4 and 5. These habitats that support total algal cover of between 24 and 55%. Hard coral cover was reported to have decreased generally across the reefs of the wider Caribbean by as much as 80% over the last three decades from 50% total hard coral cover to just 10% (Gardner *et al*, 2003). Therefore habitats 6 and 1 represent environments that are generally healthier, in terms of hard coral cover than the mean for the reefs of the region. But if one was to compare the results of slightly earlier survey work reported by Amada-Villa, *et al* (2002), the reefs for Sian Ka'an supported mean hard coral cover of 20.3%. *Montastraea annularis* was by far the dominate species of hard coral across all sites, comprising >5% of the total benthos in habitat 1, 3 and 6. This is encouraging, as Gardner, *et al* (2003) has described a general shift amongst Caribbean reefs where by communities dominated by framework builders such as *Acropora* and *Montastrea* are being replaced by non framework builders such as *Agaricia* and *Porites* and sponges. These results are confirmed by Salvat *et al* (2002) for reefs generally within the reserve, and according to the findings of Ruiz-Zarate *et al* (2003) *M. annularis* colonies increase to 14.9% of the mean benthic cover on fore reefs of 8-12m. Habitats 5 and 6 both recorded abundances of *Porites astreoides* of >3% total cover.

Partly bleached colonies were recorded at 11 of the 12 sites, but impacts appear not to be as great for the sites surveyed by Ruiz-Zarate *et al* (2003), who recorded 18-35% of the large stony corals to be bleached in the extreme north and south of the Reserve on the fore reef areas. With the aid of information from the WCMC, 7 diseases were

positively identified infecting 11 species of hard coral across the 12 sites with yellow band disease affecting *M. annularis*, as suffering the greatest impact. Interestingly Spalding et al (2001) only list 1 coral disease as being recorded in the whole of Mexico. Ruiz-Zarate et al (2003), recorded white plague disease, yellow blotch disease, black band disease, dark spot disease and a form of red band disease to the north of UNESCO SKBR. Incidences of disease and partial bleaching are cause for concern across the reefs surveyed in Ascension Bay.

Gorgonians feature strongly in the make up of habitats 1, 3, 4 and 6, with totals of >12% cover. Indeed habitat 6 supported 23.4% coverage of gorgonians. Sea fans (*Gorgonia* sp) were recorded as the most important species in deeper environments within the Reserve according to work by Salvat et al (2002). In the shallower environments surveyed by SKCRCP sea rods (*Muricea* spp and *Plexaurella* spp) and plumes (*Pseudopterogorgia* spp) were the most abundant. Algae cover was characteristically high, as is the norm on many Caribbean reefs (littler et al, 1989), comprising >24% for habitats 2-6, *Halimeda* spp generally is the most abundant, with *Dictyota* high at habitat 4-6. Ruiz-Zarate et al (2003) discovered that turf algae was the most abundant on fore reefs within the Reserve, only benthic class 5 showed high turf algae coverage at 14.5%, similar to a range recorded by Ruiz-Zarate et al (2003) of 13-19% on deeper for reefs.

Eight of the 12 sites could possibly be described as *diffuse patch reef* according to the classification scheme developed by Mumby and Harborne (1999), although a direct comparison is difficult as the data is lacking the detailed geomorphologic descriptions used by Mumby and Harborne (1999).

Fish data

The total number of fish species positively identified during this study (101) was considerably more than the number published by Salvat et al (2002). Ruiz-Zarate et al (2003) recorded 128 species but included sites south of the Reserve close to the Belize border. Species richness and diversity is greatest at Chenchomac. This is supported by the fact that the site has the highest hard coral cover and greatest abundance of butterflyfish (Chetodontidae), often recognised as a biological indicator to reef health and associated to hard coral rich environments (Linton & Warner, 2003). Eight of the 12 sites surveyed had higher than mean Caribbean wide abundances of butterflyfish (>6.4 fish per 100m²) (Hodgson and Liebeler, 2002). Despite the complete absence of the butterflyfish, Sol had considerably higher abundances of parrotfish (Scaridae), snapper (Lujantidae) grouper (Serranidae), grunts (Haemulidae) and very high abundances of surgeonfish (Acanthuridae) supporting 542.9 individuals per 100m². Both parrotfish and snapper occur in abundances higher than mean abundance recorded by Hodgson and Liebeler, (2002) across 8 of the 12 sites, a possible indication of low to medium fishing pressure (Linton and Warner 2003).

There is variation in diversity, abundance and biomass of fish recorded across the 12 sites during the SKCRCP. Nuzez et al (1998), account 52% of this variation within UNESCO SKBR reef fish populations to topographical complexity, depth and encrusting coral coverage. According to Nuzez et al (1998), one would expect to find relatively low densities of parrotfish, snappers, butterflyfish and grunts in the lagoonal

and back reef environments where SKCRCP surveyed, with higher densities on outer reef slopes and reef crests. Thus, the higher than average densities for the Caribbean for butterflyfish at Chenchomac, La Colonia, Punta Allen, Mikes Reef, Dani's Buoy, Dani's Buoy 2, El Faro and Mike's Reef 2 suggest even healthier populations on outer reef slopes and reef crests with the UNESCO SKBR. The higher than mean abundances of snapper at Chenchomac, Chenchomac 2, Punta Allen, Dani's Buoy, Sol, Dani's Buoy 2, El Barco and Mikes Reef 2, and Parrotfish at Chenchomac, La Colonia, Mike's Reef, Niccehabim, Sol, Dani's Reef, El Faro and Mike's Reef 2 further supports the claim of comparatively healthy environments.

Overall, target fish species biomass was highest at Punta Allen and Mike's Reef. Results reported by Arias-Gonzalez (1998) state that fish biomass across the reefs of UNESCO SKBR is considerably varied, with the maximum biomass generally recorded on the reef slope, and minimum on the back reef environments. Again, this suggests that biomass is possibly at its lowest on some of the sites surveyed by SKCRCP. Arias-Gonzalez (1998) revealed that herbivores and generalised carnivores had particularly high biomass on certain areas of local back reef. These results are supported by high parrotfish biomass at Chenchomac, Mike's Reef and Dani's Buoy, high surgeonfish biomass at La Colonia, Chenchomac 2, Punta Allen, Dani's Buoy, Niccehabim and Sol and Snappers at Chenchomac, Chenchomac 2, Punta Allen, and Dani's Buoy. This was thought to be due to plant and detritus feeders being located in tropic levels similar to carnivorous fish, due to the strong association between invertebrates and algae (Arias-Gonzalez, 1998). This could explain why grunt biomass is so high at algal dominated sites of Punta Allen and Mike's reef. Interestingly, groupers (generalists that feed on fish and invertebrates) didn't represent much biomass at the sites where large records were made for the other families mentioned that fall into these tropic groups.

Invertebrate data

The cryptic nature of most reef invertebrates makes populations difficult to assess through under water visual senses with SCUBA gear. The MBRS SMP program only includes *Diadema* spp in the target species list, whereas the SKCRCP developed the methods to include all species currently surveyed by Reef Check for their Caribbean and Atlantic surveys, all of which are general indicators to reef health. Banded coral shrimp (*Stenopus hispidus*) abundance was lower across 10 of the 12 sites, than the mean abundance for the wider Caribbean (Hodgson and Liebler, 2002). (with Chenchomac and El Faro supporting the highest populations). Hodgson and Liebler, (2002) have not been collecting data for Flamingo tongue (*Cyphoma gibbosum*) for long enough to calculate mean regional averages abundance figures, but Mike's Reef and Niccehabim were the only sites where the species were recorded, both occurring at densities of 0.7 individuals per 100m². The species is reported to show an association with sea fans, particularly *Gorgonia flabellum* and *G. ventalina*, both a food source, and both of which occurred at the two sites.

Diadema spp urchins serve as indicators to certain aspects of reef health: for example - on over fished reefs where there is a lack of predators for example triggerfish (Balastidae), populations can reach high levels. These large populations can cause excessive bio-erosion of reefs and make it difficult for new coral recruits to become

established (Vo and Hodgson, 1997). Alternatively, very low populations of *Diadema* spp. can have detrimental effects on reefs due to the loss of the animals as grazers, which causes an exponential increase in algae. As has been the case of some regions of the Caribbean, a species specific pathogen resulted in a mass die off of 99% of existing populations of *Diadema* spp. in some areas in the early 1980s (Lessios, 1995). Our results suggest that *Diadema* spp. abundance is far lower than the mean of 10.3 per 100m² for the Caribbean recorded by Hodgson and Lebel (2002). *Diadema* spp. were recorded on every reef except Mike's Reef and Mike's Reef 2, which both support habitats abundant in *Halimeda*, *Dictyota* and other groups of algae. Interestingly, Mike's Reef supported no record of triggerfish, while Mike's Reef 2 supported small population of triggerfish possibly explaining the absence of the *Diadema* spp. Pencil urchins (*Eucidaris* spp), often collected as curio in many parts of the world showed higher than average regional abundance at Chenchomac and Mike's Reef.

The mean abundance of lobster (*Panulirus argus*), was higher than the mean for the Caribbean region across 8 of the 12 sites. Indeed, Hodgson and Lebel (2002) state that 49% of surveyed reefs in the Caribbean are completely devoid of records for the species. In 2000 almost 36,000 metric tonnes of lobster were exported from the Caribbean and west central Pacific (FAO, 2002) indicating the valuable resource potential of the species. Only 3 sites, Chenchomac, Chenchomac 2 and Sol supported no lobsters recorded, and the higher than regional mean abundances across 8 of the 12 sites is probably testament to the responsible nature that the local lobster fishery is managed within the Bay.

The triton trumpet (*Caronia variegata*) has suffered very badly due to over collection for the curio trade. As a result, the gastropod is now globally very scarce with mean abundances across Caribbean reefs as low as 0.05 animals per 100m² (Hodgson and Lebel, 2002). Encouragingly, figures in excess of this were recorded at Punta Allen, Mike's Reef, Niccehabim, Sol and Mike's Reef 2.

