



STATUS OF THE MARINE RESEARCH PROGRAMME
AT CALABASH CAY, TURNEFFE ATOLL
BELIZE

PROGRESS REPORT

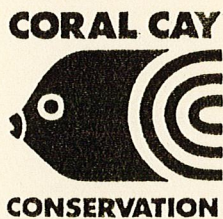
Submitted to

THE DARWIN INITIATIVE FOR THE SURVIVAL OF SPECIES

By

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ABBREVIATIONS USED

CCC	-	Coral Cay Conservation
CARICOMP	-	Caribbean Coastal Marine Productivity Programme
CZMU	-	Coastal Zone Management Unit
GIS	-	Geographical Information System
GPS	-	Global Positioning System
MRC	-	Marine Research Centre
SWCMR	-	South Water Cay Marine Reserve
UCB	-	University College of Belize

1. SUMMARY

Coral Cay Conservation (CCC) is a non-profit, UK-based organisation which since 1986 has provided assistance to the Government of Belize with the collection, analysis and synthesis of physical and biological data in support of initiatives to prepare integrated management plans for the protection and sustainable use of marine and terrestrial coastal resources in the region (Appendix 1).

Using large teams of volunteer scientists and divers, CCC has completed a four year research and survey programme in the Central Reef Province of the Belize barrier reef and prepared a comprehensive management plan for the establishment of a 180km² marine reserve (the South Water Cay Marine Reserve (SWCMR)) in the area (McCorry *et al* 1993). As a result of the success of this project, CCC has been invited by the Coastal Zone Management Unit (Department of Fisheries) of Belize to initiate a detailed survey of the coastal resources of Turneffe Atoll (Northern Reef Province) and prepare a management plan for the protection and sustainable use of these resources.

In 1993, CCC signed a Working Agreement with the University College of Belize (UCB) which aims to assist with the development of UCB's Marine Studies Programme, and includes the development of an institutional capacity in Belize to undertake coastal resource research and educational programmes independently of foreign expertise or aid. Under the terms of this agreement, CCC will work together with counterparts from UCB and various Government departments to establish a Marine Research Centre (MRC) on Calabash Cay (Turneffe Atoll), and establish an environmental database for Turneffe (Appendix 1).

In 1993, CCC was awarded a grant under the Darwin Initiative for the Survival of Species to assist with the survey of marine & terrestrial habitats of Turneffe Atoll and produce a database and management plan to protect its biodiversity. In January 1994, CCC relocated its main operational field base in Belize to Calabash Cay and commenced a detailed survey of the natural resources within the surrounding area.*

This report summarises progress made since January 1994 towards the fulfilment of CCC's obligations under the terms of the grant provided by the Darwin Initiative and the terms of reference under the UCB/CCC Working Agreement. The results of a preliminary analysis of data gathered by CCC are provided and discussed in relation to proposals for future research and development work to be conducted at the MRC.

2. STATUS OF THE TURNEFFE ATOLL

2.1 PHYSICAL GEOGRAPHY

The Turneffe Atoll is located approximately 8 nautical miles east of the Belize barrier reef (Figure 1). Largest of the three atolls of Belize, Turneffe measures over 49km north to south and up to 20km east to west, covering an area of over 850km². Through geological time, the atoll formed along one of the three fault-controlled submarine ridges off the coast of Belize (James and Ginsburg, 1979).

The waters that surround the atoll range in depth from 300m between its western boundary and the barrier reef, to over 1500m east of the atoll.

A well defined coral reef lies to the windward (eastern) side of the atoll (Figure 2). The edge of the atoll is fringed with a sand ridge which has a maximum width of approximately 150m (Gibson, 1990). A series of breaks (bogues) in this side of the atoll are widely used as navigation channels by fishermen. The sand ridge is submerged to the west of the atoll and supports a dense growth of red mangrove (*Rhizophora* sp.) and black mangrove (*Avicennia* sp.). This mangrove fringe is narrow and traversed by numerous narrow creeks.

