

The Health of Utila's Coral Reef :

The distribution and diversity of fish species around Utila and the Effect of Hurricane Mitch, 1998 on the habitats that they occupy

(University of York, Coral Cay Conservation)



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Abstract

This report focuses on the health of Utila's Reef, recorded by Coral Cay Conservation using 3 separate Survey methodologies. It has been shown that there is a clear pattern in the distribution of substratum types around Utila and that fish species exhibit strong preferences for certain habitats, for example Spotfin Butterflyfish exhibiting a preference for SEBR. This pattern is strengthened and highlighted further when looking at family data. From the project Utila data it was thus possible to see how substratum cover had been affected by Hurricane Mitch and subsequently, which species of fish are likely to have been impacted by the destruction and decline in substratum cover due to the reduction in food and shelter exhibited. Although not carried out here, by analyzing the fish species, project Utila data, as a future project it would be possible to determine how numbers have changed at certain sites, and if numbers are increasing in other places, how this is affecting competition between the species. The project could have been improved by analysis of the dive shop data and reef check data, both of which would have increased the validity of the results, but could not be included due to the size of the project. The reef check data has been placed in the appendices (536 +) and the dive shop data, is held by Coral Cay, although I took this into consideration when analyzing the data.

ACKNOWLEDGMENTS

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ABBREVIATIONS

SMB	Surface Marker Buoy
GPS	Global Positioning Satellite
CCC	Coral Cay Conservation
ANOVA	Analysis of Variance
SIMPER	Similarity Percentage Analysis

BENTHIC CLASSES

BDBR	Bedrock/ Rubble & Dense Gorgonians + Back Reef
BDF	Bedrock/ Rubble & Dense Gorgonians + Forereef
BSBR	Bedrock/ Rubble & Sparse Gorgonians + Back Reef
BSDE	Bedrock/ Rubble & Sparse Gorgonians + De. Patch Reef
BSE	Bedrock/ Rubble & Sparse Gorgonians + Escarpment
BSF	Bedrock/ Rubble & Sparse Gorgonians + Forereef
BSLS	Bedrock/ Rubble & Sparse Gorgonians + L. Spur & Groove
BSRC	Bedrock/ Rubble & Sparse Gorgonians + Reef Crest
DEF	Dense Massive & Encrusting Corals + Forereef
SCSL	Seagrass with Distinct Coral Patches + Shallow Lagoon
SEBR	Sparse Massive & Encrusting Corals + Back Reef
SEE	Sparse Massive & Encrusting Corals + Escarpment
SEF	Sparse Massive & Encrusting Corals + Forereef
SERC	Sparse Massive & Encrusting Corals + Reef Crest
SF	Sand with Sparse Algae + Forereef
UBR	Unknown + Back Reef
UE	Unknown + Escarpment
UF	Unknown + Forereef
URC	Unknown + Reef Crest

STUDY AREAS

AP	Airport
BB	Blue Bayou
BH	Black Hill
BB	Big Bight
DC	Diamond Cay
JN	Jack Neils
LH	Lighthouse
PB	Pretty Bush
PK	Pumpkin Hill
RC	Ragged Cay
RH	Rock Harbour
SWC	Southwest Cay
TH	Turtle Harbour
WC	Water Cay
SC	Sandy Cay

Introduction

Section 1 Background

1.1 Honduras

Honduras is located in Central America and is found bordering El Salvador and Nicaragua to the South and Guatemala to the West. The country has a 644 km long stretch of Caribbean coastline and a 124 km stretch of Pacific coastline. The economic zone of Honduras stretches 200 nautical miles out to sea. It has a land area of 112,492 sq km and a population of 5,997,327 (July 2000 estimate). It is one of the poorest countries in Central America, a problem compounded recently by Hurricane Mitch in 1998.

Honduras has two very diverse ecosystems in tropical rainforests and coral reefs. These are both of vital importance, ecologically and economically. Coral reefs are of particular importance due to the revenue they create through tourism. However, coral reefs are under a number of threats due to over fishing, sedimentation, pollution, etc. The rainforests are also under threat from deforestation, which is currently taking place at a rate of 3000 sq km per year. If it carries on at this rate, then Honduras will become a treeless desert in the next 20 years. Deforestation also places impacts on the reefs as Honduras has a mountainous, rugged landscape and deforestation will causes increased eutrophication, hence run-off and leaching of nutrients from the soil into the ocean. This can be shown to be due to the inhibition of reef growth off the mainland of Honduras, which is caused by high rainfall. The predominant reef development in Honduras occurs at the offshore Bay Islands, Islas de Bahia. If these environments continue to be over exploited and destroyed it will lead to increased poverty in communities relying on fishing, agriculture and tourism.

Fig 1: Map of Honduras¹



1.2 The Bay Islands

The Bay Islands form an arc between 29 and 56 km off the coast of Honduras. The Bay Islands are located in an East West orientation along the Southern margin of the trench, and sit on the Bonacca Ridge. The Bonacca ridge forms the edge of the Honduran shelf. This results in reefs that extend seaward to depths of 30 – 40 ft before dropping off to depths of up to 250 ft. The reefs around the Bay islands are known as “fringing escarpment reefs.” Growth of *Montastraea annularis* is common on the reefs of the Bay Islands. Off the southeastern coast of Utila shallow ramparts leave the corals exposed at low tides resulting in much dead coral. This has been covered with dense turf algae (Fenner, 1993).

A large proportion of the dense forests of the Bay islands have been removed to provide building materials for the local community. The only areas left with significant amount of forest include the island of Barbareta and the hills of Roatan and Guanaja. The height of the islands tends to increase from West to East, from Utila to Roatan and Guanaja.

Fig 2: Photo of forests of Roatan

¹ <http://www.hoi.org/mapof.htm>



Utila is the smallest of the 3 main Bay Islands and is 11 km long and 5 km wide. Two thirds of the land area is composed of lowland swamp. Stuart's Hill and Pumpkin Hill, located on the east of the island are of volcanic origin. Utila has a population of approximately 2000, the majority of which inhabit the area of East Harbour, located on the south side of the island. Of the southwest of Utila are 12 small cays, the main ones being Suc-Suc and Pigeon cay.

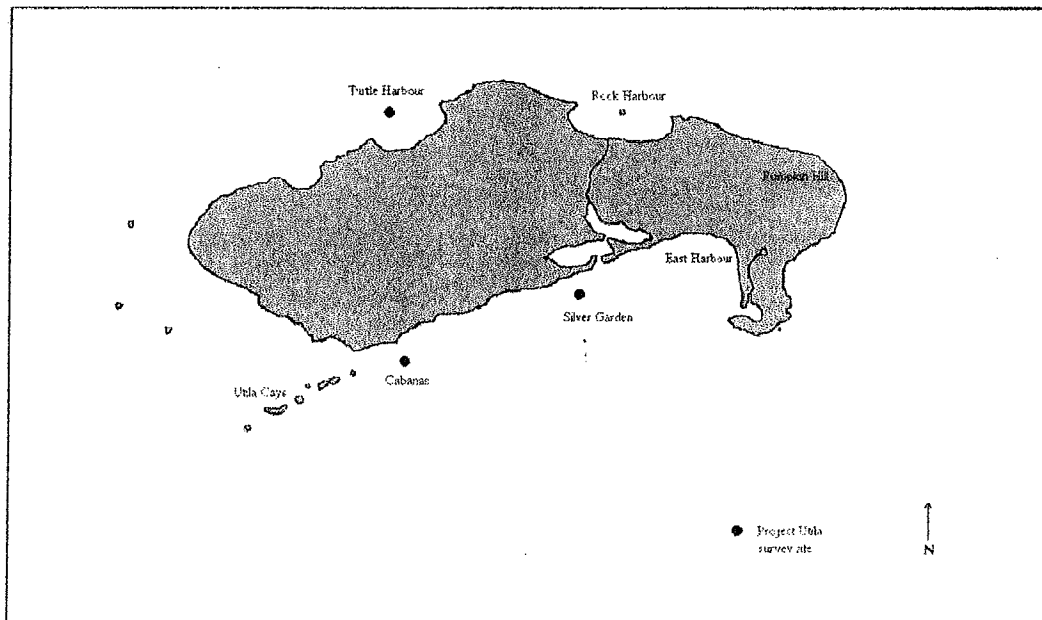
Up until 1992, fishing and agriculture were the main activities on the island of Utila, which has changed slightly due to the development of the tourist sector, which is now a major source of income for the island's economy. There are about 14 dive shops on Utila, and many people come to learn to dive here, as it is, "the cheapest place in the world". However, this influx in tourism has an impact on the local people and their traditional ways of life. There has been an increase in crime and an increase in the cost of commodities and goods. The use of local resources is also being over exploited.

At present, there are a number of threats to Utila's ecosystem which are listed below:

- i) Sedimentation – from runoff, leaching of nutrients, etc.
- ii) Erosion – extraction of sand and coral from the island's coastline, which may result in loss of significant areas of beachfront during Hurricanes, storms, etc.

- iii) Mangrove deforestation – use for building materials resulting in loss of nesting habitats for birds and breeding grounds for species such as conch and lobster.
- iv) Effluent and waste run off – lead to excessive algal growth
- v) Physical damage – anchors, divers, etc.
- vi) Over-fishing – impact on local fisheries due to increased numbers of tourists and increasing algal levels due to reduced grazing by fishes.
- vii) Coral bleaching and disease.

Fig 3: Map of Utila²

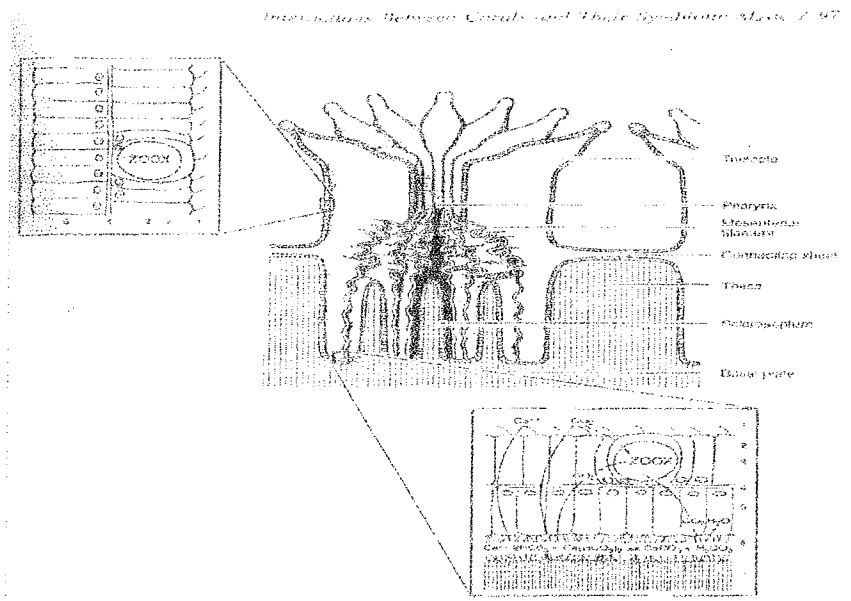


1.3 Coral Reefs

Corals are composed of two cell layers, the epidermis (ectodermis) and the gastrodermis (endodermis). These cell layers are separated by a thin layer of connective tissue, commonly known as the “Mesoglea.” The Mesoglea is composed of collagen, mucopolysaccharide and cells.

² <http://www.coralcay.org>

Fig 4: Diagram showing coral structure³



The lower epidermal layer secretes a calcareous skeleton and the upper epidermal layer is in contact with the seawater. Polyps are small fleshy extensions of the coral cover and are usually 1 mm in diameter. Coral polyps are biradially symmetrical and have a central gut cavity, which is lined by the gastrodermis. The tentacles and mouth are used for the capture of zooxanthellae. The polyp mouths are used for the direct exchange of water, particulate food and waste. The zooxanthellae reside in the membrane bound vesicles in the gastrodermal cells. Scleractinian corals are colonies of polyps linked by a common gastrovascular system, and can be metres in diameter.

Diversity of coral reefs can be measured at the spatial scale, which involves within habitat (α diversity), between habitats (β diversity) and regional diversity (γ diversity). Diversity is strongly influenced by environmental conditions and geographic location. This reflects both obligate reef associates and taxa that also occur in non reef environments. Coral reefs are home to most marine animal phyla and all algal divisions. A number of factors can affect species diversity, which are listed below:

- i) Environmental favourability

³ The Life & Death of Coral Reefs, Charles Birkland, chapter 5, p 97

- ii) Productivity
- iii) Habitat heterogeneity
- iv) Niche diversity
- v) Interspecific interactions
- vi) Historical stability
- vii) Species origination and extinction.

Coral reefs are found in warm water where there is little seasonal variation.

Diversity can also be divided into three ecologically important guilds, which are:

- | | | |
|------|---------------------------------------|--|
| i) | Photo symbiotic associations - | recycling of nutrients as a result of symbiotic associations between microscopic plants and their animal hosts. |
| | Reef algal symbionts - | Dinoflagellates – zooxanthellae
symbiodinium |
| ii) | Reef builders - | Colonial scleractinians
Helioporans
Milleporas
Coralline algae |
| iii) | Reef eroders - | Microorganisms - bacteria, cyanobacteria, fungi, endolithic red & green algae.
Macroboras - sponges, polychaetes, bryozoans, etc.
Echinoids & fish, gastropods, chitons and decapoids. |

1.4 Hurricane Mitch, 1998 (Hurricanes, storms & cyclones)

The impact a storm causes on a coral reef is usually determined by a number of factors. Below are a few examples⁴:

⁴ Life and Death of Coral Reefs, Charles Birkland p363

- i) Directional approach of the storm
- ii) Its intensity and resultant wave height and energy
- iii) The vertical relief of the site
- iv) Its protection from direct influences
- v) The reef community type and its susceptibility to high energy conditions
- vi) Past history of disturbance at the site.