Site descriptions

Sol

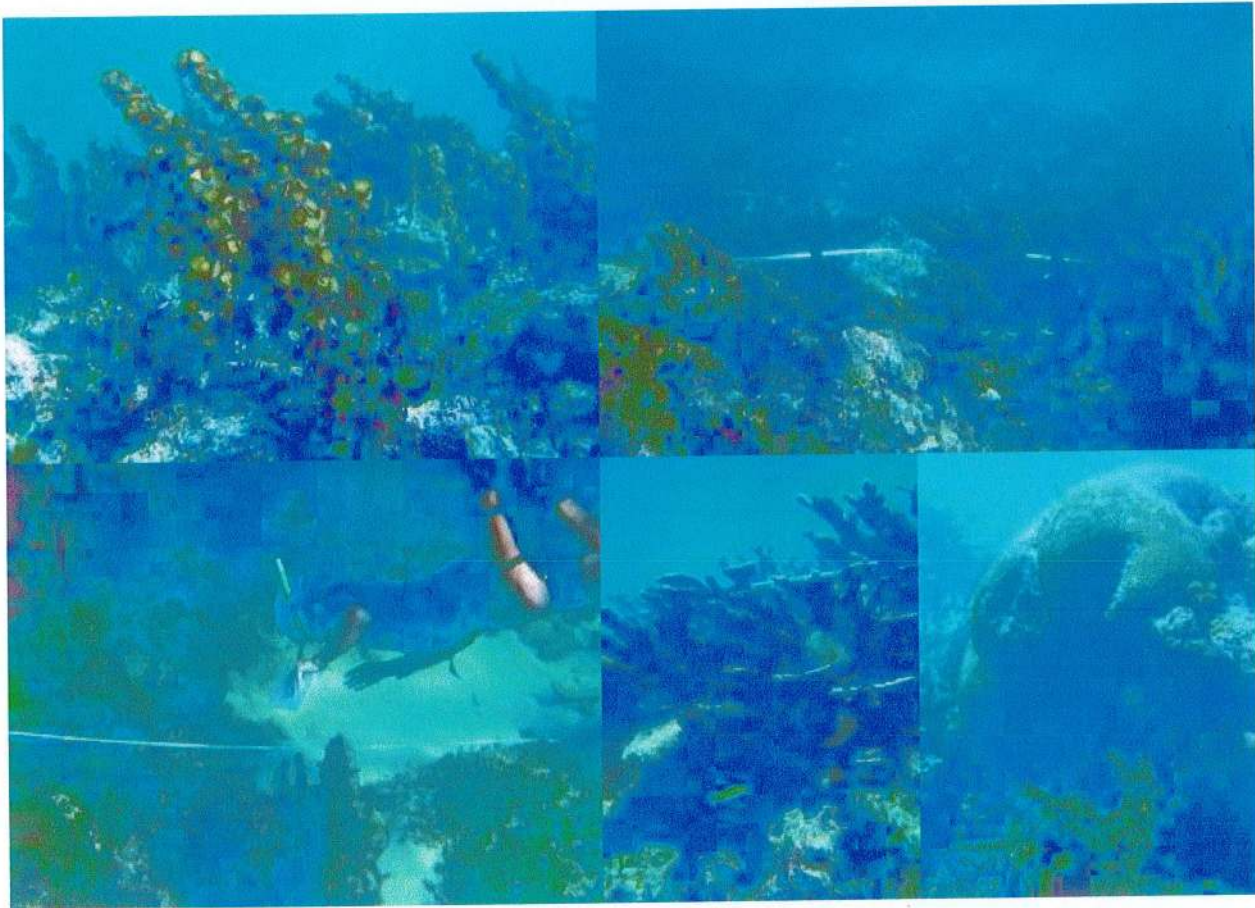


Figure 12 Underwater images of the SKCRCP survey sites at Sol showing a shallow algal dominated substrate.

Sol was comprised of three shallow statistically discrete habitats: 20% of *Shallow lagoonal environment with exposed substrate / sparse Halimeda and Dictyota*, 20% of *shallow sandy Halimeda and Dictyota dominated with sparse gorgonians and sponge*, and 60% of *shallow dominated with algae*. Coral mortality was confined to 0.13 m² of black band disease impacting *Porites astreoides* and *Solentrea bournoni* colonies and 0.67 m² of *Acropora palmata*. Hard coral cover was recorded at 17.51% for the site, with medium species richness and diversity. Coral associated butterflyfish (Cheatodontidae) were completely absent from the surveys, but abundance of parrotfish (Scaridae), snapper (Lujanidae), surgeonfish (Acanthuridae), grouper (Serranidae) and grunt (Haemulidae) were the highest for the 12 sites, with the highest recorded biomass of the 12 sites for snappers. Species richness and diversity could be considered medium for this site. This site supported the highest abundance of *Diadema* spp urchins, but encouragingly also the highest abundance of triton trumpet (*Charonia variegata*) of all the sites, far higher than the regional mean for the

Caribbean of 0.05 per 100m². Higher than regional mean abundances were also recorded for grouper, snapper, parrotfish, surgeonfish and grunt. Despite this the site only scored a “low” on the relative conservation management rating due to low hard coral cover and the higher than mean abundance of disease induced coral mortality.

Chenchomac

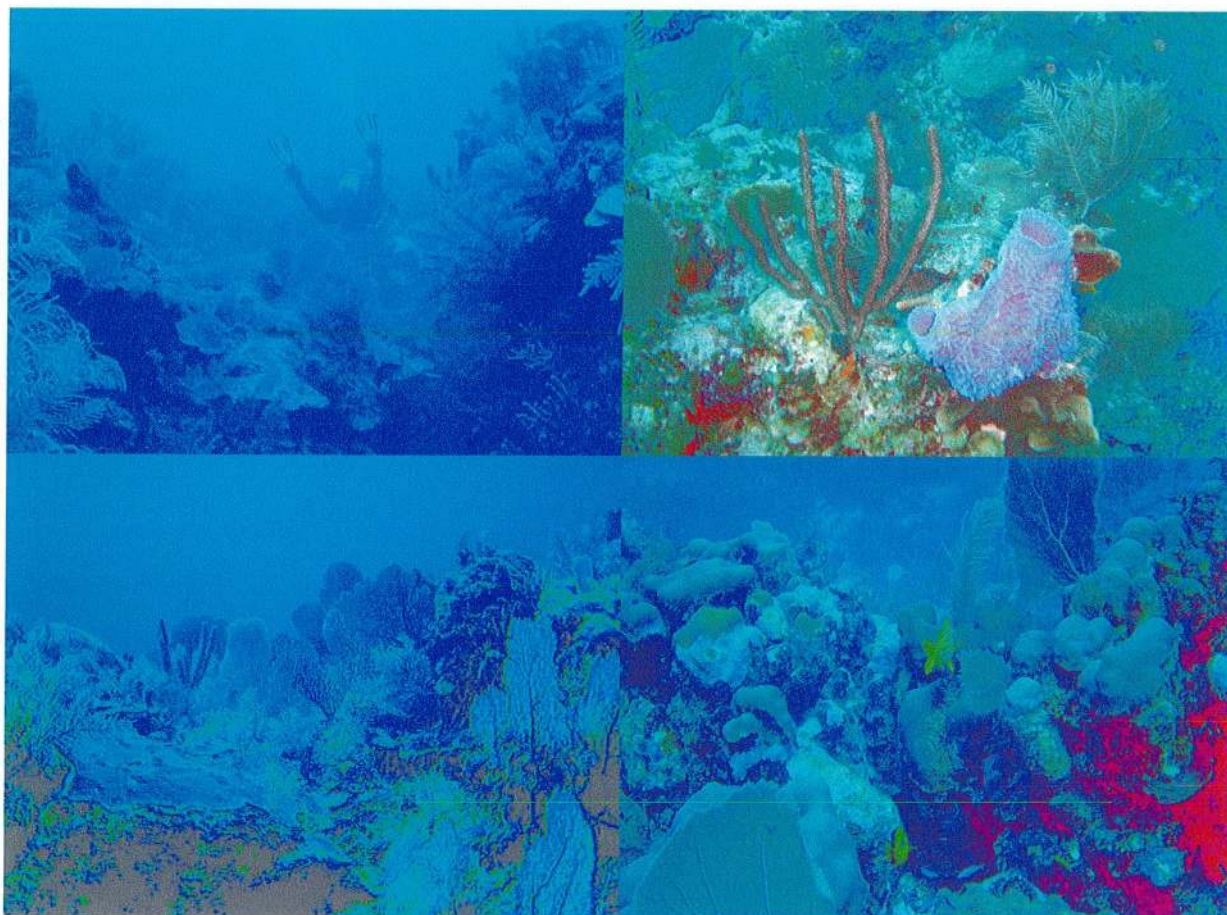


Figure 13 Underwater images of the SKCRCP survey sites at Chenchomac; the deepest site supporting the highest hard coral cover, diversity, species richness and little evidence of coral mortality.

Chenchomac comprised of three moderate to deep habitats: 17% of *Moderate depth bedrock with sparse gorgonians and hard corals*, 17% of *shallow sandy Halimeda and Dictyota dominated substrate with sparse gorgonians and sponges*, and 66% *deep mixed reef dominated by Montastraea and Porites astreoides with sponge coverage*. Coral mortality was low with no evidence of disease, and only 0.11m² of bleached *Agaricia agaricites*, *Montastraea annularis*, *P. astreoides* and *Siderastrea radians*. Hard coral cover represented 26.46% of the substrate recorded, the highest of all 12 sites and far in excess of what is now considered average for the Caribbean (Gardner *et al*, 2003) (with high species richness and diversity). Butterflyfish abundance was also the highest, and greater than the mean abundance recorded for the wider



Caribbean, along with parrotfish, snapper and grouper. Fish diversity and species richness was the highest of the 12 sites. Banded coral shrimp (*Stenopus hispidus*) were the highest of the 12 sites and occurred in greater abundance than the mean abundance for the wider Caribbean. High coral cover, diversity, species richness, low mortality and diverse make Chenchomac the best example of a health and productive reef environment of the 12 sites surveyed by the SKCRCP.

Chenchomac 2.