The atoll encloses two distinct lagoons which range in depth from 1 to 6m. The North Lagoon has a single small entrance on the windward side and is therefore suspected to have restricted water circulation. The western side of the South Lagoon is split by 13 creeks which are believed to be maintained by strong tidal currents.

In 1961, sections of Belize's reef system were devastated by the winds of Hurricane Hattie which reached 187 miles per hour. Turneffe Atoll suffered catastrophic damage throughout a 20 mile wide swath. Almost all living coral in this belt was destroyed and there was no sign of regeneration four years later. Stoddart (1962) estimated that the reefs would take 25-30 years to recover.

2.2 BIOLOGICAL IMPORTANCE

The flora and fauna of the waters in and around the atoll are dependent either directly or indirectly on the coral reef, mangrove and lagoonal habitats of the area. These systems are intrinsically linked and provide food, shelter, substrata and habitat for a huge diversity of species at some time during their life history. Important grouper spawning grounds are known to exist at the north-west corner of the atoll, at Soldier Cay and at Blackbird Cay.

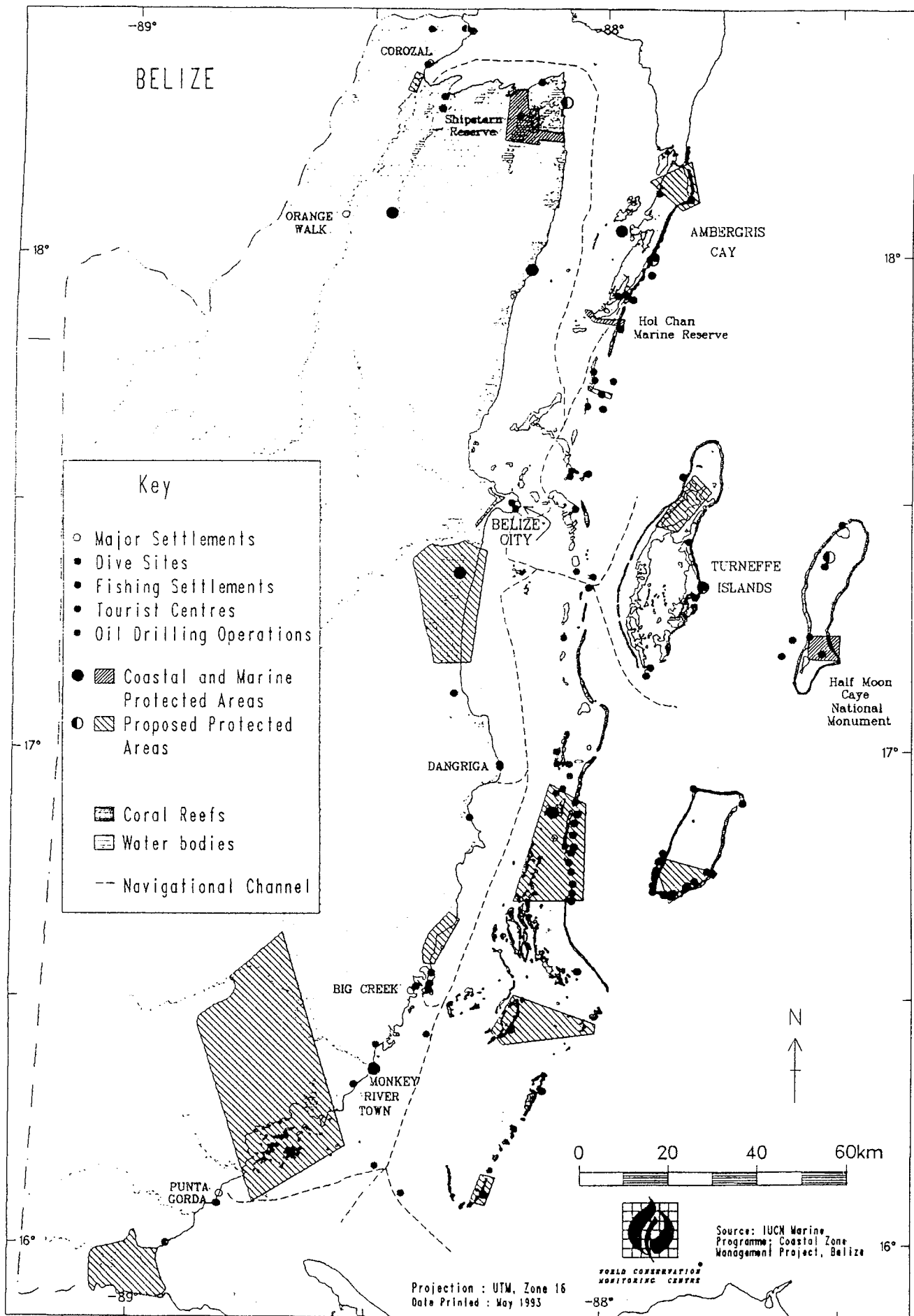


Figure 1. Map of Belize illustrating the position of the Turneffe Atoll along with human activities and marine protected areas.
(Source: World Conservation Monitoring Centre).