Damage to coral reef as a result of hurricanes is usually due to wave action and subsequent movement of rubble. There is increased sedimentation and turbidity and increased run off after heavy rain. Most storm damage occurs at a depth of 0-20 m. however, damage can occur at greater depths by coral blocks falling down steep slopes, "avalanche effect". It has been shown previously that branching corals such as Staghorn and Elkhorn appear to suffer the most from storm damage.

Hurricane Mitch occurred late in the season, towards the end of October. A tropical depression first formed on October 21st 1998. It was classed as a force 5 hurricane and is considered the largest and deadliest tropical cyclone of the century. Hurricane Mitch moved NW slowly over the first few days and on the 23rd October there was a sharp increase in intensity. Mitch strengthened from 60 knots to a Saffir Simpson category 5 Hurricane. Winds reached a peak of 157 knots on October 26th just off the NE coast of Honduras. It maintained this level of intensity for nearly 24 hours. On the morning of October 28th the wind strength dropped to 105 knots. Hurricane Mitch stalled and slowed just off the Bay Islands from the 27th to the 29th. This slow movement caused heavy rain in Central America, causing extensive flooding and mudslides. Particularly hard hit was the capital of Honduras, Tegucigalpa where 11,000 people died and 2000,000 were left homeless. Greater than 50 % of the infrastructure was destroyed and for weeks following the storm, trees, mud and debris were washed up onto the beaches and reefs. Hurricane Mitch then turned into the Gulf of Mexico towards Florida.

Fig 5: Track of Hurricane Mitch and Satellite Image⁵



⁵ <http://www.usatoday.com/weather/hurricane/1998/wmitch2.htm>
<http://www.osei.noaa.gov/mitch.html>

1.5 Report Outline

The aim of this report is to investigate the health of Utila's reef by looking at the distribution and diversity of fish and coral species around the island, to see what habitats fish species are commonly found inhabiting and how Hurricane Mitch has affected their distribution and diversity. This will be achieved using 3 survey methodologies, carried out by Coral Cay Conservation, described in the following section.

Section 2: Methods

2.0: General

The collection of the data used for the analysis of Utila's reef in Honduras involved 3 main techniques, and 2 minor techniques. These are as follows:

1. Baseline transects
2. Reef Check
3. Project Utila
4. Validation
5. Dive shop surveys

All of the above techniques were employed and carried out by Coral Cay Conservation Staff and Volunteers at the research sites.⁶

2.1: Baseline transect

A series of plotless transects are utilized, perpendicular to the reef, starting from the 28 metre contour and terminating at the reef crest or in very shallow water. A survey team is comprised of 2 pairs of trained divers. The transects are subdivided up into sub-transects as it usually takes more than one diver to complete a transect.

At the start of the transect Buddy pair B remains stationary with diver 3 holding one end of the 10 metre rope. Buddy pair A then swims away from them. Diver 1 is holding the opposite end of the rope. Diver 2 holds the Surface marker buoy (SMB). Pair A swims away on a designated bearing until the 10 metre line becomes taught. Pair A then marks a spot and pair B swims towards them to meet them. Pair A point the spot to pair B where the sub-transect finished and then pair A start another sub-transect. This process is repeated in a Constantine fashion until the end of the planned dive profile. At the end of

⁶ www.coralcay.org

Refer to Project Utila 99 & 00 report at this site for more details

the dive an SMB is tied off to mark the position for the continuation of the transect at a latter date. The process is repeated until the transect is completed at the reef crest. The position of the SMB is fixed using GPS at the start and end of each dive.

During the dive a number of tasks are carried out by each diver, which are as follows:

- | | | |
|---------|---|--|
| Diver 1 | - | Leads the dive |
| | - | Takes a depth reading at each 10 metre interval |
| | - | Documents signs of Anthropogenic Impact (e.g broken coral, fishing nets, etc.) |
| | - | Current direction / strength |
| | - | Temperature reading |
| | - | Water sample for salinity measurements |
| | - | Describes the substratum (dead coral, bedrock, etc.) |
| Diver 2 | - | Fish surveys |
| Diver 3 | - | Hard Coral surveys |
| Diver 4 | - | Algae, Soft Corals, Inverts and Sponges |

Diver 3 surveys an area of approximately 1 metre to each side of the transect line whilst divers 1, 2 and 4 survey an area of approximately 2.5 metres either side of the line. During the course of each sub-transect, divers may traverse two or more apparently discrete habitats, based upon the gross geo-morphological or biological differences. (e.g dense coral reef, sand or rubble). The data for each habitat type is recorded separately for subsequent analysis. Each species, lifeform or substratum category is assigned an abundance rating from the ordinal scale, shown in Table 1.

Table 1:

Abundance Rating	Coral and Algae	Fish and Invertebrates (Number of Individuals)
0	None	0
1	Rare	1-5
2	Occasional	6-20
3	Frequent	21-50
4	Abundant	51-250
5	Dominant	250 +

The data is then transferred to recording forms (Appendix 1) prior to incorporation into the database for further analysis. During a dive, the Boat Marshall is responsible for taking data on surface water temperature, salinity, vertical turbidity, wind strength and direction and boating activities. Wind strength is estimated using the Beaufort scale and vertical turbidity measured using a sechi disk.

2.2: Reef Check

Reef Check⁷ is an international program used to create a global synoptic survey of the health of the World's reefs. The Reef Check protocol utilizes 2 transects at a depth of 3 metres and 10 metres. Four, 20 metre long transects are carried out along each contour. The transects follow the designated depth contour in sequence, but the start and end point is separated by a 5 metre space. The total distance of the transect is 100 metres. For each transect, 5 types of survey are carried out. These are as follows:

- i. Site description - anecdotal, observational, historical, etc.
- ii. Fish belt transect - Four, 5 M x 20 M transects
 - The diver swims along the transect, stopping every 5 metres to count target fish.
- iii. Invertebrate belt transect - Four, 5 M x 20 M transects
 - Quantitative counts are made of each species

⁷ <http://www.Reefcheck.org>
www.coralcay.org

- iv. Substratum line type
 - Coral bleaching/ disease also noted.
 - Four 20 M long transects are pointed at 0.5 M intervals to determine the substratum types on the reef
 - The diver looks at a series of points where the transect touches the reef and notes down what lies under these points.
 - The categories recorded are Hard Coral, Soft Coral, etc...
- v. Anthropogenic data
 - Impacts are assessed for coral damage via anchors, dynamite fishing, etc...
 - 0-3 Scale (0 = none, 3 = High)

On Utila Coral Cay conservation staff and volunteers surveyed 2 sites in 1999 at Ragged Cay and Silver Gardens. In 2000, Coral Cay expanded their survey to cover more sites around Utila and improved the methodology, going into more detail for substrate type. Table 2 shows the sites surveyed and their location on Utila.

Table 2: Reef Check monitoring Sites

	Site	Location - GPS	Depth
A	Ragged Cay	N 1605'31.7" W 8659'33.1"	5 M 9 M
B	Silver Gardens	N 1604'58.9" W 8655'02.5"	4 M 12 M
C	Rock Harbour	N 1607'27.8" W 8656'08.9"	6 M 11 M
D	Flight Path	N 1605'13.9" W 8653'06.6"	6 M 11 M
E	Turtle Harbour	N 1606'53.4" W 8656'50.9"	4 M 9 M
F	Aquarium	N 1606'26.3" W 8652'27.8"	9 M 12 M
G	Cabanas	N 1604'10.9" W 8657'11.8"	5 M 8 M

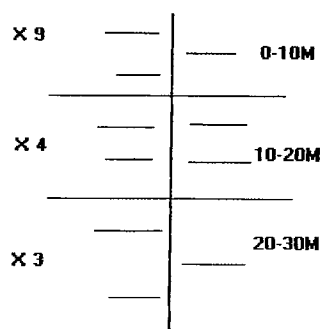
2.3 Project Utila Reef Monitoring Program⁸

Project Utila has been an ongoing project since 1995. Between 1995 and 1999 3 sites were established at Silver Gardens, Turtle Harbour and Cabanas. At each site 2 permanent baselines needed to be established. Two 100 m baselines are laid perpendicular to the shore. One of these lines is layed directly below the buoy, the other 100 m away in a clockwise direction. The idea behind this is that one of the sites will illustrate diver impact as these sites are frequented by local dive schools who moor at the buoys and the other site will not be impacted as divers rarely swim more than 100 m during the course of a dive. The lines were fixed at 28 m or at the top of the reef crest. The location of each site is fixed by GPS.

Each baseline is divided into 3 depth zones which are as follows:

- Deep (30-20m)
- Medium (20-10m)
- Shallow (<10m)

Surveys are carried out at random points along the baseline, with 16 subtransects perpendicular to each baseline. The diagram below shows the layout of these surveys.



⁸ www.coralcay.org

For more details on the following methodology refer to the interim report – June 1999 (Coral Cay Conservation)

The depth of the substratum is recorded at 5 m intervals along the transects.

Hard corals are surveyed using a 10 m line intercept transect. Categories are measured to the nearest cm and include hard corals, sponge life forms, etc⁸.

The numbers of soft corals are recorded via a 10 m by 1 m belt. Soft corals are grouped into the following categories. Rods-branched, rods-unbranched, whips, fans and plumes. Sponges are surveyed using the same survey transect as for soft corals.

Fish are surveyed along a transect which is 50 m long by 2 m above and to either side of the line of swimming. Fish are identified to species level. Table 3 shows the abundance score used for fish counts.

Table 3: Abundance scale

Number of fish	Abundance
0	0
1-2	1
3-10	2
11-30	3
31-75	4
>75	5

Finally a point intercept technique was used to provide an overview of the reef. A 50 m tape is laid out and the life form category recorded under the tape at each meter interval.

2.4 Dive shop surveys⁹

A number of surveys were carried out on the local dive schools in Utila to find out the sites being most frequented by divers, hence which sites were suffering the greatest from human impact.

⁹ www.coralcas.org

2.5 Validation

To ensure the accuracy of the data being collected it was necessary to carry out a coral, fish and algae test before surveying by volunteers commenced. A pass mark of 80% and above was required. These test involved studying pictures of fish and corals from the books by Paul Humann. Once these tests were passed it was then necessary to carry out validation tests to ensure volunteers were recording the correct species. This was done for corals by means of a coral trail laid out by staff at a site. Along this trail a tag with a number was attached to a rope besides a particular coral. During the course of a dive volunteers had to record the corals they saw next to the tags which could then be compared with the coral recorded by the staff. Fish validation involved 2 divers recording the fish they saw on the course of a dive as they swam along together and then Bray-Curtis similarity coefficients was carried out to compare how similar the 2 divers records were.

The Bray Curtis similarity coefficient is given by the following formula:

$$\text{Bray Curtis Similarity} = \frac{\sum_{i=1}^P (X_{ij} - X_{ik})}{\sum_{i=1}^P (X_{ij} + X_{ik})}$$

where X_{ij} = abundance of the i th species in the j th sample and there are P species overall.

2.6 Data Analysis

2.6.1 Reef Check

To analyse the Reef check data both substrate cover and fish and invertebrate species were investigated. For the substrate data the proportion contributing to each survey was worked out and then the mean, standard deviation and standard error calculated. From this data the abundance of each substrate type was investigated within sites, shallow and deep, and between sites, for example, Ragged Cay and Silver Gardens. The diversity of each site was then calculated using the commonly used Shannon–Weiner Index and then the Bray Curtis Similarity coefficient was used to determine how similar a site was at the shallow and deep depth and how similar different sites were, related to their location around Utila. Comparisons were also drawn between the year 99 and 00. The same method of data analysis was carried out on the fish and invertebrate species data.

2.6.2 Project Utila

The project Utila data set is divided up into four sections, which are as follows:

- i) Physical
- ii) Soft Corals & Sponges
- iii) Hard Corals
- iv) Fish data

For each section 3 sites are analysed over 5 years, from 1995 to 1999. Each site has 2 locations, impacted and non-impacted.

To analyse this data set I have looked at how the abundance of each category varies at each site for all of the above groups to see how the distribution and diversity of corals, fish, sponges, etc. varies around the island. For each site a diversity index was carried out to see how diverse the sites were, which could then be cross referenced to other sites to see how much diversity varied and if there was a decline in diversity at the same site over the 5 year time scale. The idea behind this is that it is possible to look at the impact of Hurricane Mitch and the Coral Bleaching event in 1998 by measuring the % change from

1995 to 1999 and from 1997 to 1999. The Bray Curtis similarity coefficient was also used to determine the % similarity between sites, within sites and over time. This data can be compared with the Reef Check and baseline data sets as well as a report highlighting the impact of the Hurricane and the damage caused¹⁰.

2.6.3 Baseline Data – Utila

The baseline data was used to assign a habitat label to each of the transects carried out around Utila and then the abundance of fish species was linked to the habitat labels to enable one to gain a picture for the distribution and diversity of fish around Utila, as well as the habitats being occupied by particular species. It is then possible to correlate this with the other data sets to see if a decline in habitat cover caused a decline in certain species of fish, their migration to other sites, increased competition, etc.

2.6.3.1 Habitat Classification

The habitats were classified using a combination of Cluster, Simper and discriminate analysis. Cluster analysis was used to group a subset of the data. Any data not falling within the clusters was removed and classified unknown. Simper analysis was then carried out to assign habitat labels to the clusters, hence the survey transects falling within specific clusters. Finally, the remaining clusters were assigned to the cluster formed using a simple index. For each cluster already formed the mean of each substrate type was taken and a Bray Curtis similarity test was carried out to compare the remaining sites against these clusters. The sites were then assigned to whichever cluster they had the highest similarity with. Any site with a similarity of less than 50% was classed as unknown, to ensure a conservative estimate was obtained. The Habitat labels are composed of a benthic class and a geomorphological class.