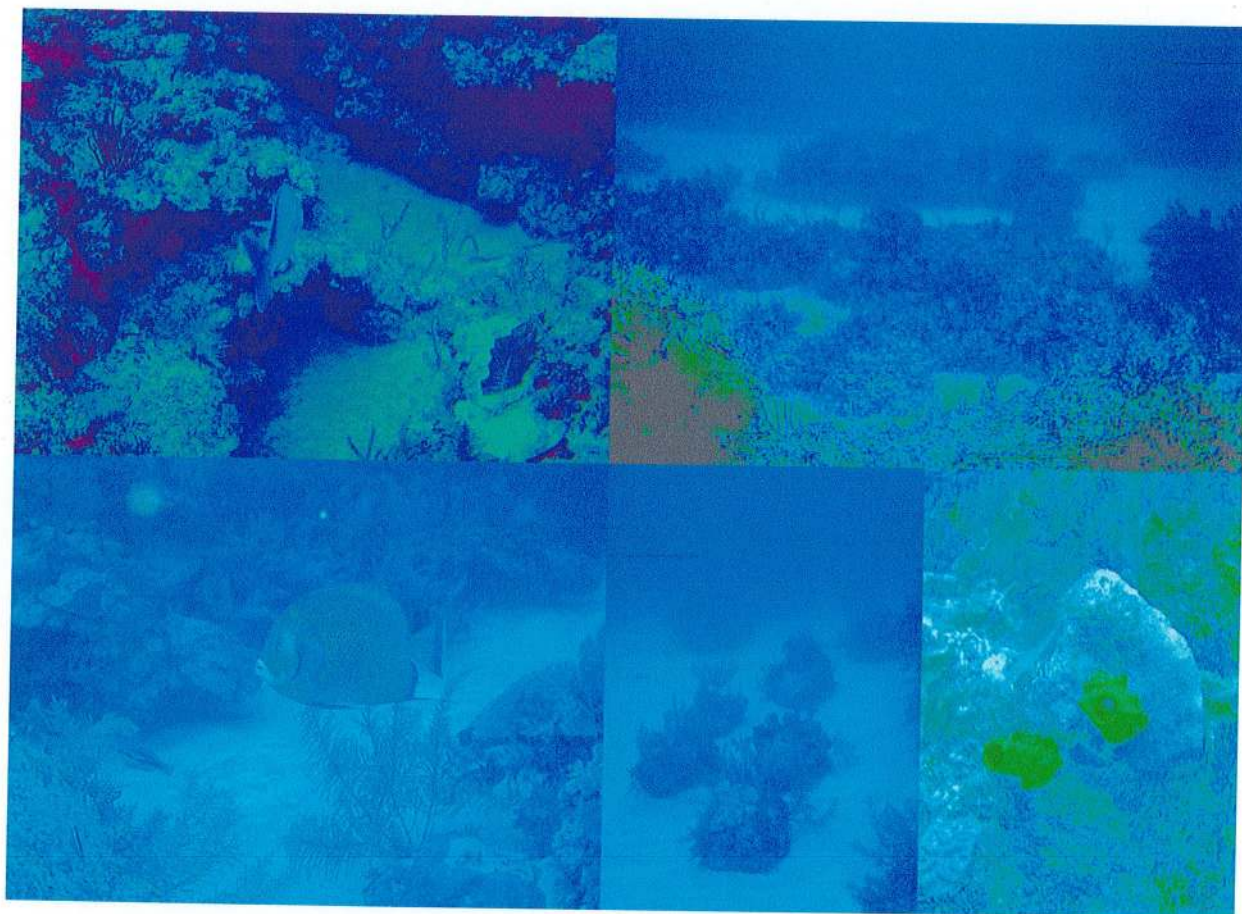


Figure 14 Underwater images of the SKCRCP survey sites at Chenchomac 2, a moderate to deep site supporting generally low medium to hard coral cover.

The survey transects of Chenchomac 2 supported three habitat classes of which 13% comprised of *Moderate depth bedrock with sparse gorgonians and hard corals*, 37% *Shallow dominated with algae* and 50% *Deep mixed reef dominated by Montastraea and Porites astreoides with sponge cover*. Hard coral cover was relatively low at 8.13%, supported by a complete recorded absence of butterflyfish. No evidence of disease was observed, but bleaching was recorded for individual colonies of *Diploria labyrinthiformis*, *Madracis mirabilis* and *Millepora alcicornis*. Parrotfish and grouper

were completely absent from Chenchomac 2, but the site supported the second highest abundance of snappers, with relatively high biomass recorded for this family and surgeonfish. Snapper abundance was considered higher than the mean regional abundance recorded by Reef Check for the wider Caribbean. This site supports the highest relative abundance for pencil urchins (*Eucidaris* spp), but no records were made for banded coral shrimp (*S. hispidus*), Flamingo tongue (*Cyphoma gibbosum*), lobster (*Pandulirus argus*) or triton trumpet (*Charonia variegata*). Values lower than the relative mean for species richness, amongst live substrate and fish has resulted in the relative conservation management value of Chenchomac 2 being recorded as “low”.

La Colonia

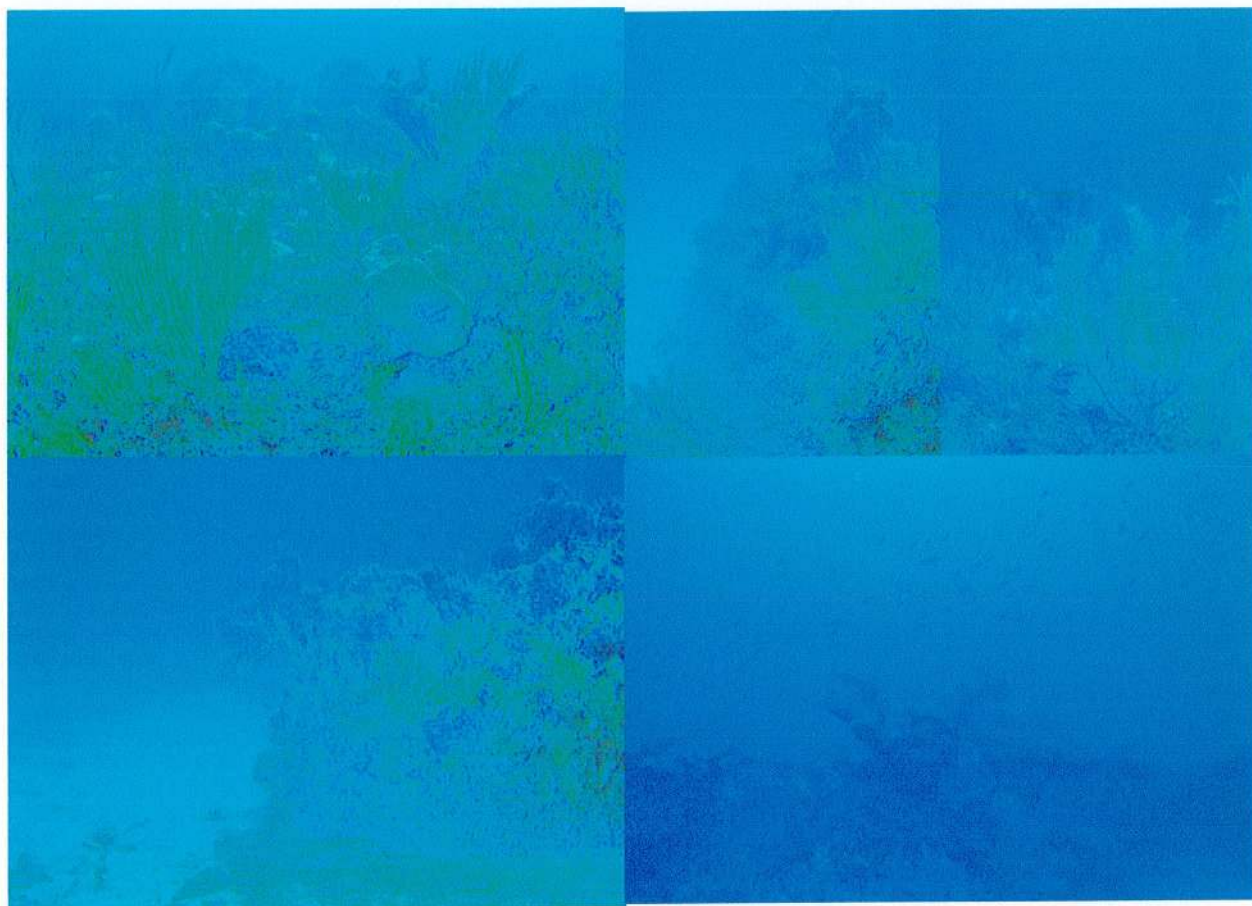


Figure 15 Underwater images of the SKCRCP survey sites at La Colonia, a site that supported high hard coral cover and good species richness and diversity.

La Colonia supported a benthic make up of which 17% of the surveyed benthos comprised of *Shallow sandy lagoonal environment with sparse mixed gorgonians and Montastraea*, and 83% *Deep mixed reef dominated by Montastraea and Porites astreoides with sponge coverage*. Hard coral cover comprised 17.89% of the benthos

within the site. Bleaching was recorded to be affecting colonies of *A. agaricites*, *M. annularis*, *P. astreoides*, and black band disease was present on colonies of *S. bournoni*. Species richness and diversity of live substrate was higher than the mean across the 12 sites. La Colonia supported a higher than mean abundance of butterflyfish if compared against data collected for the whole of the wider Caribbean region, supporting 4 of the 5 five species targeted by the survey. Abundances and biomass were relatively low for most groups of fish with only two species of snapper, no species of grouper and three species of grunt recorded for the site. This was also reflected in the species richness and diversity, with the site recording figures of less than the relative mean across the 12 sites. Target invertebrate species also were generally low, with a complete absence of Flamingo tongue (*C. gibbosum*) and triton trumpet (*C. variegata*). La Colonia recorded a relative conservation management value of “medium”.

Punta Allen

Punta Allen supported the highest amount of statistically different habitats, with all classes represented except the class *Shallow dominated with algae*. Hard coral cover was the lowest of the 12 sites at just 5.05% of the benthic make up. This can be explained by the benthic classes supporting the highest coral cover; *Deep mixed reef dominated by Montastraea and Porites astreoides with sponge coverage* and *Shallow sandy lagoonal environment with sparse mixed gorgonians and Montastraea*, only made up only a relatively small percentage of the surveyed area. Diversity and species richness for living substrate was reasonably low in comparison to the other 12 sites. A small amount of yellow band disease was recorded impacting *M. annularis*. *S. bournoni* suffered dark spot disease mortality and evidence of bleaching was also recorded for same species. Interestingly, lack of hard coral cover had little impact on local butterflyfish populations, with four of the five species recorded in abundances higher than one would expect for the wider Caribbean, according to published Reef Check data. The abundance of grunts and snappers was higher than regional mean abundances. Biomass was generally low across the site except in the case of grunts, with Punta Allen recording the second highest biomass across the 12 sites, the family comprising of almost 90% of the recorded biomass for the site. Punta Allen was the only site where spotted trunkfish (*Lactophrys bicaudalis*), were recorded. Fish species diversity and richness was below average for the 12 sites. Records of lobster (*P. argus*) and triton trumpet (*C. variegata*) abundance were higher than the regional mean for the wider Caribbean. Punta Allen's low hard coral cover, and generally low species richness and diversity of live substrate and fish population resulted in the site being classed in the category “low” in conservation management rating.

Mike's Reef



Figure 16 Underwater images of the SKCRCP survey sites at Mikes Reef; the reef supports a high number of gorgonians in a shallow algal rich environment.