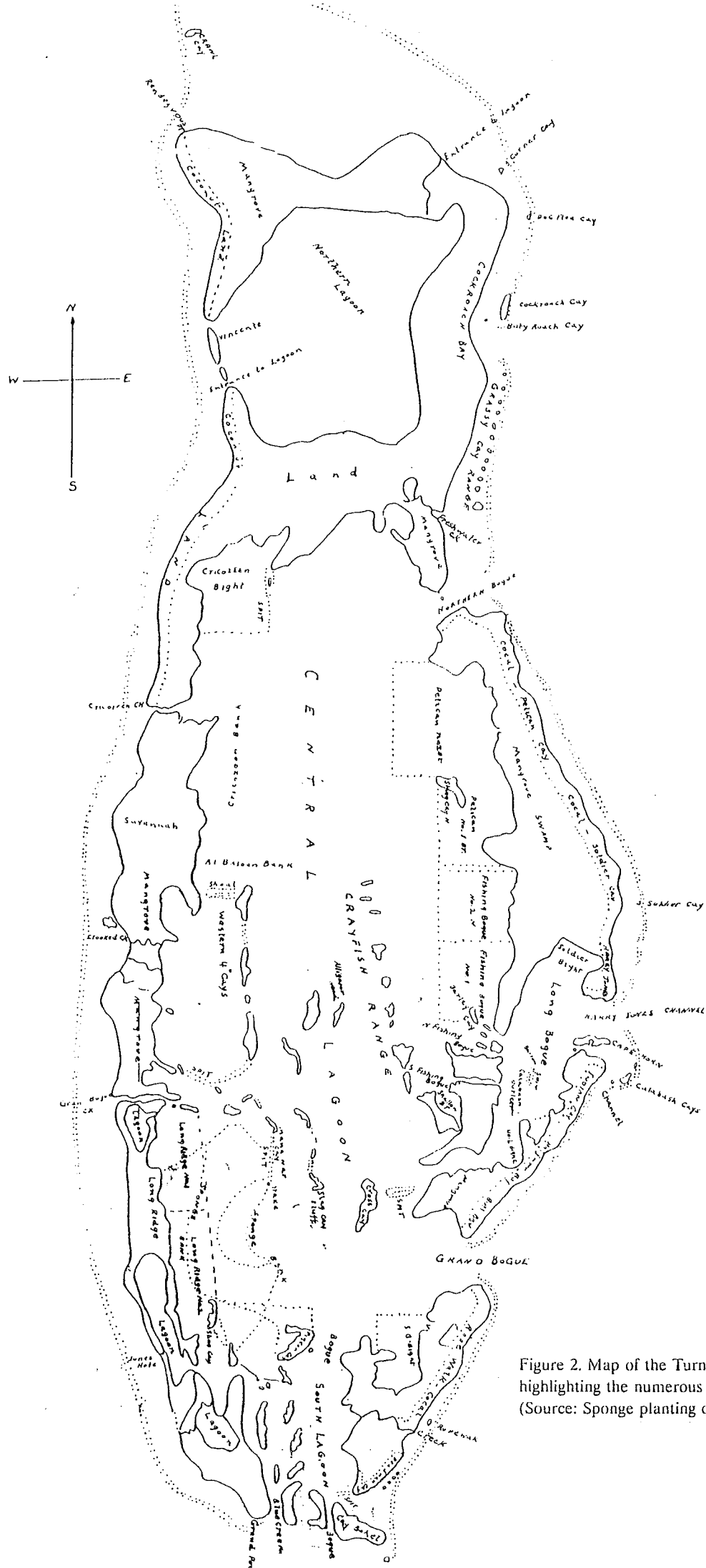


Figure 2. Map of the Turneffe Atoll highlighting the numerous cays and lagoons. (Source: Sponge planting officer, 1958).

The mangroves on Turneffe Atoll are an important nesting site for several rare or endangered birds (for example, the roseate tern, *Sterna dougallii*, and brown booby, *Sula leucogaster*). Furthermore, mangroves and associated lagoons comprise a critical habitat for dolphins (*Tursiops truncatus* and *Stenella plagiodon*), manatees (*Trichechus manatus*), american crocodiles (*Crocodylus acutus*) and the morelets crocodile (*C. moreleti*). It is estimated that Turneffe has the largest population of marine crocodiles in the Caribbean, numbering 500-600 individuals (Perkins, 1983). The sand beaches of the cays are also suspected to be important nesting sites for turtles.

2.3. HUMAN ACTIVITY

South Lagoon was the site of a thriving commercial sponge industry in the late nineteenth century. Disease wiped out the sponge beds in 1919 and a subsequent recurrence of the industry, centred on Calabash Cay, lasted until 1939 when a fungal infection decimated the beds of commercial sponges once again.

Suitable areas of the atoll were cultivated for the cocal industry in the 1940's, 50's and 60's. The resulting "copra" was exported and used in the making of soaps. Calabash Cay was the centre of a large industrial operation producing coconut oil until terminated by damage from Hurricane Hattie (1961).

Turneffe Atoll has historically been a major fishing ground. The main species targeted by fishermen are the spiny lobster (*Panulirus argus*), queen conch (*Strombus argus*), groupers and snappers. Turneffe is also widely renowned for sportfishing; chiefly for bonefish (*Albula vulpes*), tarpon (*Megalops atlantica*) and seasonal billfish. In addition to sportfishing, boats frequently visit the atoll for recreational diving purposes. The most popular dive sites are the 'elbow' near Cay Bokel, Rendezvous Point and Calabash Cay.