¹⁰ Ecological Status of the Mesoamerican Barrier Reef System, Kramer, P.A., Kramer, P.R.

2.6.3.2 Fish Data

For each species the mean abundance was calculated for each habitat formed, and then the mean abundance was calculated for each species overall on Utila. Standard deviations were calculated for each species. A Kruskal-Wallis one way ANOVA was carried out to assess the variation between the habitats. The species data was then used to produce a table showing mean abundances for family and likewise, standard deviation and Kruskal-Wallis tests were carried out. For each family the order of habitat preference was noted by comparing the mean abundances.

Finally a map was produced showing the 14 study areas around Utila and a table was produced from the fish data illustrating the sites most individual species and their respective family were found at, on Utila as a whole and at each individual habitat area.

Section 3: Results

3.1 Data Collection

Three sets of data were used in this report. The baseline data, to date, consisted of 596 transects, involving 15 study areas, collected from the 14th July 1999 to the 24 May 2000. The final baseline data, after analysis consist of 543 surveys. Since this report has been written approximately 200 extra surveys have been completed.

3.2 Baseline Data

The Coral Cay methodology was used to generate the results in the baseline data section (section 3.2-3.4) and the Commercial fish species report on Belize written by Alastair Harborne, CCC was used as a reference point.

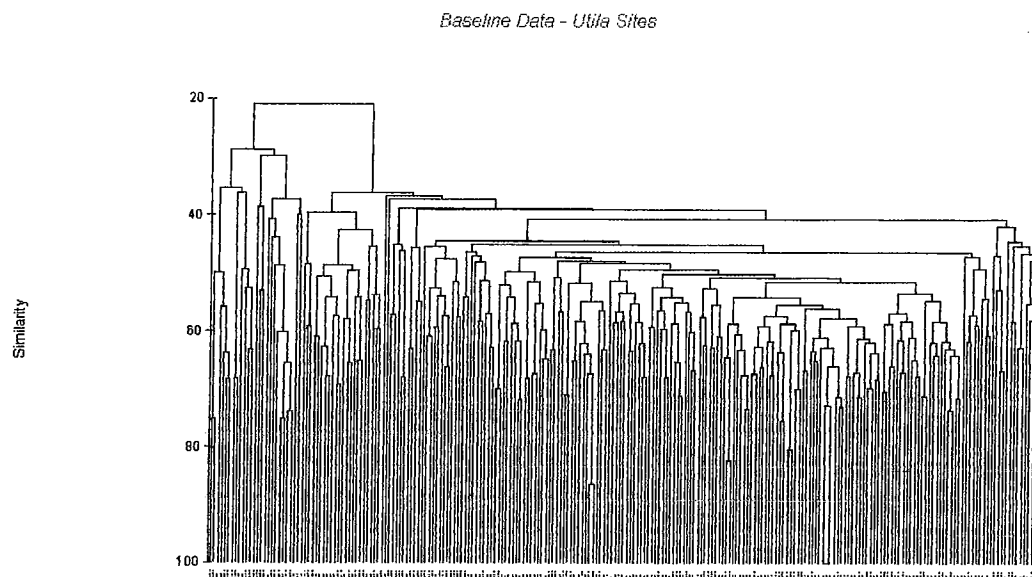
The benthic data¹¹ was used to assess the distribution and diversity of Utila's Coral Reef. Cluster analysis was carried out on a random subset of 250 from the data set¹² and was used to produce a dendrograph. From this dendrograph¹³ clusters were assigned at a Bray-Curtis similarity of between 50-60 %. Any sites not fitting the main clusters were removed for clarity and classed as unknown. The remaining 230 sites were reclustered. Of the 250 sites to start, 20 were removed and classed as unknown. Six clusters were highlighted from the remaining 230 sites as shown by the dendrograph produced, Figure 10.

¹¹ Appendix 1

¹² Appendix 2

¹³ Appendix 3

Figure 10: Final dendrogram used to produce the 6 clusters from the remaining 230 sites. The Y-axis represents the Bray Curtis similarity Coefficient (%)¹⁴.



SIMPER analysis was then carried out on each of the 6 clusters formed to determine which species contributed most to each¹⁵. Table 4 shows the key benthic categories contributing to each cluster and the benthic class labels assigned to each of the clusters. The labels were assigned according to the classification scheme of Mumby and Harborne (1999)¹⁶.

¹⁴ Appendix 4

¹⁵ Appendix 5

¹⁶ Biological Conservation 88 (1999) p155-163

Table 4:Characteristic species of each cluster as highlighted by SIMPER analysis. The percentage contributions of each category are shown in parentheses.

		Cluster			
1	2	3	4	5	6
Seagrass with distinct Patches	Sand with sparse algae	Dense Massive & encrusting corals	Sparse Massive & encrusting corals	Bedrock/ Rubble & sparse gorgonians	Bedrock/ Rubble & dense gorgonians
		Characteristic	species		
<i>Thalassia testudinum</i> (25.10)	Sand (71.13)	Sand (27.11)	<i>Dictyota</i> spp. (10.44)	<i>Lobophora variegata</i> (6.8)	Bedrock (11.73)
Sand (24.04)	<i>Rhypocephalus phoenix</i> (9.48)	<i>Lobophora variegata</i> (7.75)	Bedrock (8.59)	<i>Dictyota</i> spp. (6.07)	Branching Rod (5.68)
<i>Rhypocephalus phoenix</i> (8.18)	<i>Dictyota</i> spp (8.87)	<i>Montastrea cavernosa</i> (6.87)	Branching Plume (5.50)	Bedrock (8.59)	<i>Dictyota</i> spp. (5.65)
<i>Syringodium filiforme</i> (7.75)	<i>Polyphysa polyphysoides</i> (1.21)	Bedrock (5.25)	Common Sea Fan (5.34)	Branching Plume (5.34)	Branching Plume (5.02)
<i>Dictyota</i> spp. (3.56)		<i>Dictyota</i> spp. (5.11)	Branching Rod (5.09)	<i>M. annularis</i> (5.15)	Common Sea Fan (5.02)
<i>Avrainvillea</i> spp. (3.10)		<i>Agaricia agaricites</i> (4.72)	<i>Porites astreoides</i> (4.99)	Branching Rod (4.96)	Sand (4.83)
Branching Rod (2.66)		<i>M. annularis</i> (4.58)	Sand (4.57)	<i>A. agaricites</i> (4.03)	<i>Siderastrea siderea</i> (4.47)
<i>Dictyosphaeria cavernosa</i> (2.10)		Branching Plume (4.24)	<i>M. annularis</i> (3.61)	<i>M. cavernosa</i> (3.65)	Squirrel tail (3.87)
<i>Halimeda tuna</i> (1.59)		<i>Siderastrea siderea</i> (3.35)	<i>M. cavernosa</i> (3.55)	Common Sea Fan (3.62)	<i>Diploria strigosa</i> (3.82)
Bedrock (1.56)		Branching Rod (3.26)	Dead (3.15)	<i>Porites astereoides</i> (3.48)	<i>Neomeris annulata</i> (3.5)

Cluster 1 shows a high abundance of Turtle and Manatee grass, *T. testudinum* and *S. filiforme* respectively.¹⁷ There is a reasonably high percentage of sand, which is to be expected as seagrasses tend to occupy these areas. Cluster 2 was characterised by an especially high percentage of sand and some algal species were also present, such as *L. variegata* so the habitat label, “sand and sparse algae” was assigned accordingly. Cluster 3 and 4 were characterised by the presence of hard coral species such as *M. cavernosa* and *M. annularis*, with cluster 3 having a slightly higher proportion of hard corals and

¹⁷ Appendix 6 - Species list

hence being assigned as “Dense Massive and encrusting” and cluster 4 being assigned as “Sparse Massive and encrusting”. Cluster 5 and 6 were assigned to their classes respectively due to the presence of gorgonia.

3.3 Assignment of Benthic Classes

The benthic classes assigned using cluster analysis were then combined with the geomorphological data collected during the surveys to produce habitat labels which were used to produce a map of the survey signs being studied around Utila. Table 5 shows the habitat labels produced. Any habitat contributed less than 0.01 % was discarded.¹⁸

Table 5 Habitat codes

Benthic Class	Geomorphological Class	Habitat code	Proportion of surveys	Total
Seagrass with distinct Coral Patches	Forereef	SCF	0.507614213	3
	Escarpment	SCE	0	0
	Reef Crest	SCRC	0	0
	Spur & Groove	SCSG	0	0
	L. Spur & Groove	SCLS	0	0
	H. Spur & Groove	SCHS	0	0
	Di. Patch Reef	SCDP	0	0
	De. Patch Reef	SCDE	0.169204738	1
	Patch Reef	SCPR	0	0
	Back Reef	SCBR	0	0
	De. Lagoon	SCDL	0	0
	Lagoon	SCL	0.169204738	1
	Sh. Lagoon	SCSL	1.692047377	10
Sand with sparse algae	Forereef	SF	1.353637902	8
	Escarpment	SE	0	0
	Reef Crest	SRC	0	0
	Spur & Groove	SSG	0	0
	L. Spur & Groove	SLS	0	0
	H. Spur & Groove	SHS	0	0
	Di. Patch Reef	SDP	0	0
	De. Patch Reef	SDE	0	0
	Patch Reef	SPR	0	0
	Back Reef	SBR	0.169204738	1
	De. Lagoon	SDL	0.169204738	1
	Lagoon	SL	0	0

¹⁸ Appendix 7

Dense Massive and encrusting coral	Sh. Lagoon	SSL	0.338409475	2
	Forereef	DEF	4.060913706	24
	Escarpment	DEE	0.676818951	4
	Reef Crest	DERC	0	0
	Spur & Groove	DESG	0	0
	L. Spur & Groove	DELS	0.169204738	1
	H. Spur & Groove	DEHS	0	0
	Di. Patch Reef	DEDP	0	0
	De. Patch Reef	DEDE	0	0
	Patch Reef	DEPR	0	0
	Back Reef	DEBR	0.169204738	1
	De. Lagoon	DEDL	0	0
	Lagoon	DEL	0	0
	Sh. Lagoon	DESL	0	0
	Forereef	SEF	4.399323181	26
Sparse Massive and encrusting corals	Escarpment	SEE	1.184433164	7
	Reef Crest	SERC	1.184433164	7
	Spur & Groove	SESG	0.169204738	1
	L. Spur & Groove	SELS	0.338409475	2
	H. Spur & Groove	SEHS	0	0
	Di. Patch Reef	SEDP	0	0
	De. Patch Reef	SEDE	0.169204738	1
	Patch Reef	SEPR	0.338409475	2
	Back Reef	SEBR	1.015228426	6
	De. Lagoon	SEDL	0	0
	Lagoon	SEL	0	0
	Sh. Lagoon	SESL	0.169204738	1
Bedrock /Rubble and sparse gorgonians	Forereef	BSF	30.62605753	181
	Escarpment	BSE	11.33671743	67
	Reef Crest	BSRC	1.692047377	10
	Spur & Groove	BSSG	0.676818951	4
	L. Spur & Groove	BSLS	1.861252115	11
	H. Spur & Groove	BSHS	0.338409475	2
	Di. Patch Reef	BSDP	0	0
	De. Patch Reef	BSDE	0.338409475	2
	Patch Reef	BSPR	0.338409475	2
	Back Reef	BSBR	3.045685279	18
	De. Lagoon	BSDL	0	0
	Lagoon	BSL	0	0
	Sh. Lagoon	BSSL	0	0
Bedrock / Rubble and dense gorgonians	Forereef	BDF	8.798646362	52
	Escarpment	BDE	0	0
	Reef Crest	BDRC	0.169204738	1
	Spur & Groove	BDSG	0.169204738	1
	L. Spur & Groove	BDLS	0	0
	H. Spur & Groove	BDHS	0.169204738	1
	Di. Patch Reef	BDDP	0	0
	De. Patch Reef	BDDE	0	0

Unknown	Patch Reef	BDPR	0	0
	Back Reef	BDBR	1.184433164	7
	De. Lagoon	BDDL	0	0
	Lagoon	BDL	0	0
	Sh. Lagoon	BDSL	0	0
	Forereef	UF	9.983079526	59
	Escarpment	UE	4.399323181	26
	Reef Crest	URC	1.692047377	10
	Spur & Groove	USG	0.169204738	1
	L. Spur & Groove	ULS	0.338409475	2
	H. Spur & Groove	UHS	0	0
	Di. Patch Reef	UDP	0.169204738	1
	De. Patch Reef	UDE	0	0
	Patch Reef	UPR	0.169204738	1
	Back Reef	UBR	2.199661591	13
	De. Lagoon	UDL	0.169204738	1
	Lagoon	UL	0.676818951	4
	Sh. Lagoon	USL	0.676818951	4
			100	591