Mike's Reef supported 4 habitat classes, with 50% comprising of *Shallow sandy lagoonal environment with sparse mixed gorgonians and Montastraea*, and the remaining 50% recorded as *shallow sandy Halimeda and Dictyota dominated substrate with sparse gorgonians and sponges*, *Shallow lagoonal environment with exposed substrate / sparse Halimeda and Dictyota* and *Shallow dominated with algae*. The site recorded a mean of 11.42% hard coral cover, with evidence of black band and yellow band disease affecting *M. annularis*, and dark spot disease attacking colonies of *S. bournoni*. Bleaching was recorded as impacting *A. agaricites*, *M. annularis*, *Porites furcata* and *S. bournoni*. Mortality was highest at this site with 0.85m² of reef affected per 100m², with both species richness and diversity for living substrate higher than average for the Bay. Butterflyfish, groupers and grunt abundance was higher than the regional mean for the wider Caribbean. Grunt biomass was the highest of any of the 12 sites, with 54.04kg per 100m² of reef. Diversity and species richness of fish for this site was above average for the 12 sites. Abundance of lobster (*P. argus*) and triton trumpet (*C. variegata*) and pencil urchin (*Eucidaris* spp) were greater than the regional mean abundance for the wider Caribbean. Low relative coral cover and the high relative incidence of hard coral mortality resulted in Mike's reef scoring a "medium" in the relative conservation management rating.

Dani's Buoy



Figure 16 SKCRCP survey sites for Dani's buoy; the site supported low fish diversity and species richness and low live benthic cover and diversity.

Dani's Buoy supports three of the six habitat classes, with 50% of the site comprising of *Shallow lagoonal environment with exposed substrate / sparse Halimeda and Dictyota*. The rest of the site is a mixture of *Shallow dominated with algae* and *Shallow sandy Halimeda and Dictyota dominated substrate with sparse gorgonians and sponges*. Hard coral cover was only recorded as 5.77% of the benthic make up, with bleached colonies of *P. furcata*. Incidences of red band disease II and white band disease were recorded for *M. annularis* and *Acropora prolifera*. Mortality was the second lowest of any of the 12 sites, recording just 0.05m² per 100m² of reef. Live benthic diversity and species richness was lower than the mean for the 12 survey sites. Butterflyfish abundance was again higher than the regional mean for the wider Caribbean for this site. Snappers and grouper too occurred in numbers greater than the regional mean for the Caribbean. Surgeonfish supported the greatest biomass for the site recording 6.89 kg per 100m² of reef. Fish diversity and species richness was the lowest for the 12 sites surveyed by the SKCRCP. Lobsters (*P. argus*) were recorded in

numbers greater than the regional mean for the Caribbean; 0.5 individuals per 100m² compared to 0.39 individuals recorded by Reef Check. Dani's Buoy recorded a relative conservation management value of "low".

Niccehabin

Niccehabin was the least diverse of the 12 sites, supporting just a single habitat class: *Shallow sandy lagoonal environment with sparse mixed gorgonians and Montastraea*. Bleaching was recorded for *M. annularis* and *S. bournoni* and evidence of black band disease on *M. annularis* was recorded. Hard coral cover was slightly above the mean for the 12 sites at 12.28%, with live substrate species richness also recorded as higher than the mean for the 12 sites surveyed by SKCRCP. Piscivour abundance was high, grouper was abundance higher than the relative mean abundance for the wider Caribbean. The site also contained the highest abundance of barracuda (*Sphyraena barracuda*) and second highest abundance of bar jack (*Caranx ruber*). Surgeonfish biomass was high at 4.54 kg per 100m². Fish diversity and species richness a little higher than the mean for the 12 sites. Abundance of lobster (*P. argus*) and tritons trumpets (*C. variegata*) were greater than the regional mean for the Caribbean. Niccehabin scores a "medium" relative conservation management value.

El Faro

El Faro supported a similar habitat to Niccehabin, 80% of the site was dominated by *Shallow sandy lagoonal environment with sparse mixed gorgonians and Montastraea*, with the remaining 20% supporting *Shallow lagoonal environment with exposed substrate / sparse Halimeda and Dictyota*. Coral mortality was the lowest of the 12 sites at just 0.02m² of bleached coral per 100m² of reef. *M. annularis* was the only species recorded as effected. Hard coral cover was generally quite low at 10.69%, and species diversity was just above average for the 12 sites. Fish species richness and diversity was the second highest of the 12 sites. Butterflyfish, parrotfish and grouper abundance was higher than the regional mean for the wider Caribbean, but snappers recorded the lowest abundance for the sites. Biomass was dominated by grunts, which comprised over 40% of the recorded fish, at 2.53 kg per 100m². El Faro was only one of two sites where higher than Caribbean wide regional mean abundances of banded coral shrimp (*S. hispidus*) were recorded. Lobster (*P. argus*) also showed healthier than regional mean abundances. Low coral mortality, high fish species richness and diversity and good live substrate species diversity account for El Faro recording a relative conservation management value of "high".

El Barco

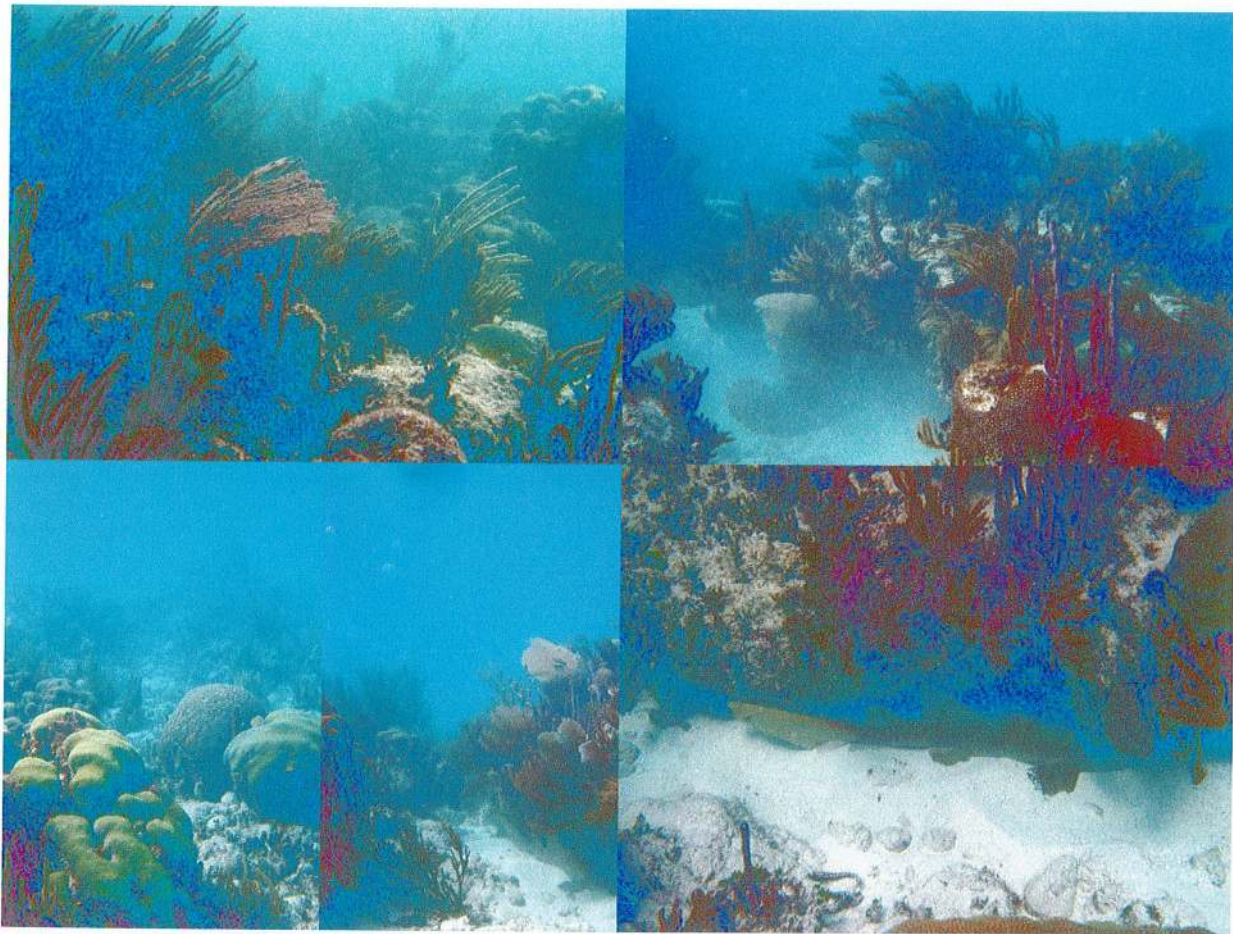


Figure 17 SKCRCP survey sites for El Barco; this sandy site supported relatively high numbers of snapper grouper and grunt.

El Barco supports four different habitat classes: *Moderate depth bedrock with sparse gorgonians and hard coral*, *Shallow lagoonal environment with exposed substrate / sparse Halimeda and Dictyota*, *Shallow sandy Halimeda and Dictyota dominated substrate with sparse gorgonians and sponges*, with 60% of the site comprised of *Shallow sandy lagoonal environment with sparse mixed gorgonians and Montastraea*. Hard coral cover was low and bleaching was evident effecting *M. annularis* and *S. bournoni*, and Yellow band disease was recorded for *M. annularis*. Abundances of snapper grouper and grunt were higher than the regional mean for the wider Caribbean, non-pescivours such as butterflyfish, surgeonfish and parrotfish showed some of the lowest abundances across the 12 sites. Species richness and diversity of both fish and live substrate was lower than the overall mean for the 12 sites at El Barco. Invertebrate abundance was generally low with a complete absence of flamingo tongue (*C. gibbosum*) and triton trumpets (*C. variegata*). The site recorded “low” on the relative conservation management rating.