There are a small number of established tourist resorts on some of the eastern cays and applications for development purposes are likely to increase in the near future.

The Yucatan shipping lane for heavy tanker traffic between Venezuela and the United States of America lies to the east of the atoll. There is, therefore, the potential for oil spills and possible impact on the atolls including Turneffe. A 1990 study by the Indian government and Caribbean Community (CARICOMP) found high concentrations of hydrocarbons in the Turneffe Atoll area. It was not possible to ascertain whether this was because of natural ground seepage or from tanker discharge. Beach tar is also common on some of the eastern beaches.

The Turneffe Atoll is of high ecological and economic importance and pressure for sound management planning will grow as island development and resource utilization continues to increase.

3. STATUS OF RESEARCH & TRAINING PROGRAMMES AT THE MARINE RESEARCH CENTRE, TURNEFFE ATOLL.

3.1. MARINE RESEARCH CENTRE, TURNEFFE ATOLL.

In 1993, following the success of CCC's work in establishing the South Water Cay Marine Reserve (Appendix 2), CCC signed a working agreement with the University College of Belize (UCB) to assist with the development of UCB's Marine Studies Programme and develop an institutional capacity within Belize for coastal zone research and education programmes (Appendix 1). This Agreement is a pre-cursor to a more comprehensive Memorandum of Understanding which has been drafted to include the three main Government Ministries (Natural Resources; Agriculture & Fisheries; and Tourism & the Environment).