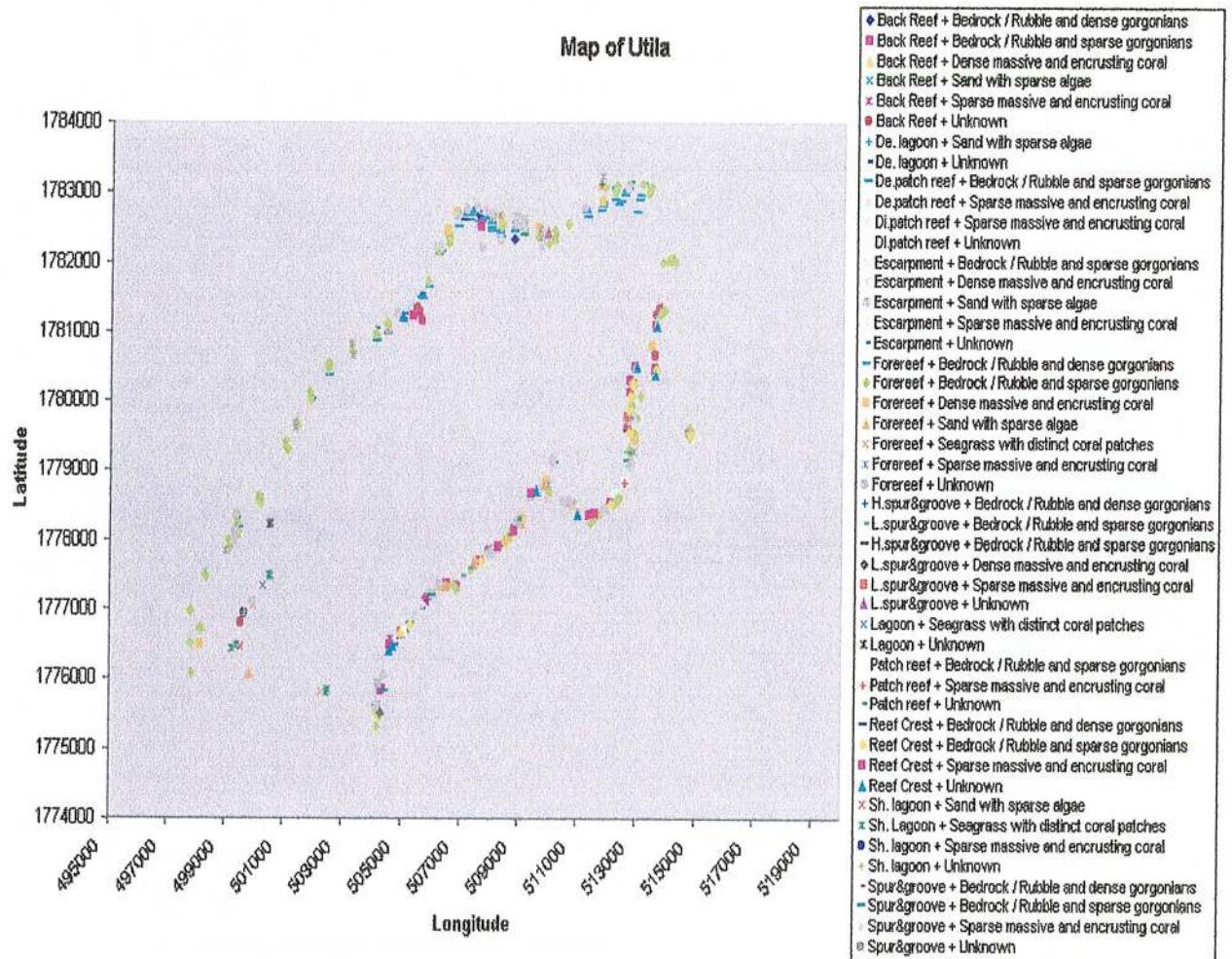
Table 6 shows the proportion of surveys carried out at each study area and the number of habitats found at each which can be looked at as a measure of the diversity of the area.

Table 6: Study areas

Study Area	Number of Transects	Percentage of transects	Number of habitat types
AIRPORTR (AP)	63	11.58088235	15
BLUE BAYOU (BB)	40	7.352941176	13
BLACK HILL (BH)	14	2.573529412	4
BIG BIGHT (BB)	41	7.536764706	10
DIAMONDCAY (DC)	17	3.125	7
J.NEILS (JN)	84	15.44117647	13
LIGHTHOUSE (LH)	4	0.735294118	2
PRETTY BSH (PB)	8	1.470588235	7
PUMPKIN (PK)	43	7.904411765	8
RAGGEDYCAY (RC)	52	9.558823529	9
ROCK HARB (RH)	80	14.70588235	9
SWEST CAY (SWC)	17	3.125	4
TURTLE HAR (TH)	78	14.33823529	10
WATER CAY (WC)	2	0.367647059	1
Sandy Cay (SC)	1	0.183823529	1
	544	100	

This data was then used to produce a map, fig 11 showing the habitat classes around Utila, which could then be used to look out where particular fish species inhabited around the island, whether north facing, south facing, etc.

Fig 11: Map of Utila showing the habitat classes assigned using cluster analysis¹⁹.



3.4 Fish Data

¹⁹ Appendix 8 – Habitat Map

3.4 Fish Data

The habitat codes formed by cluster analysis were related to their corresponding sites for the fish data and this was used to look at species and family trends. The original data table shows the raw data collected during the surveys²⁰.

3.4.1 Species data

Table 7 shows the mean abundance of each species at each of the habitats assigned by cluster analysis as well as the mean abundance for the whole of Uti²¹. Standard deviations were calculated for each species, which appear to be relatively high, so Kruskal-Wallis ANOVA was carried out to test whether species were exhibiting preferences for significant habitats. Calculation of Kruskal-Wallis was carried out using the program MINITAB²².

Table 7 Mean abundance of each fish species in each habitat type. For list of habitat codes refer to table 5, appendix 7. N represents the number of sites contributing to each habitat. Numbers in bold represent the standard deviation. Mean abundance and standard deviation values were also calculated for the Uti. Shading shows which habitat each species is most abundant at. Kruskal-Wallis one-way ANOVA was also carried out. (N.B: this is not the complete data table, for details of all species refer to appendix 10.)

Fish	Kruskal-Wallis Significance	Habitat Code																Uti
		000R	001R	002R	003R	004R	005R	006R	007R	008R	009R	010R	011R	012R	013R	014R	015R	
Butterfly	0.023 *	0.23	0.43	0.14	0.20	0.13	0.34	0.17	0.30	0.50	0.71	0.15	0.36	0.17	0.30	0.50	0.71	0.15
Spotted butterfly fish	0.004 *	0.55	0.82	0.86	0.59	0.44	0.57	1.00	0.30	0.50	0.71	0.15	0.36	0.17	0.30	0.50	0.71	0.15
Band snapper	0.004 *	0.20	0.41	0.14	0.38	0.33	0.50	0.22	0.43	0.58	0.71	0.15	0.36	0.17	0.30	0.50	0.71	0.15
Red snapper	0.004 NS	0.05	0.25	0.00	0.10	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longhorn butterfly fish	0.388 NS	0.02	0.00	0.10	0.20	0.12	0.14	0.05	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Angelfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rock beauty	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Queen angelfish	0.006 NS	0.10	0.27	0.00	0.00	0.10	0.30	0.11	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
French angelfish	0.342 NS	0.05	0.00	0.00	0.00	0.10	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gray angelfish	0.387 NS	0.11	0.20	0.00	0.00	0.02	0.14	0.11	0.32	0.50	0.71	0.15	0.36	0.17	0.30	0.50	0.71	0.15
Cherubfish	0.36 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Surge wrasse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ocean surgeon fish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Doctor surgeon fish	0.016 *	0.30	0.60	1.18	0.57	0.70	0.75	0.50	0.52	0.00	0.00	0.15	0.36	0.17	0.30	0.50	0.71	0.15
Banana wrasse	0.00	0.77	0.78	1.14	0.60	0.73	0.87	1.00	0.77	1.50	0.71	0.15	0.36	0.17	0.30	0.50	0.71	0.15
Jackfish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blotch wrasse	0.006 NS	0.00	0.00	0.20	0.00	0.20	0.54	0.61	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hess-eye wrasse	0.107 NS	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yellow wrasse	0.56 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mimic wrasse silver	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Succinea porgy	0.508 NS	0.05	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Demersal chub	0.00 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Atlantic spadefish	0.506 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oval barracuda	0.000 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bone fish	0.000 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
McKenzie	0.002 *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dog snapper	0.508 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cow snapper	0.503 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shoal wrasse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Snapper	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shoal wrasse	0.252 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
McKenzie snapper	0.518 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dog snapper	0.513 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gray snapper	0.575 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hutton snapper	0.488 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Line snapper	0.501 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yellowtail snapper	0.002 *	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cobuna snapper	0.111 NS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

²⁰ Appendix 9

²¹ Appendix 10 Fish species table

²² Appendix 11 Kruskal-Wallis Species calculations

Table 8:²³ Mean abundance of each family at each habitat type and on *Utila* as a whole. N represents the number of sites contributing to each habitat type. Numbers in bold represent the standard deviation. The shaded cells indicate at which habitat each family was most abundant.

[illegible]

²³ Appendix 12 – Fish family table
²⁴ Appendix 13 – Order of habitat preference for families
²⁵ Appendix 14-16 Kruskal-Wallis ANOVA calculations using MINITAB

Table 9

[illegible]

3.4.3 Study areas around Utila

In looking at study areas it was first necessary to calculate the mean contribution by each species at each of the habitats. For example, if habitat Y contains 3 study areas for species X then the mean contribution of species X will be calculated for the 3 study areas, a, b and c. If species X contributes most heavily to study area b then this is the study area assigned. This allows one to determine which study areas are most important for each species. The most important study area was also looked at the family level by totaling the mean of the 19 habitat areas for each species and assigning the study area with the highest contribution. This gives the most important study area around Utila for each species. The total of these, for example the 5 species of butterfly fish allows one to work out the most important study area for each family. This is shown in table 10²⁶.

²⁶ Appendix 17 – Study areas table

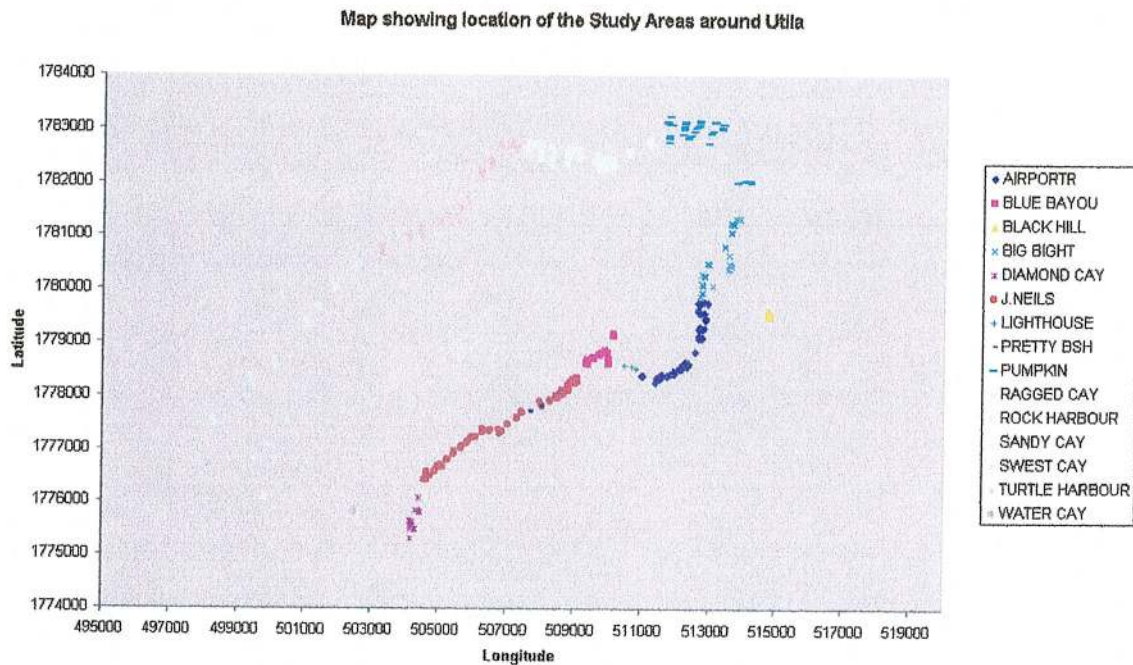
Most important study area for each species and family. Numbers in parentheses indicate the mean contribution at each study area.

(N.B this is not the complete table, for full details refer to appendix 17)

[illegible]

A map was drawn, fig 12, showing the location of the study areas around Utila which provides a visual reference as to the location of certain species inhabiting certain study area around Utila²⁷.

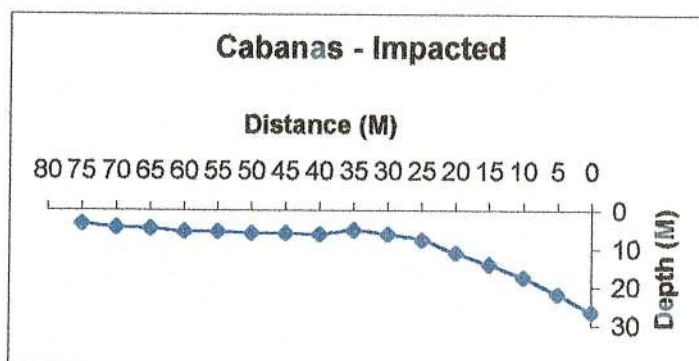
Fig 12 Map of the study areas around Utila



3.5 Project Utila Data

The data collected for project Utila was carried out from 1995 onwards by Coral Cay Conservation. 3 sites were surveyed every year, the profiles of which are shown below.