Mike's reef 2

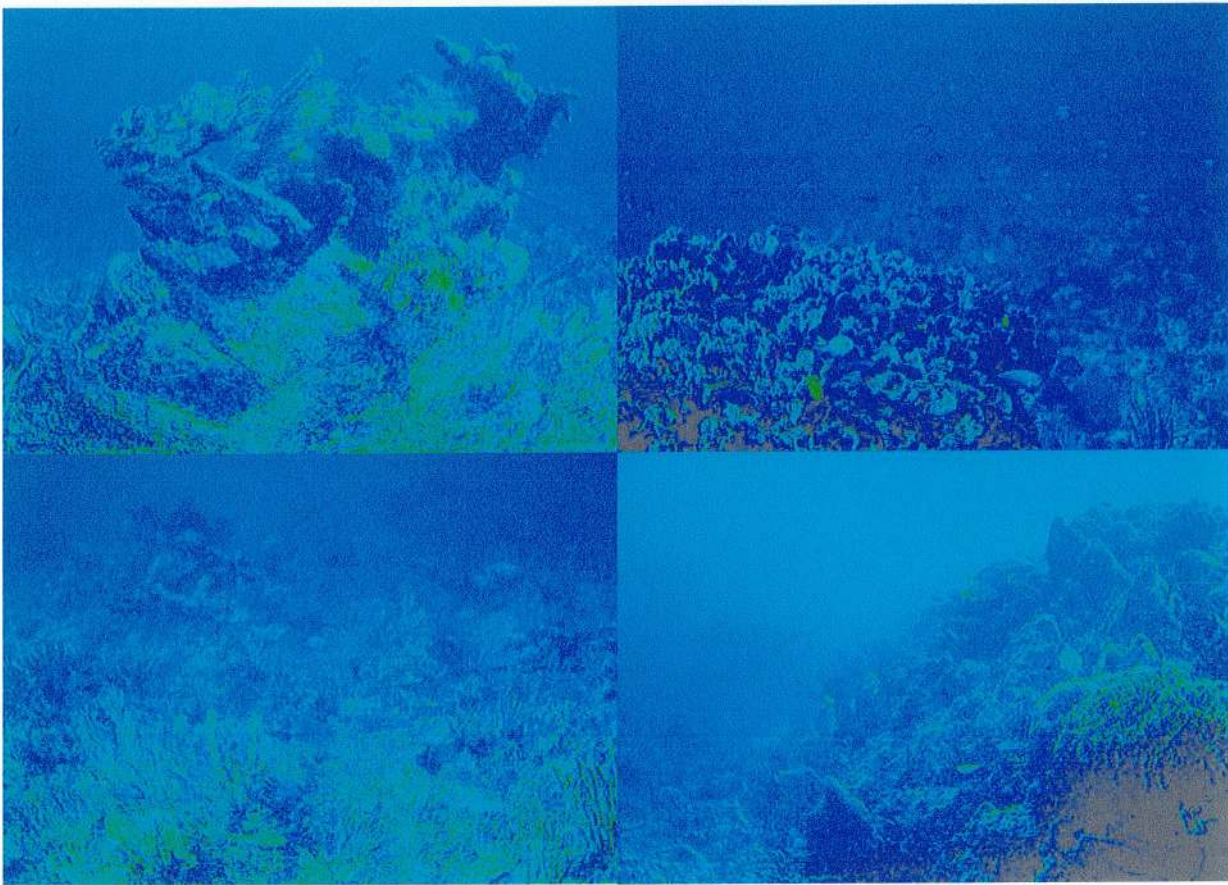


Figure 18 SKCRCP survey sites for Mikes Reef 2; the site supported good overall fish and benthic diversity and low coral mortality.

Mikes reef 2 was comprised of 75% *Shallow sandy Halimeda and Dictyota dominated substrate with sparse gorgonians and sponges*, with the remaining habitat class described as *Moderate depth bedrock with sparse gorgonians and hard corals*. Hard coral cover was recorded at 11.74% and both diversity and species richness of live substrate was high. Mortality is low 0.13m² per 100m², with only small incidences of bleached *S. bournoni* and no recorded disease impacts or mortality. Butterflyfish abundance was greater than the regional mean abundance for the wider Caribbean and diversity and species richness was high for fish. This site had healthy populations of lobster (*P. argus*) and triton trumpet (*C. variegata*) compared to the mean for the Caribbean. Mike's Reef 2 could be regarded as a good example of a healthy and productive reef and is considered to have a "high" relative conservation management value.

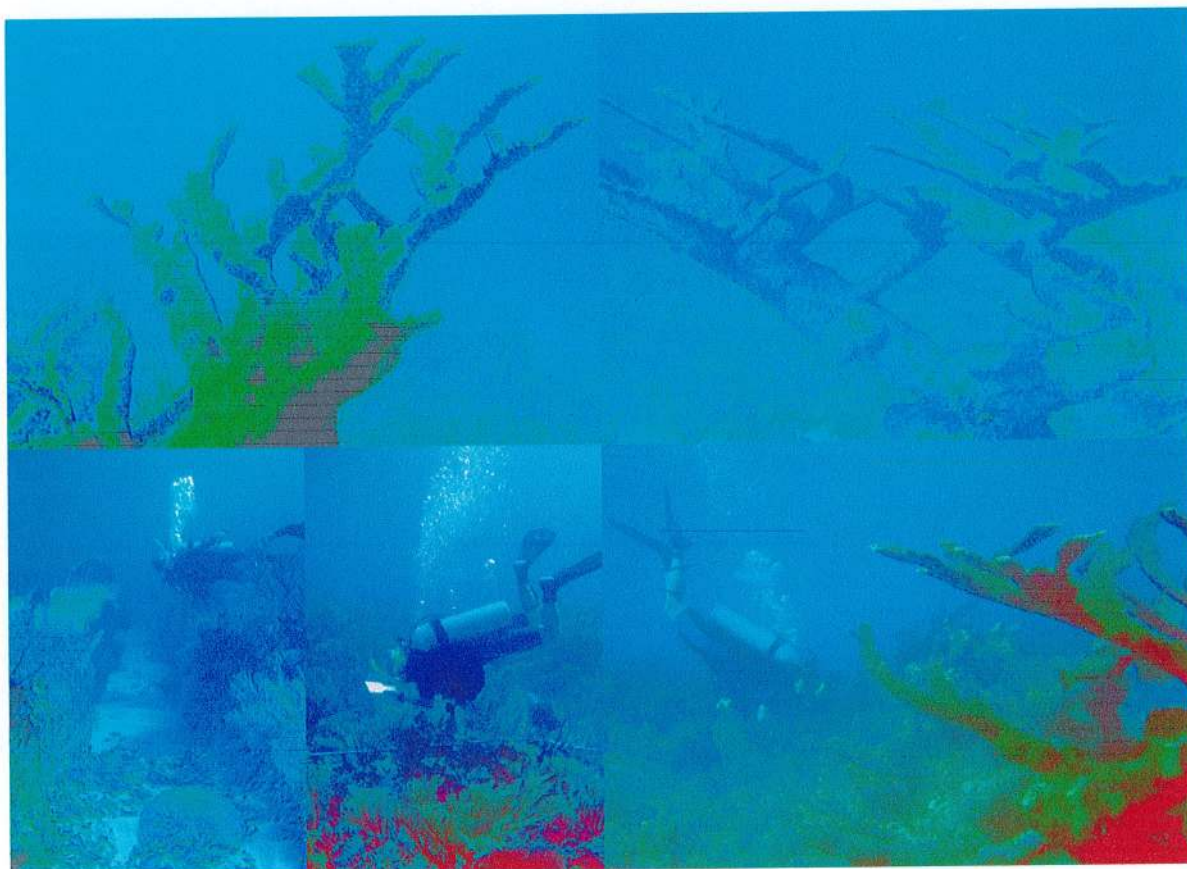
Dani's Buoy 2

Figure 19 SKCRCP survey sites for Dani's Buoy 2; healthy productive site with a high conservation management value.

Dani's Buoy 2 supports 60% moderate depth bedrock with sparse gorgonians and hard corals and 40% Shallow sandy *Halimeda* and *Dictyota* dominated substrate with sparse gorgonians and sponges. Mortality was present at 0.007m² per 100m² of reef, with bleaching affecting *A. agaricites*, *P. astreoides* and *S. bournoni*. Yellow blotch disease was recorded for *Siderastrea radians*. Five species of butterflyfish were recorded at this site, with abundances greater than the regional mean for the wider Caribbean. Parrotfish and groupers also fared well with higher than regional mean abundances. Overall abundance and diversity of live substrate and fish was better than the mean for the 12 sites, with grunts recording the highest biomass for the site. Overall, invertebrate abundance was low, with lobsters (*P. argus*) probably being the most significant at 0.4 individuals per 100m². Dani's Buoy 2 has a "high" relative conservation management value.

Management recommendations

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

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

The biggest perceived threat to the UNESCO SKBR is from those engaged in tourism activities (Salvat *et al*, 2002). Tourism is now recognized as both the largest and fastest growing industry in the world. Of course tourism suffers glitches on its path of growth, but the trend is one of increase, with the human population having ever-greater amounts of disposable income and time. Tourism now generates 11% of global gross domestic product, employs 200 million people worldwide and engages 700 million tourists annually. These figures are predicted to double by 2020. The resources of the UNESCO SKBR are a great draw to the tourist, but unless managed carefully and in a sustainable manner, they will not provide a long-term financial and social gain to the area.

For this very reason it is important that the patch reefs of Ascension Bay utilised by snorkelers are managed in the most sustainable way possible. Figure 20 illustrates a model developed for Hol Chan Marine Park, Belize. A reef without proper management will deteriorate to such an extent divers and snorkelers will not wish to use the reef, and will go elsewhere. The model shows that the number of users increases till the year 2024, generating increased levels of revenue in the short term. After that the number begins to decline as divers and snorkelers see the ecological consequences caused by lack of management. In the "with" management scenario, the number of snorkelers and divers will stay constant, thus maintaining a constant revenue for the local area.

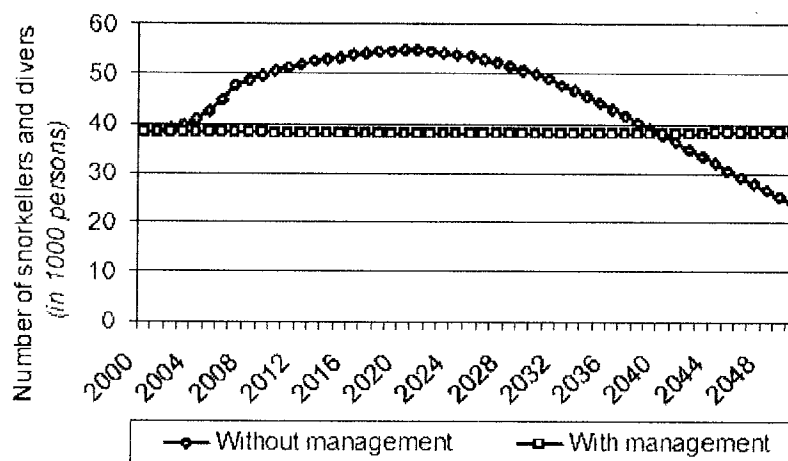


Figure 20 Model to show number of snorkellers and divers to visit Ho Chan Marine Park – Belize, in “with management” and “without management” scenarios. *Source: Cesar and Walker, 2003.*

The following are a summary of management measures, that need to be implemented to decrease snorkeler related impacts to the 12 patch reefs surveyed by the SKCRCP.

- **Limit the number of visitors to each site:** By restricting the total number of visitors to each of the 12 sites, physical impact and damage caused by careless snorkelers can be minimised. Zakai *et al* (2002) suggest from their work that a similar reef environment in Eilat could support a carrying capacity of 5,000-6,000 divers per site per year. The authors of this report suggest that this figure is reduced to account for the general greater impact sustained by snorkelers than divers (Cesar and Walker, 2003) and recommend a total of no more than 4,000 snorkelers per site per year. This equates to approximately 12 snorkelers per day using each site.
- **Distribute the number of snorkelers between sites:** By equally distributing the snorkeling related pressure, the impacts will be more evenly distributed, thus allowing the reef environment more chance of recovery (CORAL, 2002).
- **Ensure all snorkelers wear buoyancy aids:** By respecting the UNESCO SKBR regulation and ensuring all snorkelers wear buoyancy aids, the risk of physically damaging delicate corals and marine life is minimised. This policy has proved to be successful in other regions of the world (Fenner, 2001).
- **Ensure that all boats are moored to buoys:** By ensuring all snorkel tour boats are properly moored, there becomes no need for anchoring. Thus the risk of damage to the reef is reduced.
- **Ensure that Reserve user fees are directed towards buoy installation and maintenance:**
- **Site closure:** The authors of this report recommend that the sites Chenchomac and Mike's Reef 2 be closed to snorkelling and extractive activities such as fishing. Both sites have excellent conservation management value as confirmed by the research under taken during the SKCRCP. These sites are also relatively deep so have less value to snorkellers. By managing these two sites as small community run Marine Protected Areas (MPAs), the sites will help to increase recruitment of coral and other species such as lobster and finfish to these and other reefs within the area. Thus, helping to maintain local fishery stock and coral recruitment and abundance on the reefs utilised by the snorkellers.
- **Ensure that all snorkelers are led by guides:** The supervision of snorkelers in the water will allow for greater control over potentially damaging activities such as collecting curio or careless damage to coral and living substrate.
- **Pre snorkel briefings:** Guides should be encouraged to give group briefing on the boat before snorkellers are allowed to enter the water. These briefings

should be informative and concise and encourage snorkelers to be aware of their fragile surroundings and not touch or collect anything.

- ***Control land based pollution and coastal development:***
- ***Implement a long term monitoring programme:*** CCC will offer to undertake this monitoring programme to assess the long term effects of this snorkel based tourism in the UNESCO SKBR. CCC will provide suggestions on how to manage the effects. CCC will continue and expand on the surveying, monitoring and education work it started during this three-month pilot phase.

Conclusion

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

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

Often the difference between the severity of impacts caused by the development of a tourism industry is the degree to which impacts are mitigated against in the management planning stage. The people of Punta Allen depend directly on the reef of Ascension Bay for their livelihoods, both from snorkel based tourism and fisheries. This study has revealed that by regional Caribbean standards the generally high abundance of key indicator species of reef health suggest that the reefs of Ascension Bay are in good, healthy, productive condition. At least three of the sites surveyed can be classed as having special conservation importance. The potential revenue generated by this valuable and now very scarce resource can amount to \$1,000s of per year, in the form of tourism and fisheries potential. The key to harnessing this potential revenue, but maintaining a healthy productive environment is for the key stakeholders such as the fishing community of Punta Allen and those that manage the UNESCO SKBR, to implement the science driven management recommendations. By implementing the recommendations suggested as a result of the SKCRCP, there should be little reason to suggest that potential impacts can't be mitigated against, and the local reef environment should remain productive indefinitely.

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Appendix 1

Synoptic Monitoring Program Data Recording Forms.

CCC have adapted the standard SMP data entry forms in order to account for the higher level of detail recorded by CCC volunteers.

Form 1: MBRS Benthic Data Entry Form

Form 2: MBRS Point Intercept Transect Data Entry Form

Form 3: MBRS Adult Fish Data Entry Form

Form 4: CCC – MBRS Adult Fish and *Diadema* Belt Transect Data Entry

Form 5: CCC – MBRS Point Intercept Transect Data Entry

MSMP_1A

[illegible]

MBRS ADULT FISH DATA ENTRY FORM

MSMP_2A

Location:		Latitude:		Date:		
Site ID:		Longitude:		Time:		
Recorder:		Transect # _____ of _____				
Families	Scientific Name	0-5 cm	6-10 cm	11-20 cm	21-30 cm	31-40 cm
ALL SPP in the following families						
Surgeonfishes	<i>Acanthurus bahianus</i>					
Acanthuridae	<i>A. chirurgus</i>					
	<i>A. coeruleus</i>					
Butterflyfishes	<i>Chaet. capistratus</i>					
Chaetodontidae						
Grunts	<i>Haemulon plumieri</i>					
Haemulidae	<i>H. chrysargyreum</i>					
	<i>H. flavolineatum</i>					
Snappers	<i>Lutjanus apodus</i>					
Lutjanidae	<i>Lutjanus mahogoni</i>					
	<i>Ocyurus chrysurus</i>					
Angelfishes	<i>Pomacant. paru</i>					
Pomacanthidae	<i>P. arcuatus</i>					
Parrotfish	<i>Sparisoma viride</i>					
Scaridae	<i>S. taeniopterus</i>					
ALL SPP in these genera of Serranidae						
Myxotroperca	<i>M. bonaci</i>					
Epinephelus	<i>E. guttatus</i>					
	<i>E. fulvus</i>					
	<i>E. striatus</i>					
Ballistidae	<i>Balistes vetula</i>					
only these SPP	<i>B. capricornis</i>					
	<i>Melichthys niger</i>					
	<i>Asterus scriptus</i>					
	<i>Canther. pudes</i>					
	<i>C. macrocerus</i>					
Five misc. SPP	<i>Bodianus rufus</i>					
	<i>Caranx ruber</i>					
	<i>Lachnol. maximus</i>					
	<i>Microsp. chrysurus</i>					
	<i>Sphyr. barracuda</i>					

MRBS ADULT FISH AND INVERTEBRATE BELT TRANSECT DATA ENTRY

Location		Name	
Site ID		Date	
Latitude		Time	
Longitude		Transect #	

FISH SPECIES		SIZE CATEGORIES					
Families	Common Name	0-5cm	6-10cm	11-20cm	21-30cm	31-40cm	>40cm
Surgeonfish <i>Acanthuridae</i>	Blue Tang						
	Ocean Surgeonfish						
	Doctorfish						
Butterflyfish <i>Chaetodontidae</i>	Banded Butterflyfish						
	Foureye Butterflyfish						
	Spotfin Butterflyfish						
	Reef Butterflyfish						
	Longsnout Butterflyfish						
Grunts <i>Haemulidae</i>	French Grunt						
	Bluestriped Grunt						
	Smallmouth Grunt						
	White Grunt						
	Caesar Grunt						
	Tomtate						
	Cottonwick						
	Striped Grunt						
	Spanish Grunt						
	Sailors Choice						
	Porkfish						
	Black Margate						
	White Margate						
Snappers <i>Lutjanus</i>	Red Snapper						
	Mutton Snapper						
	Cubera Snapper						
	Grey Snapper						
	Dog Snapper						
	Mahogany Snapper						
	Lane Snapper						
	Yellowtail Snapper						
	Schoolmaster						
FISH SPECIES		SIZE CATEGORIES					
Families	Common Name	0-5cm	6-10cm	11-20cm	21-30cm	31-40cm	>40cm
Angelfish <i>Pomacanthidae</i>	Queen Angelfish						
	French Angelfish						
	Grey Angelfish						
	Rock Beauty						

Parrotfish Scaridae	Blue Parrotfish						
	Midnight Parrotfish						
	Rainbow Parrotfish						
	Queen Parrotfish						
	Stoplight Parrotfish						
	Princess Parrotfish						
	Striped Parrotfish						
	Redband Parrotfish						
	Redtail Parrotfish						
	Yellowtail Parrotfish						
Groupers Serranidae	Goliath Grouper						
	Nassau Grouper						
	Red Grouper						
	Red Hind						
	Rock Hind						
	Black Grouper						
	Scamp						
	Tiger Grouper						
	Yellowmouth Grouper						
	Yellowfin grouper						
	Gag						
Triggerfish & Filefish Balistoidea	Queen Triggerfish						
	Grey Triggerfish						
	Black Surgeon						
	Scrawled Filefish						
	Whitespotted Filefish						
	Orangespotted Filefish						
Miscellaneous species	Spanish Hogfish						
	Bar Jack						
	Hogfish						
	Yellowtail Damselfish						
	Barracuda						
TARGET INVERTEBRATES							
Invertebrate species	<i>Diadema</i> spp.						
	Pencil urchins						
	Banded coral shrimp						
	Triton shell						
	Flamingo tongue						
	Lobster						

MRBS POINT INTERCEPT TRANSECT DATA ENTRY

Location		Name	
Site ID		Date	
GPS		Time	

SUBSTRATE		SOFT CORALS		HARD CORALS			
Bare Rock	BR	Sea Fan	SF	Mountainous Star	MS	Low Relief Lettuce	LRL
Sand	SD	Sea Rod	SR	Cavernous Star	CS	Ribbon	RI
ALGAE		Sea Plume	SP	Smooth Brain	SB	Elkhorn	EL
Coralline Algae	CA	Sea Whip	SW	Grooved Brain	GB	Staghorn	ST
Turf Algae	TA	Corky Sea Finger	CSF	Knobby Brain	KB	Yellow Pencil	YP
Dictyota	D	Encrusting	SG	Club Finger	CF	Eight Ray Finger	ERF
Lobophora	L	Gorgonian		Finger	FI	Green cactus	GC
Halimeda	H			Thin Finger	TF	Fungus	FG
Blue-green algae	BG			Mustard Hill	MH	Thin Fungus	TFG
SPONGE				Honeycomb Plate	HP	Grooved Fungus	GF
Encrusting	ES	Ball	BS	Fragile Saucer	FS	Ridgeless Cactus	RC
Barrel	BS	Plate	PS	Sheet	SH	Smooth Starlet	SS
Vase	VS	Rope	RS	Scroll	SC	Rough Starlet	RS
Tube	TS			Leaf	LF	Giant Brain	GB
Branching	BRS			Massive Leaf	ML	Saucer	SA

0 – 10m				10.5 – 20m				20.5 – 30m			
1		21		41		61		81		101	
2		22		41		62		82		102	
3		23		42		63		83		103	
4		24		44		64		84		104	
5		25		45		65		85		105	
6		26		46		66		86		106	
7		27		47		67		87		107	
8		28		48		68		88		108	
9		29		49		69		89		109	
10		30		50		70		90		110	
11		31		51		71		91		111	
12		32		52		72		92		112	
13		33		53		73		93		113	
14		34		54		74		94		114	
15		35		55		75		95		115	
16		36		56		76		96		116	
17		37		57		77		97		117	
18		38		58		78		98		118	
19		39		59		79		99		119	
20		40		60		80		100		120	

Appendix 2

Percent cover of each respective substratum, life form or species for each of the six habitat types classified during the Sian Ka'an Coral Reef Conservation project.