Fig 13 Cabanas Reef Profile²⁸



²⁸ Appendix 19 – Cabanas Reef Profile

Fig 14 Silver Gardens Reef Profile²⁹

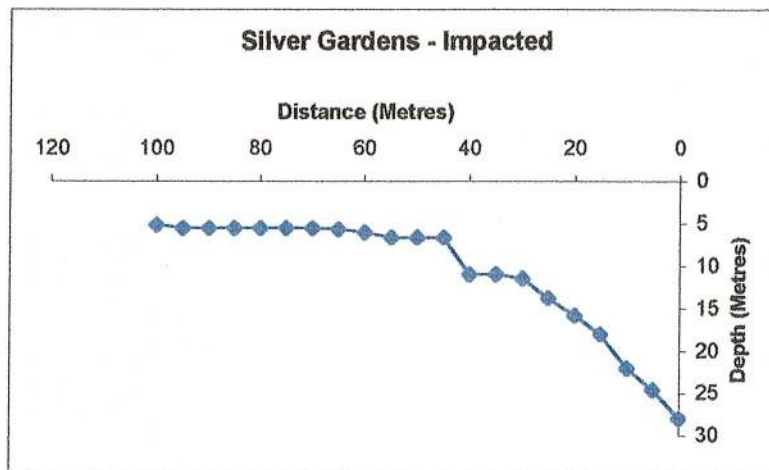
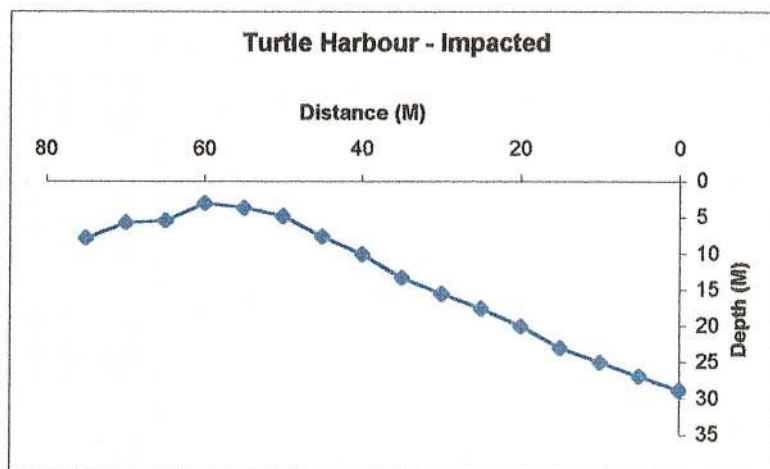


Fig 15 Turtle Harbour Reef Profile³⁰



3.5.1 Physical Data

In looking at the physical data a number of graphs and statistical tests were carried out whilst working towards a final end point, the change that occurred over 5 years, hence the

²⁹ Appendix 20 – Silver Gardens Reef Profile

³⁰ Appendix 21 – Turtle Harbour Reef Profile

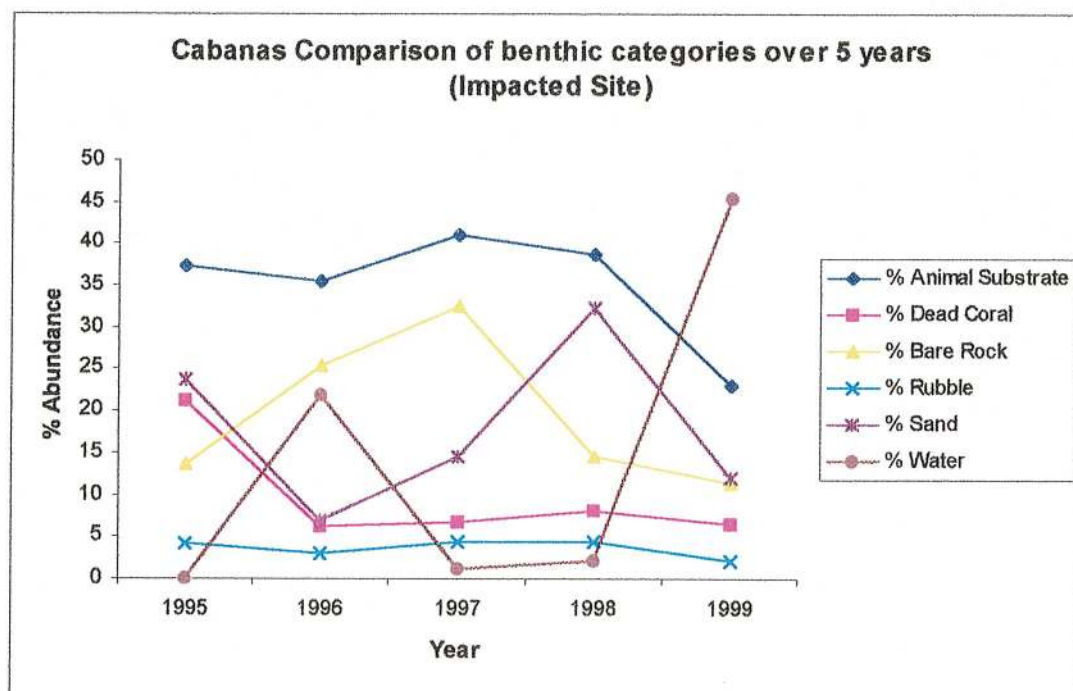
impact caused by Hurricane Mitch in 1998. A number of the graphs and tables whilst working towards this have not been included due to the number and have been placed in the appendix³¹.

3.5.1.1 1995 – 1999

A summation of the 5 years data at Cabanas can be found in the appendices³². This data was then used to plot graphs showing how substrate cover has varied over the 5 years, before Hurricane Mitch and after, hence the impact caused.

Cabanas 1995-1999

Fig 32 Variation in abundance of different substratum types over 5 years (Impacted)³³



³¹ Appendix 22A List of appendices for physical data not included in results section

³² Appendix 165

³³ Appendix 166

Fig 33 % change in substratum types 1995 - 1999³⁴

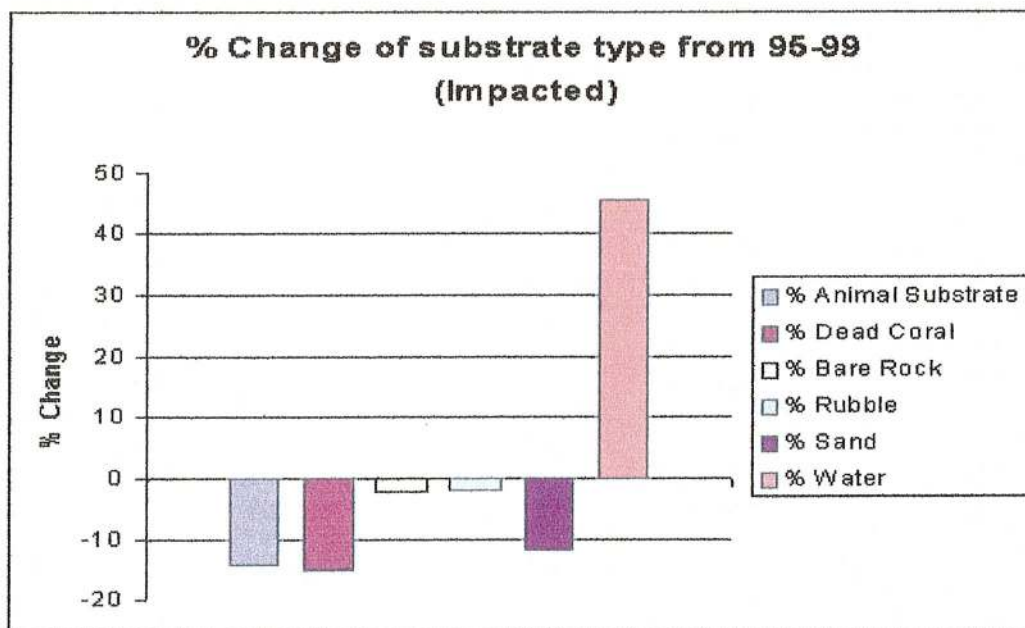
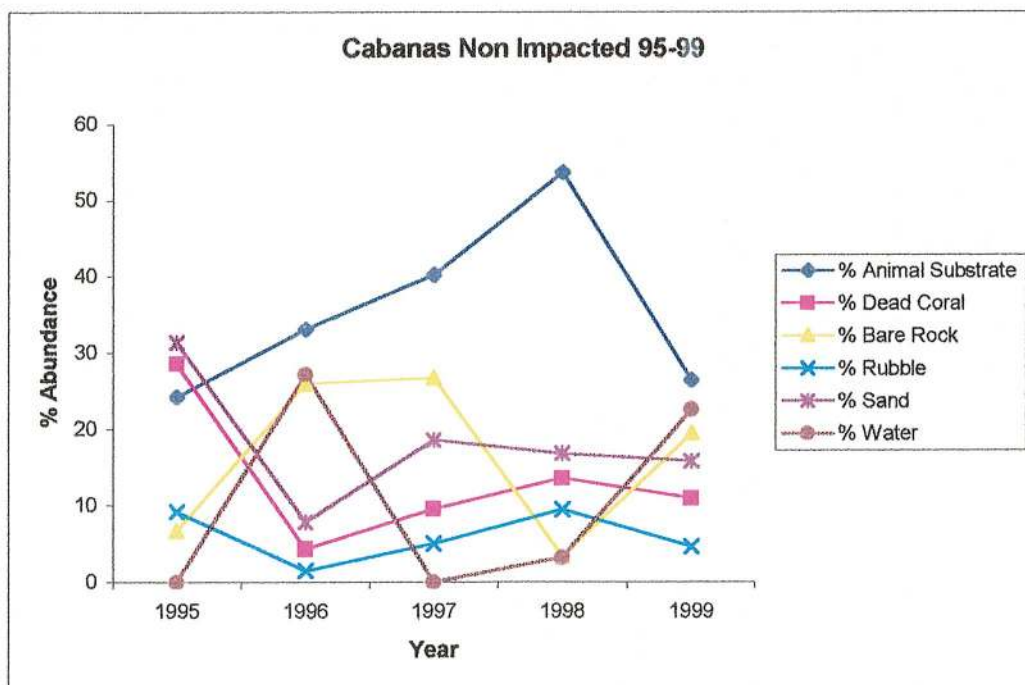


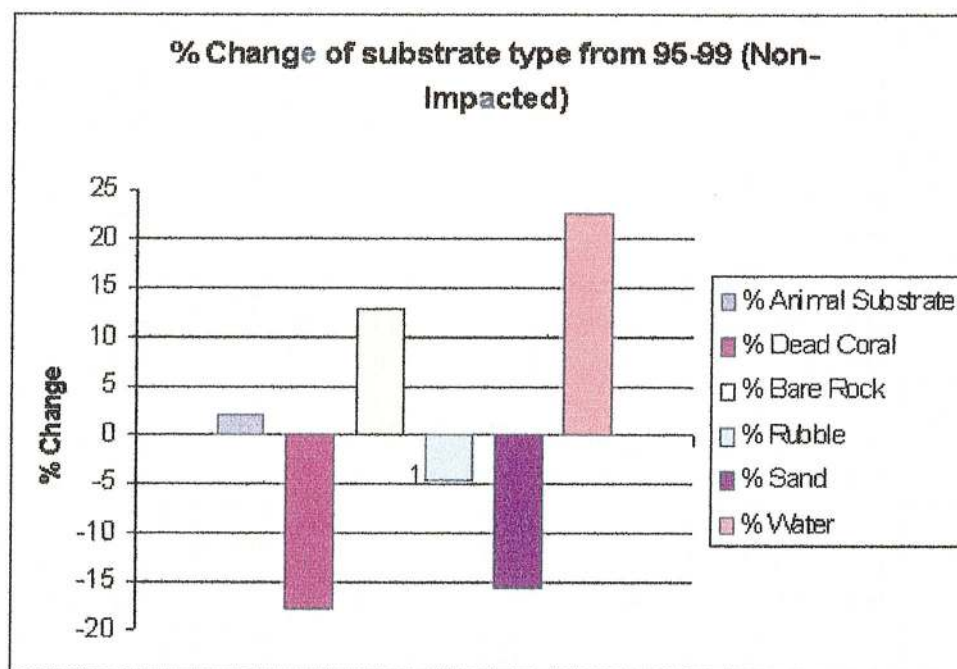
Fig 34 Variation in abundance of different substratum types over 5 years (Non-Impacted)³⁵



³⁴ Appendix 167

³⁵ Appendix 168

Fig 35 % change in substratum types 1995 - 1999³⁶



Diversity indexes were calculated and used to plot graphs showing over the 5 years whether the impacted or non-impacted site was more diverse³⁷.