Habitat	1	2	3	4	5	6
<i>Depth (m)</i>	<i>8.2</i>	<i>2.8</i>	<i>4.7</i>	<i>5.4</i>	<i>2.1</i>	<i>11.6</i>
bare rock	43.5	30.9	7.0	13.2	8.1	3.4
sand	17.0	31.4	45.4	24.1	20.5	13.6
corraline algae	0.0	0.5	0.6	0.1	3.0	0.1
turf algae	0.4	1.4	6.6	1.9	14.5	2.5
dictyota	0.4	10.2	6.9	16.9	13.8	19.4
lobophora	0.0	0.0	0.0	0.2	0.0	2.6
halimeda	8.5	12.1	10.9	18.0	23.1	14.0
blue green algae	0.0	0.0	0.0	0.0	0.0	0.0
alga totals	9.4	24.2	24.9	37.1	54.4	38.6
sea fan	2.5	1.5	1.3	1.2	0.0	3.3
sea rod	6.0	2.4	4.2	3.9	0.0	5.4
sea plume	5.9	1.9	3.7	4.6	0.0	11.6
sea whip	0.0	0.0	0.0	0.1	0.0	0.1
corky sea finger	1.6	2.8	2.3	2.2	0.2	2.3
encrusting gorgonian	0.1	0.0	0.7	2.6	5.1	0.7
gorgonian totals	16.1	8.6	12.2	14.6	5.4	23.4
encrusting sponge	1.0	0.5	0.4	1.5	0.5	2.5
barrel sponge	0.1	0.0	0.0	0.1	0.0	0.1
vase sponge	0.0	0.0	0.0	0.0	0.0	0.0
tube sponge	0.0	0.0	0.0	0.0	0.0	0.0
branching sponge	0.0	0.0	0.0	0.0	0.0	0.4
plate sponge	0.0	0.0	0.0	0.0	0.0	0.0
rope sponge	0.3	0.1	0.1	0.2	0.1	0.2
sponge totals	1.4	0.5	0.5	1.8	0.6	3.2
mountainous star	5.3	1.2	8.7	1.4	1.3	8.4
cavernous star	0.9	0.2	0.5	0.7	0.1	0.3
smooth brain	0.2	0.0	0.2	0.3	0.4	0.4
grooved brain	0.3	0.2	0.2	0.2	0.2	0.7
knobby brain	0.0	0.0	0.0	0.1	0.1	0.0
club finger	0.4	0.1	0.1	0.0	1.6	1.4
finger	0.0	0.2	0.2	0.0	0.0	0.1
thin finger	0.2	0.3	0.2	0.3	0.0	0.0
mustard hill	1.0	0.7	0.4	1.3	3.2	3.0
honey comb plate	0.0	0.0	0.0	0.0	0.0	0.0
fragile saucer	0.0	0.0	0.0	0.1	0.0	0.0
shectr	0.5	0.0	0.2	0.4	0.0	0.0
scroll	0.0	0.0	0.0	0.0	0.0	0.1
leaf	0.2	0.2	0.3	1.2	0.0	0.8
massive leaf	0.1	0.0	0.0	0.2	0.1	0.8
low relief lettuce	1.2	0.1	0.1	0.0	0.0	0.0
ribbon	0.0	0.0	0.0	0.2	0.9	0.0
clk horn	0.4	0.0	0.1	0.1	2.8	0.0
staghorn	0.0	0.0	0.0	0.0	0.0	0.0
yellow pencil	0.0	0.1	0.1	0.4	0.0	0.5
8-ray finger	0.0	0.1	0.0	0.0	0.0	0.0
green cactus	0.0	0.0	0.0	0.0	0.0	0.1
fungus	0.0	0.0	0.1	0.0	0.0	0.0

thin fungus	0.2	0.0	0.0	0.0	0.0	0.0
grooved fungus	0.2	0.0	0.0	0.0	0.0	0.1
ridgeless cactus	0.0	0.0	0.0	0.0	0.0	0.1
smooth starlet	1.4	1.0	1.0	2.5	0.4	1.1
rough starlet	0.0	0.0	0.0	0.0	0.0	0.0
giant brain	0.0	0.0	0.0	0.0	0.0	0.0
saucer	0.0	0.0	0.1	0.0	0.0	0.0
<i>total hard coral</i>	<i>12.7</i>	<i>4.4</i>	<i>12.4</i>	<i>9.1</i>	<i>11.0</i>	<i>17.8</i>

Appendix 3

**Standing stock biomass of fish per family across the 12 sites surveyed by the
SKCRCP in kg per 100m²**

Family	Chencomac											
	Chencomac La Colonia	2	Punta Allen	Mike's Reef	Dani's Bouy	Niccehabim	Sol	Dani's Bouy 2	El Faro	El Barco	Mike's Reef 2	
Haemulidae	0.95	0.51	2.09	45.36	54.04	3.37	3.19	6.85	2.59	2.53	7.35	0.33
Carangidae	0.49	0.40	0.66	0.05	1.64	3.40	1.15	0.17	0.14	0.29	0.49	0.20
Sphyraenidae	1.76	0.00	0.11	0.00	0.00	0.00	0.84	0.00	0.00	0.00	0.39	0.44
Scaridae	1.01	1.11	0.00	0.94	2.05	0.15	1.39	1.34	2.48	0.16	0.05	1.27
Acanthuridae	0.43	1.62	3.52	2.14	1.07	6.89	4.54	6.39	1.49	1.48	0.27	0.85
Lutjanidae	2.11	0.65	2.59	2.91	0.50	2.41	0.64	3.02	1.98	1.02	0.98	0.60
Serranidae	0.96	0.00	0.00	0.03	0.03	0.02	0.25	0.08	0.01	0.06	0.43	0.01
Labridae	0.35	0.18	0.00	0.05	0.11	0.07	0.00	0.00	0.18	0.13	0.22	0.11
Balastidae	0.87	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26
Total	8.94	5.16	8.98	51.48	59.44	16.30	12.00	17.86	8.86	5.68	10.19	4.08

Appendix 4

**Detailed break down of the respective lectures that formed the SKCRCP Schools
Reef environmental Education Program.**

Education Programme

This 4-lecture programme introduces the classroom to the Reef environment and its components. It highlights the importance of this ecosystem both ecologically and economically. The programme can then be followed by a more in depth set of lectures, concentrating in particular problems or spp groups.

LECTURE 1: *Introduction to Coral Reefs*

- What is a Reef
- What do Reefs need to survive
- Coral Reefs and related ecosystems (Mangroves and sandbeds)
- Geographical location of the world Reefs

LECTURE 2: *Reef Biodiversity*

- Important spp within the Reef
- Food chains
- Spp I.D. games

LECTURE 3: *Why are Reefs so important?*

- Biodiversity
- Coastal defence
- Potential use for medicines
- Reproductive environment for commercially important spp
- Tourism
- Fisheries
- How does it affect local communities

LECTURE 4: *Problems and threats to the Reef*

- Natural problems
- Anthropogenic problems
- Sustainable use of local resources
- Importance of conservation of such resources.

Appendix 5

SKCRCP Species lists – Reef fish, Coral, Algae and Invertebrates

FAMILY		Common name	Species name
Surgeon fish	Acanthuridae	Blue tang	<i>Acanthurus coeruleus</i>
		Ocean surgeonfish	<i>Acanthurus bahianus</i>
		Doctorfish	<i>Acanthurus churigus</i>
Trumpet fish	Aulostomidae	Trumpetfish	<i>Aulostomus maculatus</i>
Trigger fish	Balistidae	Queen triggerfish	<i>Balistes vetula</i>
		Ocean triggerfish	<i>Canthidermnmis sufflamen</i>
		Sargassum triggerfish	<i>Xanthichthys ringens</i>
Toadfish	Batrachoididae	large eye toadfish	<i>Batrachoides gilberti</i>
Needlefish	Belonidae	Flat needlefish	<i>Ablennes hians</i>
Lefteye Flounders	Bothidae	Eyed flounder	<i>Bothus ocellatus</i>
Requiem sharks	Carcharhinidae	Lemon shark	<i>Negaprion breirostris</i>
		Bull shark	<i>Carcharhinus leucas</i>
Jackfish & Trevallys	Carangidae	Bar jack	<i>Carangoides ruber</i>
		Palometa	<i>Trachinotus goodie</i>
		Great amber jack	<i>Seriola dumerili</i>
		Horse eye jack	<i>Caranx latus</i>
Chubs	Kyphosidae	Chub	<i>Kyphosus sectatrix/incisor</i>
		Round scad	<i>Decapterus punctatus</i>
Snook	Centropomidae	Snook	<i>Centropomus undecimalis</i>
Butterfly fish	Chaetodontidae	Banded butterfly fish	<i>Chaetodon striatus</i>
		Four eye butterfly fish	<i>Chaetodon capistratus</i>
		Longsnout butterflyfish	<i>Chaetodon aculeatus</i>
		Reef Butterflyfish	<i>Chaetodon sedentarius</i>
		Spotfin butterfly fish	<i>Chaetodon ocellatus</i>
Stingrays	Dasyatidae	Southern stingray	<i>Dasyatis Americana</i>
		Roughtail stingray	<i>Dasyatis centroura</i>
	Urolophidae	Yellow stingray	<i>Urolophus jamaicensis</i>
Eagle rays	Myliobatidae	Spotted eagle ray	<i>Aetobatus narinari</i>
Porcupinefish	Diodontidae	Porcupinefish	<i>Diodon hystrix</i>
Nurse sharks	Ginglymostomatidae	Nurse shark	<i>Ginglymostoma cirratum</i>
Grunts	Haemulidae	French grunt	<i>Haemulon flavolineatum</i>
		Black margate	<i>Anistremus surinamensis</i>
		Small mouth grunt	<i>Haemulon chrysargyreum</i>
		tomtate	<i>Haemulon aurolineatum</i>
		Striped grunt	<i>Haemulon cstriatum</i>
		Spanish grunt	<i>Haemulon macrostomum</i>
		Sailors choice	<i>Haemulon parra</i>
		White margate	<i>Haemulon album</i>
		Caesar grunt	<i>Haemulon carbonarium</i>
		Porkfish	<i>Anisotrenus virginicus</i>
		Bluestriped grunt	<i>Haemulon sciurus</i>
Squirrelfish	Holocentridae	Longspine squirrelfish	<i>Holocentrus rufus</i>
		Squirrelfish	<i>Holocentrus adscensionis</i>
Blennies	Labrisomidae	Hairy Blenny	<i>Labrisomus nuchipinnis</i>
		Saddled blenny	<i>Malacoctenus triangulatus</i>
Wrasse	Labridae	Bluehead	<i>Thalassoma bifasciatum</i>
		Spanish hogfish	<i>Bodianus rufus</i>
		Hogfish	<i>Lachnolaimus maximus</i>
		Pudding wife	<i>Halichoeres radiatus</i>
		Clown wrasse	<i>Halichoeres maculipinna</i>
		Yellowhead wrasse	<i>Halichoeres garuati</i>
		Blackear wrasse	<i>Halichoeres poeyi</i>
		Slippery dick	<i>Halichoeres bivittatus</i>
Snapper	Lutjanidae	Yellowtail snapper	<i>Ocyurus chrysurus</i>
		Schoolmaster	<i>Lutjanus apodus</i>
		Red snapper	<i>Lutjanus campechanus</i>
		Cubera snapper	<i>Lutjanus cyanopterus</i>
		Gray snapper	<i>Lutjanus griseus</i>
		Dog snapper	<i>Lutjanus jocu</i>
		Mahogany snapper	<i>Lutjanus mahogoni</i>
		Mutton snapper	<i>Lutjanus analis</i>
		Lane snapper	<i>Lutjanus synagris</i>
Tarpons	Megalopidae	Tarpon	<i>Megalops atlanticus</i>
Filefishes	Monacanthidae	Orangespotted filefish	<i>Cantherhines pullus</i>
Goatfish	Mullidae	Yellow goatfish	<i>Mulloidichthys martinicus</i>
		Spotted goatfish	<i>Pseudupeneus maculatus</i>
Moray eels	Muraenidae	Goldentail moray	<i>Gymnothorax miliaris</i>

Snake eels	Opichthidae	Spotted moray	<i>Gymnothorax moringa</i>
		Green moray	<i>Gymnothorax funebris</i>
		Golden spotted eel	<i>Myrichthys ocellatus</i>
Trunkfish	Ostraciidae	Sharptailed eel	<i>Myrichthybreviceps</i>
		Scrawled cowfish	<i>Acanthostracion quadricornis</i>
		Spotted trunkfish	<i>Lactophryss bicaudalis</i>
Angelfish	Pomcanthidae	Trunkfish	<i>Lactophryss trigonus</i>
		Gray Angelfish	<i>Pomacanthus arcuatus</i>
		French anglefish	<i>Pomacanthus paru</i>
Damselfish	Pomacentridae	Rock beauty	<i>Holacanthus tricolor</i>
		Yellowtail damselfish	<i>Microspathodon chrysurus</i>
		Sergeant major	<i>Abudefduf saxatilis</i>
Parrotfish	Scaridae	Threespot damselfish	<i>Stegastes planifrons</i>
		Rainbow parrotfish	<i>Scarus guacamaia</i>
		Blue parrotfish	<i>Scarus coeruleus</i>
		Princess parrotfish	<i>Scarus taenipterus</i>
		Stoplight parrotfish	<i>Sparisoma viride</i>
		Queen parrotfish	<i>Scarus vetula</i>
		Red band parrotfish	<i>Sparisoma aurofrenatum</i>
		Striped parrotfish	<i>Scarus iserti</i>
		Redtail parrotfish	<i>Sparisoma chrysopteron</i>
Grouper	Serranidae	Red grouper	<i>Epinephelus morio</i>
		Tiger grouper	<i>Myceteroperca tigris</i>
		Nassau grouper	<i>Epinephelus striatus</i>
		Yellowfin grouper	<i>Myceteroperca venenosa</i>
		Red hind	<i>Epinephelus guttatus</i>
		Rock hind	<i>Epinephelus adscensionis</i>
		Coney	<i>Cephalopholis fulva</i>
Barracudas	Sphyaenidae	Great barracuda	<i>Sphyaena barracuda</i>
Pufferfish	Tetraodontidae	Sharpnose puffer	<i>Cathigaster rostrata</i>
Lizard fish	Synodontidae	Bluestriped lizardfish	<i>Synodus saurus</i>
Scorpionfish	Scorpaenidae	Spotted scorpionfish	<i>Scorpaena plumieri</i>
Seahorses	Syngnathidae	Longsnout seahorse	<i>Hippocampus reidi</i>

FAMILY	Common name	Species
Acroporidae	Elkhorn	<i>Acropora pulmata</i>
	Staghorn	<i>Acopora cervicornis</i>
	Fused staghorn	<i>Acopora prolifera</i>
Agariciidae	Ribbon/Thin leaf lettuce coral	<i>Agaricia tenuifolia</i>
	Fragile saucer coral	<i>Agaricia fragilis</i>
	Scroll coral	<i>Agaricia undata</i>
	Leaf/Lettuce coral	<i>Agaricia agaricites</i>
	Low relief lettuce coral	<i>Agaricia humilis</i>
	Massive leaf	<i>Agaricia denai</i>
	Saucer coral	<i>Heliocoris clicullata</i>
Astrocoeniidae	Blushing star coral	<i>Stephanocoenia intersepts</i>
Anthothelidae	Encrusting gorgonian	<i>Erthropodium caribaeorum</i>
	Black sea rod	<i>Plexaura homomalla</i>
	Bent sea rods	<i>Plexaura flexuosa</i>
	Porous sea rods	<i>Plexaura spp</i>
Plexauridae	Rough sea plume	<i>Muriceopsis flavida</i>
Briareidae	Corky sea finger	<i>Briareum asbestinum</i>
Faviidae	Grooved brain coral	<i>Diploria labyrinthiform</i>
	Smooth brain coral	<i>Diploria strigosa</i>
	Giant brain	<i>Colpophyllia natans</i>
	Knobby brain coral	<i>Diploria clivosa</i>
	Great star coral	<i>Montastraea cavernosa</i>
	Mountainous star	<i>Montastraea annularis</i>
	Smooth star coral	<i>Solenastrea bournoni</i>
	Rose coral	<i>Manicina areolata</i>
	Common sea fan	<i>Gorgonia ventalina</i>
	Sea plumes	<i>Pseudopterogorgia spp</i>
Meandrinidae	Bipinnate sea plume	<i>Pseudopterogorgia bipinnata</i>
	Pillar coral	<i>Dendrogyra cylindrus</i>
Milliporidae	Elliptical star coral	<i>Dichocoenia stokesi</i>
	Branching Fire coral	<i>Millipora alcornis</i>
Mussidae	Blade Fire coral	<i>Millipora complamenta</i>
	Rough star coral	<i>Isophyllastrea rigida</i>
	Sinuuous cactus coral	<i>Isophyllia sinuosa</i>
	Ridgeless cactus	<i>Mycetopyllia reesi</i>
Poritidae	Green cactus	<i>Mycetopyllia aliciae</i>
	Finger coral	<i>Porites porites</i>
	Club finger	<i>Porites furcata</i>
	Thin finger	<i>Porites divaricata</i>
	Mustard Hill coral	<i>Porites asteroides</i>
Pocilloporidae	Yellow pencil	<i>Madracis mirabilis</i>
	Eight ray finger	<i>Madracis Formosa</i>
Siderastreidae	Smooth starlet coral	<i>Sideratrea sidereal</i>
	Rough starlet	<i>Sideratrea radians</i>
Caryophyllidae	Flower coral	<i>Eusmilia fastigiata</i>

	FAMILY	Common name	Species
sponge	Irciniidae	Black ball	<i>Ircinia strobilina</i>
	Callyspongiidae	Branching vase	<i>callyspongia vaginalis</i>
	Raspailiidae	Brown encrusting octopus	<i>Ectyoplasia ferox</i>
lobster	Palinuridae	Caribbean spiny lobster	<i>Panulirus argus</i>
Conch	Strombidae	Queen conch	<i>Strombus gigas</i>
Flamingo tongue	Ovulidae	flamingo tongue	<i>Cyphoma gibbosum</i>
Urchin	Diadematidae	Sea Urchin	<i>Diadema antillarum</i>
	Cidaridae	Pencil urchin	<i>Eucidaris tribuloides</i>
	Echinometridae	Rock-boring urchin	<i>Echinometra lucunter</i>
		Reef/Rock urchin	<i>Echinometra viridis</i>
Worms	Terebellidae	Spaghetti worms	<i>Eupolytnia crassicornis</i>
	Sabellidae	Split crown feather duster	<i>Anamobaea orstedii</i>
shrimp	Stenopodidae	(Banded) Coral shrimp	<i>Stenopus hispidus</i>
	Palaeomonidae	Pederson Cleaner Shrimp	<i>Periclemenes pedersoni</i>
		Spotted Ceener shrimp	<i>Periclemenes yacatanicus</i>
anemone	Stichodactylidae	Sun anemone	<i>Stichodactyla helianthus</i>
	Arachnactidae	Banded tube anemone	<i>Arachmanthus noturnus</i>
	Phymanthidae	Beaded anemone	<i>Epicystis crucifer</i>
	Zoanthidae	White encrusting zoanthid	<i>Palythoa caribaeorum</i>
isopod	Cymothoidae	isopod	<i>Cymothoid ?</i>
Sea star	Oreasteridae	cushion sea star	<i>Oreaster reticulatus</i>
	Ophidiasteridae	common comet star	<i>Linckia guildingii</i>
hydroid	Halocordylidae	Christmas tree hydroid	<i>Halocordyle disticha</i>
	Thoracica (Order)	sessile barnacles,	

PHYLUM	Species
Chlorophyta	<i>Udotea flabellum</i>
	<i>Udotea cyanthiformis</i>
	<i>Rhipocephalus phoenic</i>
	<i>Penicillus pyriformis</i>
	<i>Penicillus capicatus</i>
	<i>Halimeda copiosa</i>
	<i>Halimeda tuna</i>
	<i>Halimeda incrassata</i>
	<i>Halimeda apuntia</i>
	<i>Halimeda discoidea</i>
	<i>Acetabularia caliculus</i>
	<i>Neomeris annulata</i>
	<i>Ventricaria ventricosa</i>
	<i>Dictiosphaeria cavernosa</i>
	<i>Rhapilia tomentosa</i>
Phaeophyta	<i>Dictyota bartayresis</i>
	<i>Rosenvingea saritae-crucis</i>
	<i>Dictyota cervicornis</i>
	<i>Styopodium zonale</i>
	<i>Padina gymnospora</i>
	<i>Padina sanctae-crucis</i>
	<i>Lobophora verticigata</i>
	<i>Sargassum natans</i>
	<i>Turbinaria turbinata</i>
Rhodophyta	<i>Wrangelia argus</i>
	<i>Condria tenuissia</i>
	<i>Galaxaura oblongata</i>
	<i>Jania adherans</i>
	<i>Amphiroa rifida</i>
	<i>Peyssonnetia spp.</i>
	<i>Parolithon pachydermum</i>