Table 16 % Similarity at Cabanas over the 5 years³⁸

CAB

	1995	1996	1997	1998	1999	1995 NON	1996	1997	1998	1999
1996	65.52366									
1997	76.18495	78.36703								
1998	86.73	68.66107	79.80219							
1999	54.64901	71.84486	55.68885	56.7974						
1995 NON	79.99	47.14164	56.37366	74.64	49.98251					
1996	60.42115	93.85374	73.82764	63.54224	75.21591	44.5816				
1997	83.07252	77.31212	92.40769	84.23242	54.6441	63.97224	72.77892			
1998	74.99375	58.34674	70.81514	73.33367	49.78515	66.99335	53.28131	74.82501		
1999	70.90599	84.45452	72.49119	71.43716	77.32212	62.25697	82.21565	75.83	64.23453	

³⁶ Appendix 169

³⁷ Appendix 170 & 171

³⁸ Appendix 172

Silver Gardens 1995 – 1999

Fig 36 Variation in abundance of different substratum types over 5 years (Impacted)³⁹

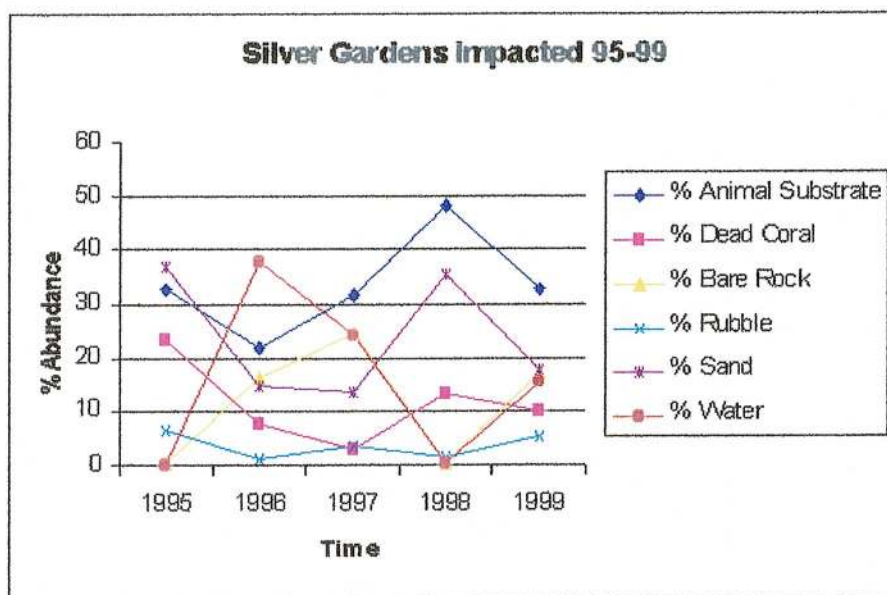
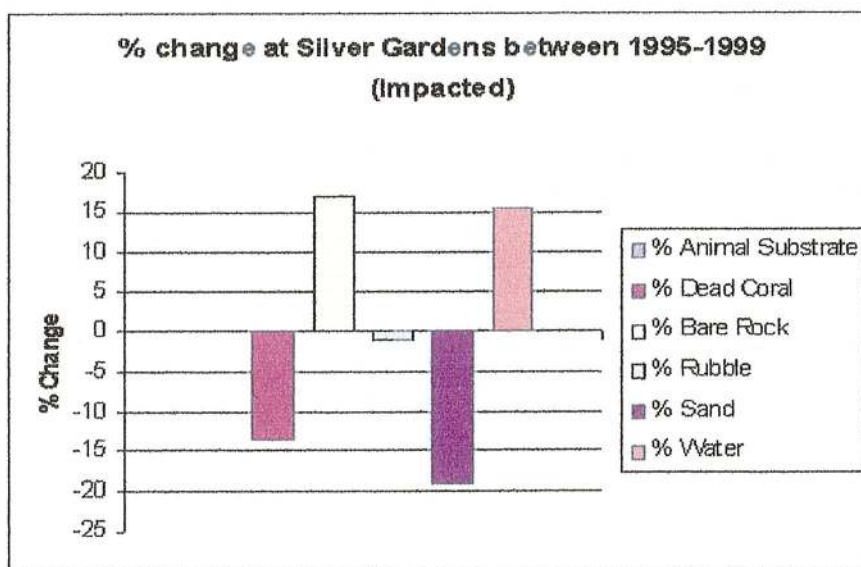


Fig 37 % change in substratum types 1995 – 1999⁴⁰



³⁹ Appendix 173

⁴⁰ Appendix 174

Fig 38 Variation in abundance of different substratum types over 5 years (Non Impacted)⁴¹

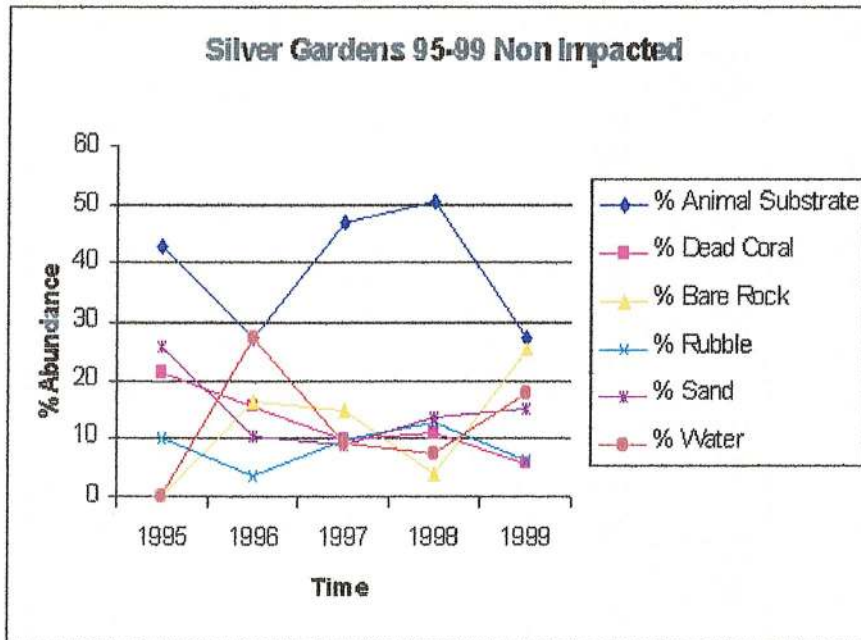
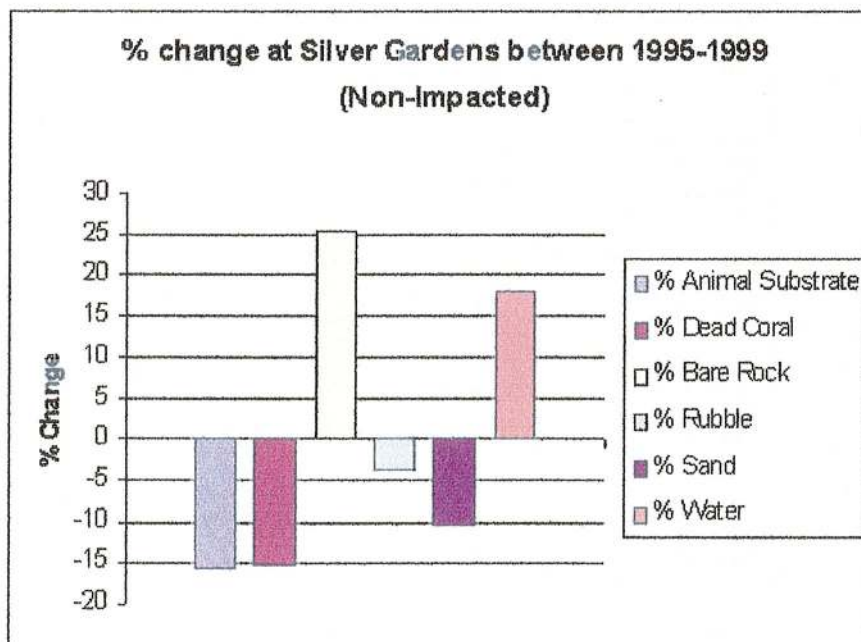


Fig 39 % change in substratum types 1995 – 1999 ⁴²



⁴¹ Appendix 175

⁴² Appendix 176

As for Cabanas, diversity indexes were also calculated and can be found in the appendices⁴³.

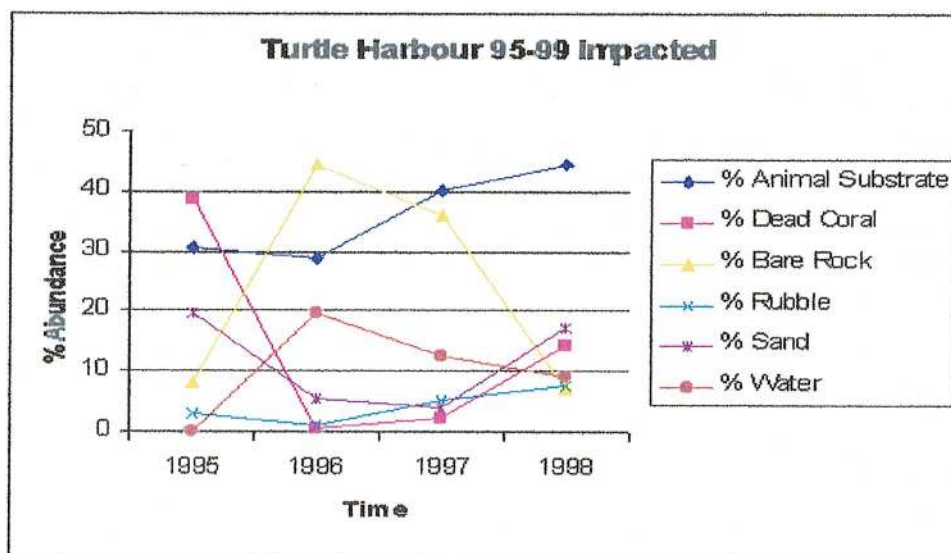
Table 17 % Similarity at Silver Gardens over 5 years⁴⁴

SG

	1995	1996	1997	1998	1999	1995 NON 1996	1997	1998	1999
1996	46.06761								
1997	51.87778	80.37336							
1998	83.73485	46.57225	50.39402						
1999	66.97272	78.11251	84.66693	63.53154					
1995 NON	86.11431	45.69498	51.50515	83.76073	66.62381				
1996	56.77	85.04516	84.40422	53.3336	83.50911	56.39718			
1997	58.25583	64.48465	71.3607	68.05618	81.73544	71.54358	73.72		
1998	64.42644	56.54731	63.16948	75.59526	74.2918	77.9439	63.62	87.19872	
1999	55.63558	79.06174	90.47441	51.28065	87.8759	55.25957	82.03897	73.50965	65.5107

Turtle Harbour 1995 – 1999

Fig 40 Variation in abundance of different substratum types over 5 years (Impacted)⁴⁵

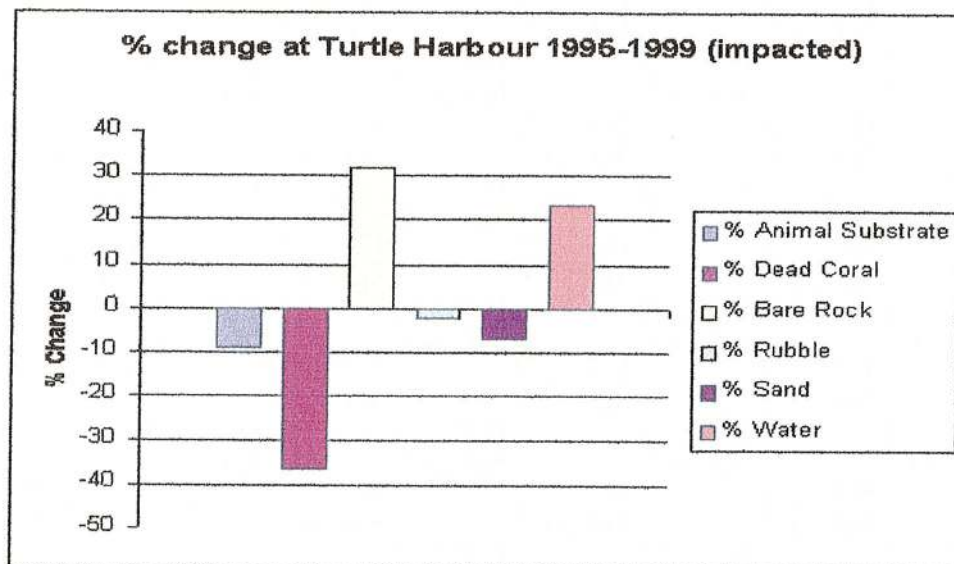


⁴³ Appendix 177 & 178

⁴⁴ Appendix 179

⁴⁵ Appendix 180

Fig 42 % change in substratum types 1995 – 1999 ⁴⁶



Diversity indexes were calculated as for Cabanas and Silver Gardens ⁴⁷.

Table 18 % Similarity at Turtle Harbour over 5 years ⁴⁸

THB IMP

1995	1995	1996	1997	1998	1999
1996	43.9539				
1997	47.67762	82.76707			
1998	71.84905	52.04604	67.75966		
1999	44.94596	87.82084	76.49502	53.04482	

3.5.2 Soft Corals & Sponges

A number of graphs were plotted whilst working towards graphs showing the change in soft coral and sponges over 5 years, as for the Physical data set. The list of appendices for this data is shown in appendix 185.

⁴⁶ Appendix 181

⁴⁷ Appendix 182 & 183

⁴⁸ Appendix 184

3.5.2.1 1995–1999

The data collected over the years was used to see how abundance had changed between 1995 and 1999. This data was then collated into a table. Within each site, impacted and non impacted, 2 graphs were plotted, one showing how the abundance changed from year to year and one showing mean diversity varied, i.e. that of soft corals as one group and that of sponges as the other, rather than individual species.

Cabanas⁴⁹

Fig 43 Mean abundance of each substratum types over 5 years at Cabanas (Impacted)

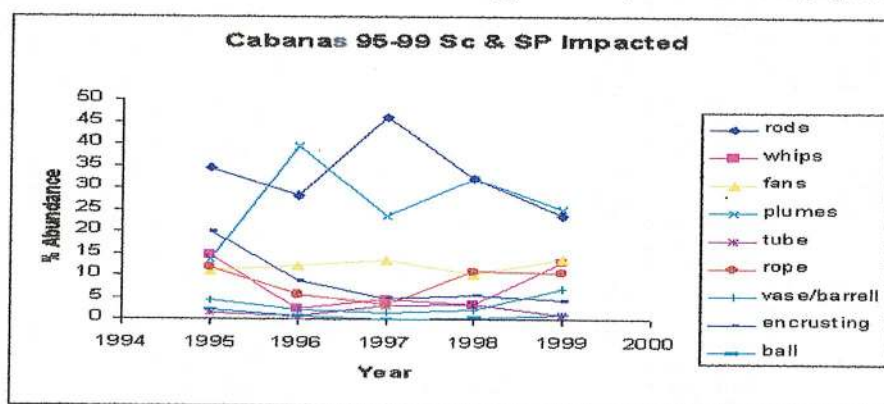
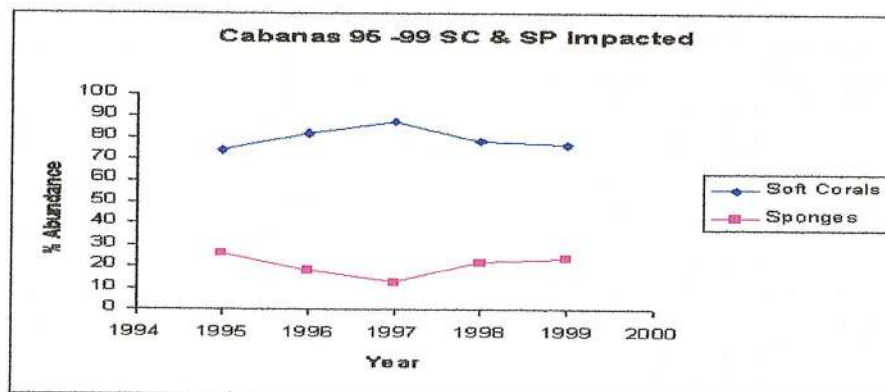


Fig 44 Diversity of soft corals and sponges at Cabanas (impacted) over 5 years, calculated by totaling the contribution by soft coral species and sponge species to give a mean score for each.



⁴⁹ Appendix 517 Table showing mean abundances at Cabanas at each year (Impacted & Non-Impacted)
 Appendix 518-521 Graphs – abundance and diversity
 Appendix 522 – Diversity table
 Appendix 523 – Bray-Curtis table

Fig 45 Mean abundance of each substratum types over 5 years at Cabanas (Non-Impacted)

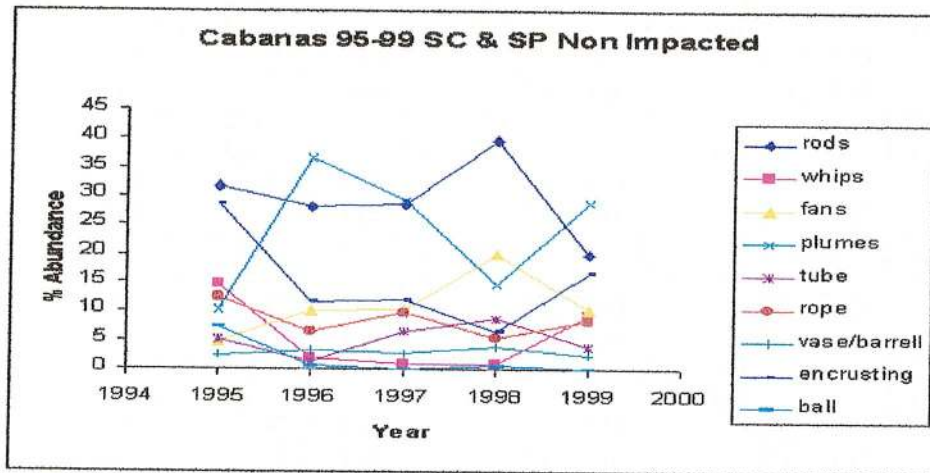
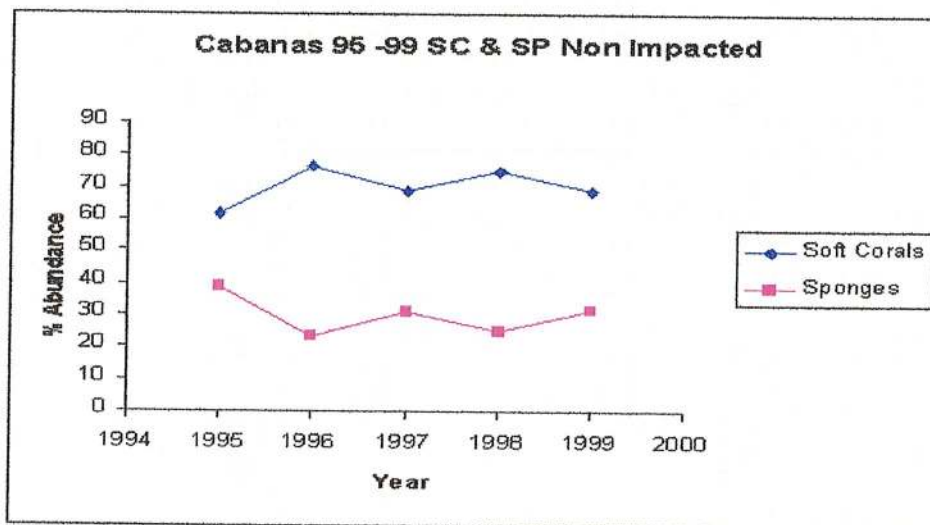


Fig 46 Diversity of soft corals and sponges at Cabanas (Non-Impacted) over 5 years, calculated by totaling the contribution by soft coral species and sponge species to give a mean score for each.



At both the impacted and non-impacted site at Cabanas there appears to be common trend with soft corals having a higher overall % abundance than sponges.

Silver Gardens⁵⁰

Fig 47 Mean abundance of each substratum types over 5 years at Silver Gardens (Impacted)

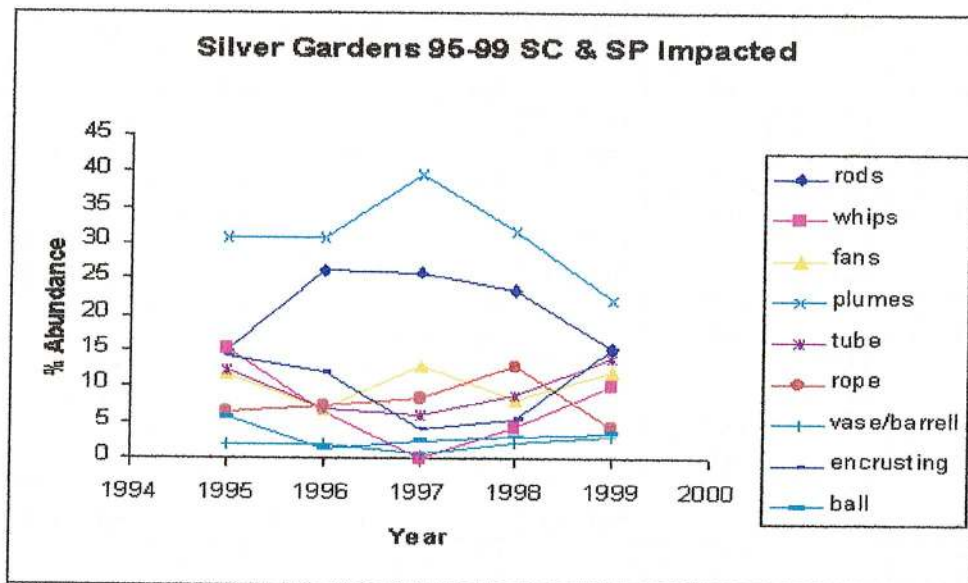
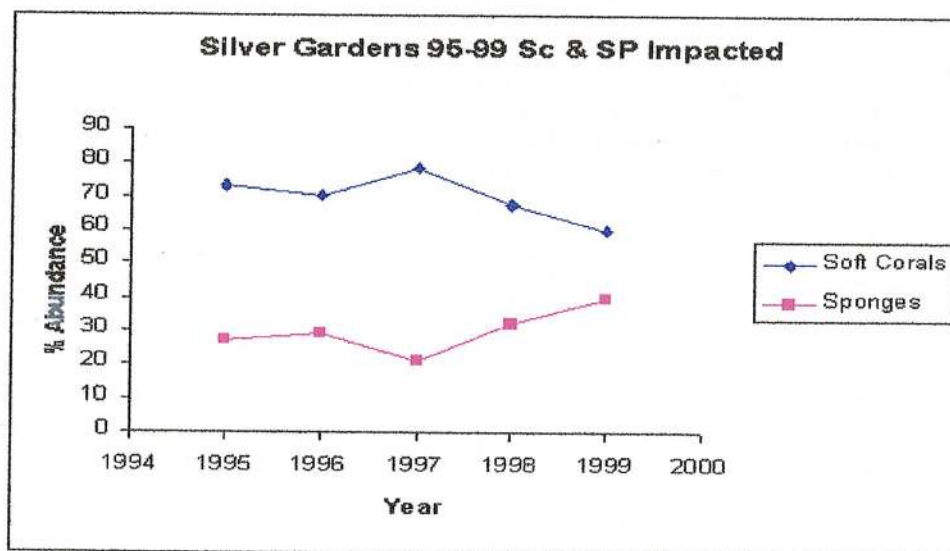


Fig 48 Diversity of soft corals and sponges at Silver Gardens (Impacted) over 5 years, calculated by totaling the contribution by soft coral species and sponge species to give a mean score for each.



⁵⁰ Appendix 524 Table showing mean abundances at Cabanas at each year (Impacted & Non-Impacted)
 Appendix 525-528 Graphs – abundance and diversity
 Appendix 529 – Diversity table
 Appendix 530 – Bray-Curtis table

Fig 49 Mean abundance of each substratum types over 5 years at Silver Gardens (Non-Impacted)

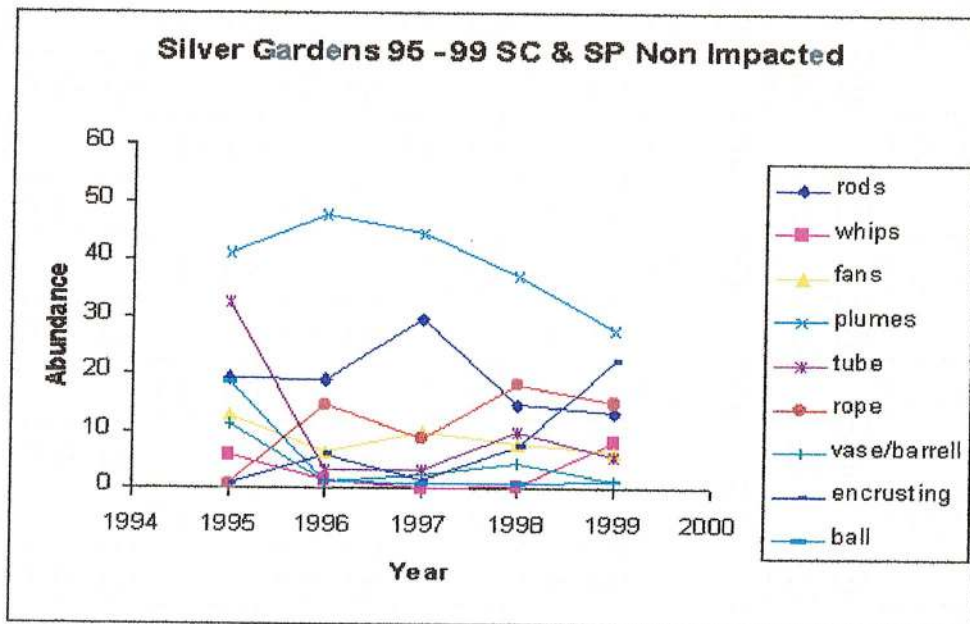
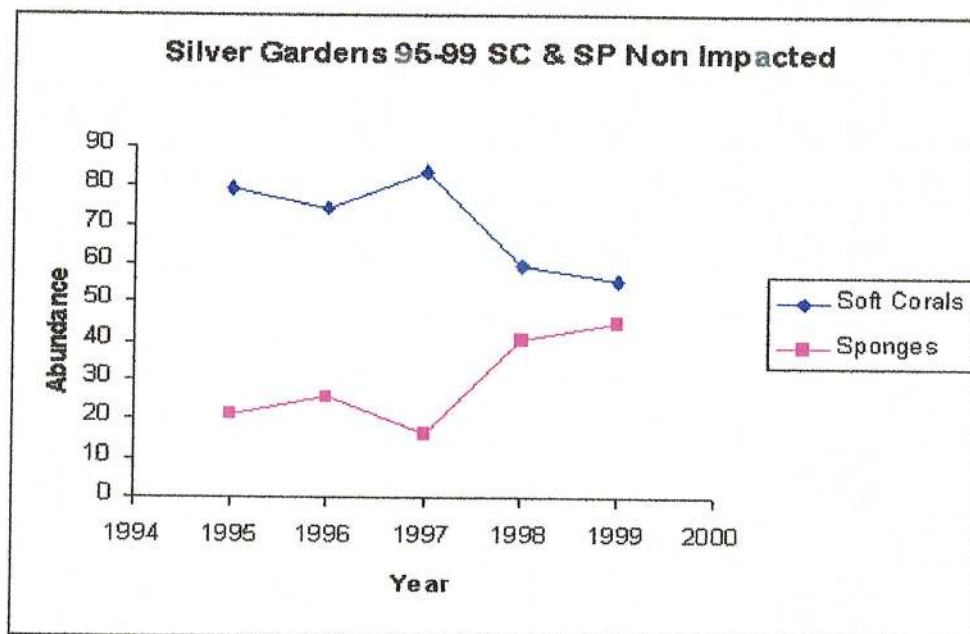


Fig 50 Diversity of soft corals and sponges at Silver Gardens (Non-Impacted) over 5 years, calculated by totaling the contribution by soft coral species and sponge species to give a mean score for each.



Turtle Harbour⁵¹

Fig 51 Mean abundance of each substratum types over 5 years at Turtle Harbour (Impacted)

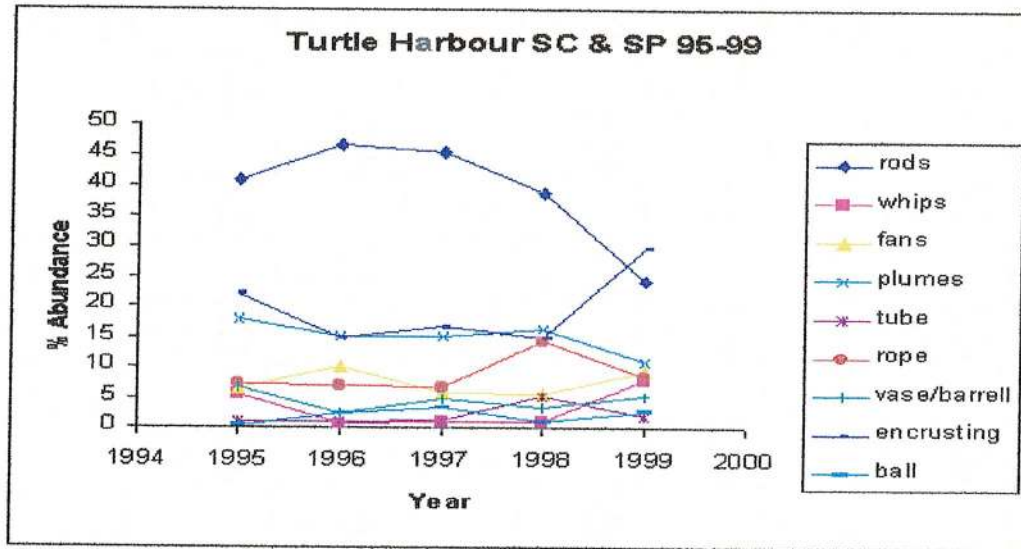
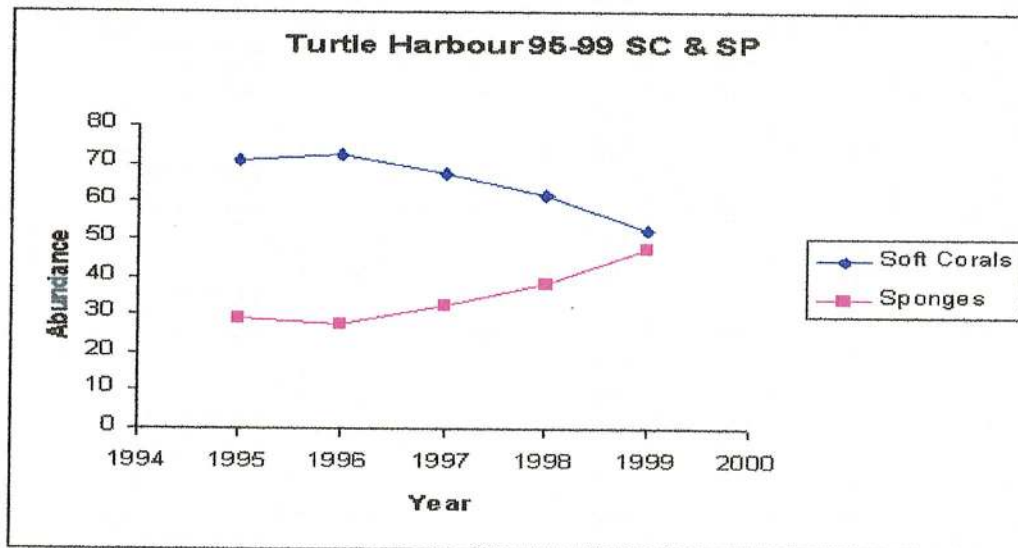


Fig 52 Diversity of soft corals and sponges at Turtle Harbour (Impacted) over 5 years, calculated by totaling the contribution by soft coral species and sponge species to give a mean score for each.



⁵¹ Appendix 531 Table showing mean abundances at Cabanas at each year (Impacted & Non-Impacted)
 Appendix 532-533 Graphs – abundance and diversity
 Appendix 534 – Diversity table
 Appendix 535 – Bray-Curtis table

Section 4: Discussion

4.1 Baseline Data (Habitat types)

The baseline data was used to produce a habitat map showing the location of different substratum categories around Utila, and the species occupying each of these habitats. Table 5 shows the habitat codes assigned and the proportion that each contributed to the surveys carried out. The habitat type contributing most heavily to the surveys was BSF (forereef & bedrock/ rubble and sparse gorgonians). The lowest contribution to the surveys gave a value of 0.169, which involved a number of different habitats (SCDE, SCL, SBR, SDL, etc.). Table 6 shows the study areas around Utila and those where the highest proportion of surveys carried out. Jack Neils had the highest proportion of surveys carried out (15.4) and Sandy Cay the lowest (0.18). However, it would appear as if Airport had greater habitat diversity with 15 different habitat types opposed to 13 at Jack Neils. Figure 11 shows a habitat map of Utila, produced by plotting the position of the benthic labels assigned with their GPS position around Utila.

Previous studies carried out on Utila by CCC show a general pattern emerging in the substratum types located around Utila, which can be compared with the habitat map produced for added accuracy. The main Utila report, June 1999, carried out by CCC showed that the North Side of the island commonly consists of escarpments and spur & groove formations. The south side was found to contain the highest proportion of dive sites used by the schools around Utila and consisted of mainly reef crests, backreefs and sloping forereefs. On the backreefs there tended to be low coral diversity whereas the reef crests tended to have a high abundance of reef builders such as *M. annularis*, *A. agaracites*, and green turf algae. The East side of the island is characterized by a deepwater trench, which results in very long shallow forereefs and large sandy areas. The lagoon at Utila is located around the Blue Bayou study area. Water depth here is rarely deeper than 4 metres and there is a high predominance of silt/sand and bedrock. This is due to high amounts of sedimentation.

The North Side of Utila contains the study areas of Ragged Cay, Turtle Harbour and Rock Harbour. The predominant habitat types located along the North Side of Utila appear to be forereef to the West and Escarpments to the East. There is a high percentage of BSF as well as SEF. To the East the habitat UE can be found. To the South, as expected the predominant habitat types are forereefs, reef crest and back reefs. The most common substratum category at the backreefs appears to be bedrock/ rubble and sparse gorgonians (BSBR), at the forereefs, bedrock/ rubble and sparse/ dense gorgonians (BSF, BDF) and at the reef crests, BSRC and SERC. The East side of Utila contains the study areas of Pumpkin Hill and Big Bight and consists primarily of two classes of forereef, being BSF and BDF. The West side of Utila contains the study areas of Diamond Cay, Sandy Cay, SWEST Cay and Water Cay. The principle type of habitat located along the West of Utila appears to be forereefs with classes such as BSF, SF and UF being assigned. However due to the location of these sites and the difficulty in surveying this area due to weather far fewer sites have been surveyed on the West than would have been liked, which raises doubt as to the significance of the results. This data will be used to identify which species and families of fish occupy which habitat areas and subsequently the distribution of these fish around Utila and the study areas being occupied by each.

4.2 Baseline Data (Fish Data)

The distribution and diversity of each species of fish was identified and this data can be found in table 7, appendix 10. For example, it can be seen that for Spotfin Butterflyfish the habitat that they were found most commonly inhabiting was SEBR. The significance of this result was determined using standard deviation and Kruskal-Wallis One Way ANOVA which both gave a significant result. This locates Spotfin Butterflyfish at the Jack Neils study area on the South Side of Utila.

Due to the nature and the size of this report it was decided not to dwell to much on the individual species data but to focus on the data by grouping the species to their respective families. This data is shown in table 8, appendix 12 and grouped to a format that was easier to interpret in table 9, appendix 13. In looking at the family data I will look at the top 3 habitats being occupied by the commercially important families for ease of

comparison between them. The remaining families may be analyzed at a later date but owing to the nature of this report and the space available this was not deemed to be necessary.

Jacks

Jacks were found occupying the habitats, SERC, SEBR and UBR respectively, in order of habitat preference. They are commonly found in coral rich areas between depths of 0 and 22 m (Ewald Lieske, Robert Myers, 1994). Looking at the habitat map once again this appears to locate them on the South side of Utila, and the study areas each is occupying can be shown in table 10. Jacks are found at the study areas Jack Neils for all the study areas. This places the majority of Jacks between the study areas of Diamond Cay and Airport. However, this could not be confirmed statistically although, due to the number of surveys it is likely to be to a sufficient level of accuracy.

Snappers

Snappers were found occupying the study areas of SEBR, BSRC and BSBR in order of habitat preference. This locates Snappers, as for the other fish species on the Southern side of Utila, and they can be shown to be occupying the study areas of Jack Neils and Airport, Pretty Bush and Jack Neils respectively for these habitats. Taking into consideration all the habitats being occupied by Snappers, Jack Neils appears to be the most frequented study area, locating them in a similar area to Jacks, although they exploit slightly different habitats within this area.

Grunts

Grunts can be found occupying the habitat areas of SERC, SEBR and UE respectively. This locates them on the South and Northeast side of Utila. Looking at the study areas being inhabited at each of these habitat areas shows Grunts found at Jack Neils for SERC

and SEBR and at Ragged Cay for UE. Overall, Grunts are found most at Jack Neils locating them in the south.

Groupers

Groupers are found most commonly at the habitats of BSDE, BSF and BDF. This appears to locate the majority of groupers on the Northern side of Utila. By looking at table 10 it is possible to see that the study areas being most frequented by Groupers in relation to their habitats are Ragged Cay for BSDE and BDF, Pumpkin Hill for BSF. This locates them on the North East side of Utila.

Section 4.3 Project Utila Data

The location of the project Utila sites can be found in figure 3 located in the introduction. Cabanas is located in the Southwest of Utila and is located in Jack Neils study area. Silver Gardens is located East of Cabanas on the south of Utila and is found occupying the study area of Blue Bayou, near the lagoon. Finally, Turtle Harbour is located on the North side of Utila.

Section 4.3.1 Physical Data

Figure 32 and 34 shows how the benthic categories varied over 5 years at Cabanas, impacted and non-impacted. At each, there are small differences, which would be expected, but the general pattern being exhibited at both sites is similar. Between 1995 and 1997 the % animal substrate fluctuates between 35 and 40 %. The % bare rock increases and the % of sand and dead coral decreases. The % of rubble remains approximately constant throughout. The water reading is used where there are spur and groove formations and it is difficult to determine the substrate class between them. The % of animal substrate shows a marked drop between the years of 1998 and 1999. This could be due to the fact that Hurricane Mitch occurred in 1998 and hence the decline in the following year. From 1997 the % animal substrate at the non-impacted site is increasing

and at the impacted site it is fluctuating around a standard level. The difference is more marked in the non-impacted site, which is likely to be of greater significance anyway, as other contributing factors such as diving are not brought into the account. However, due to the nature of the data collected it is difficult to be sure whether the hurricane event caused the decline in numbers or some other factors. To take this into account and try to answer this question I looked at a report on the MesoAmerican Barrier reef system⁵², which looked at the impact of Hurricane Mitch on Utila, as well as a number of the other islands. In Utila there were highly variable effects of hurricane damage between shallow and deep Forereef sites. The % damage occurring on Utila's reef was calculated as 8 %. The sites with the highest damage occurred on the North, Northeast side of the shallow reefs. Common types of hurricane damage on shallow reefs included knocked over or abraded corals. Damage tended to be lower at deep Forereef sites. Mortality at shallow sites around Utila was shown to be 23% and these were classed as being highly disturbed. 2 sites were located around Utila in this report which correspond with the study areas of Ragged Cay and Rock Harbour, both on the North side of Utila. At both these sites there was severe disturbance and this corresponds with the information taken at the project Utila sites, especially which show evidence of a decline in substratum cover, suggesting that Hurricane Mitch may have had an impact. Figure 33 and 35 show the overall change in substrate composition between 1995 and 1999 at both sites and once again, both show a similar pattern with a decline in substrate categories at both sites, except at the non-impacted site, which shows a slight increase in animal substrate composition and a larger increase in bare rock cover. The slight increase in animal substrate may be caused over time and the limited impact caused by the hurricane may not have caused enough damage to result in a net loss. At both site there is a large increase in the % water cover. Table 16 shows the % similarity of each site over the 5 years and one can see that the most substantial change in % similarity occurs between 1998 and 1999, the year of the Hurricane with values of 56.8 % for the Impacted site and 64.2% for the non-impacted site.

⁵² Ecological Status of the MesoAmerican Barrier Reef System – Impacts of Hurricane Mitch and 1998 Coral Bleaching Philip A. Kramer, Patricia R. Kramer

Both Silver Gardens and Turtle Harbour exhibit a similar pattern to that shown at Cabanas, which can be shown in figures 36 to 42. For Turtle Harbour only the Impacted site is shown as no data was collected for the non-impacted site.

Section 4.3.2 Soft Corals & Sponges

As a measure of substrate cover soft corals and sponges was also looked at to see how this changed over the 5 years and the impact had by the hurricane on these in 1998. This is relevant as soft corals and sponges tend to be more susceptible to hurricane damage than hard corals, such as massive corals, brain corals, which are more resilient to damage. For each of the sites, impacted and non-impacted, there appears to be a comparable pattern, with rods and plumes having the highest abundance and sponges having lower abundances. This is shown in figures 43, 45, 47, 49 and 51. In order to look at the impact caused by the hurricane I grouped the individual species of soft corals and sponges and the results of this can be shown in figures 44, 46, 48, 50 and 52. For all sites a similar pattern is exhibited with soft corals contributing more than sponges. However, there appears to be a direct correlation between soft corals and sponges and as one increases the other decreases. This is true at each site surveyed for the project Utila data. Between 1998 and 1999 there is a decline in the level of soft corals with a slight rise in the level of sponges. This poses the question, did the hurricane have any significant impact, as one would also expect the sponges to be decreasing as well as the soft corals if it was? So, if the hurricane is of limited impact, there must be a relationship between soft corals and sponges. This has been documented in previous work where it has been shown that certain sponges, siliceous sponges, are known to bore into calcareous substrata. These include sponges such as *cliona*, *anthosigmella*, *spherico spongia*, etc. Clionid sponges are the most common and destructive endolithic borers found on coral reefs. They split open infested corals and form 5-15 mm deep chambers. The depth of penetration by these sponges is usually no greater than 2 cm and they are revealed as brown, yellow or orange patches lining the coral interiors.

Word Count: 8000 Words (Excluding Figures, Tables, Graphs, Abstract, References, Appendices, Contents, Acknowledgements & Abbreviations)

Section 5 References

Format of Journal Adopted: Biological Conservation

Journals

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<http://www.Reefcheck.org>

APPENDICES

Due to the amount of data in the appendices one copy has been printed out and left with Dr. P.J. Hogarth (Project Director) at the University of York and can be requested from him if required.

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