Under the terms of the UCB/CCC Working Agreement, CCC has agreed to establish a Marine Research Centre (MRC) on land owned by UCB on Calabash Cay (Turneffe Atoll) for use by UCB students, government employees, Schools & colleges, and CCC research volunteers. The principle aims of the MRC are:

- (i) to provide multi-level education, training, environmental awareness and field study programmes through collaborative initiatives with UCB, CCC and Government, and with local communities, schools, colleges and non-government organisations in Belize;
- (ii) to collect, analyse and synthesise physical & biological data to support Government initiatives designed to provide integrated management plans for the protection and sustainable use of coastal marine and terrestrial resources in the region;
- (iii) to provide alternative livelihood opportunities for Belizeans through training and skill development courses;
- (iv) to develop long-term environmental monitoring and research programmes;
- (v) to strengthen the capacity of UCB and Government to carry out the above independently of foreign expertise or aid.

In January 1994, CCC relocated its main operational field base from South Water Cay to Calabash Cay, and has initiated a variety of baseline studies and mapping projects to establish an environmental database for Turneffe Atoll from which a management plan for

the Atoll can be prepared. In order to guarantee technology transfer and scientific ability from CCC to UCB, CCC has established an office at the UCB campus in Belize City and is providing counterpart funding for a MRC Associate post.

A number of training programmes have been initiated at the MRC, including courses in Environmental Conservation, and Environmental Impact Assessment. From April, over 30 Belizeans will be awarded CCC Scholarships which include tuition in Scuba diving, marine life identification and coastal marine ecology, and marine survey techniques; the CCC Scholarship programmes are funded through the CCC Charitable Trust (Charity number: 1025534).

CCC is currently preparing educational material (including interactive multimedia programmes) to improve environmental awareness in schools and colleges throughout Belize, as part of the development of a national curriculum for marine studies in Belize.

3.2. BASE MAPPING OF THE TURNEFFE ATOLL

Existing nautical charts of the Turneffe Atoll are poor with respect to both accuracy and spatial detail and synthesis of a new georeferenced base map is, therefore, a prerequisite to the production of the resource description maps required for effective management planning.

Aerial photography is widely used for mapping purposes and, in areas of shallow, clear water, can offer additional scope for mapping submerged features. The major limitation of the technique for use in remote marine areas is inadequate ground control (Mumby *et al.*, 1994). Typically, several ground control points are required per photograph (for example, geodetic survey points). Unfortunately, the Belize Lands and Survey Department (Ministry of Natural Resources) only have a single ground coordinate for the Turneffe Atoll (the lighthouse at Cay Bokel). Therefore, a novel approach to mapping is underway based upon the flexibility of ARC/INFO. Geographic Information System (GIS) technology. Mapping exercises are being conducted with the cooperation of the Land Information Centre (LIC, Ministry of Natural Resources).

Royal Air Force photography of the Turneffe Atoll was updated in February 1993. Thirty seven monochrome photographs provide overlapping coverage of the entire atoll at a scale of 1:30,000. Each photograph has been digitised into ARC/INFO GIS as an individual coverage. Individual digital coverages are then integrated using reference points that can be seen in adjacent photographs. This process is facilitated by the powerful 'rubber sheeting'

capability of ARC/INFO. Rubber sheeting will remove small discrepancies between adjacent coverages with minimal loss in mapping accuracy. Figure 3 shows the map in its current, preliminary stages.

Georeference of the entire digital image (for all 37 photographs) will be achieved by obtaining accurate coordinates for some of the reference positions. Although it is unnecessary to identify the coordinates of each reference point (of which there are 50), a broad geographic spread of points is required to avoid bias in the correction process. New ground control is currently being obtained through the deployment of a Trimble Navigation Prolite differential global positioning system (DGPS), which provides 2-5m spatial accuracy. Georeference of the digitized photographic mosaic will take place at the LIC once complete ground control is available.

The georeferenced map will demarcate all land areas, water bodies, cay developments (for example, land clearance), reef location and major marine geomorphological zones. The map and aerial photographs will then be used to direct the baseline field surveys, thus enabling distinct geomorphological zones to be surveyed, classified and mapped.

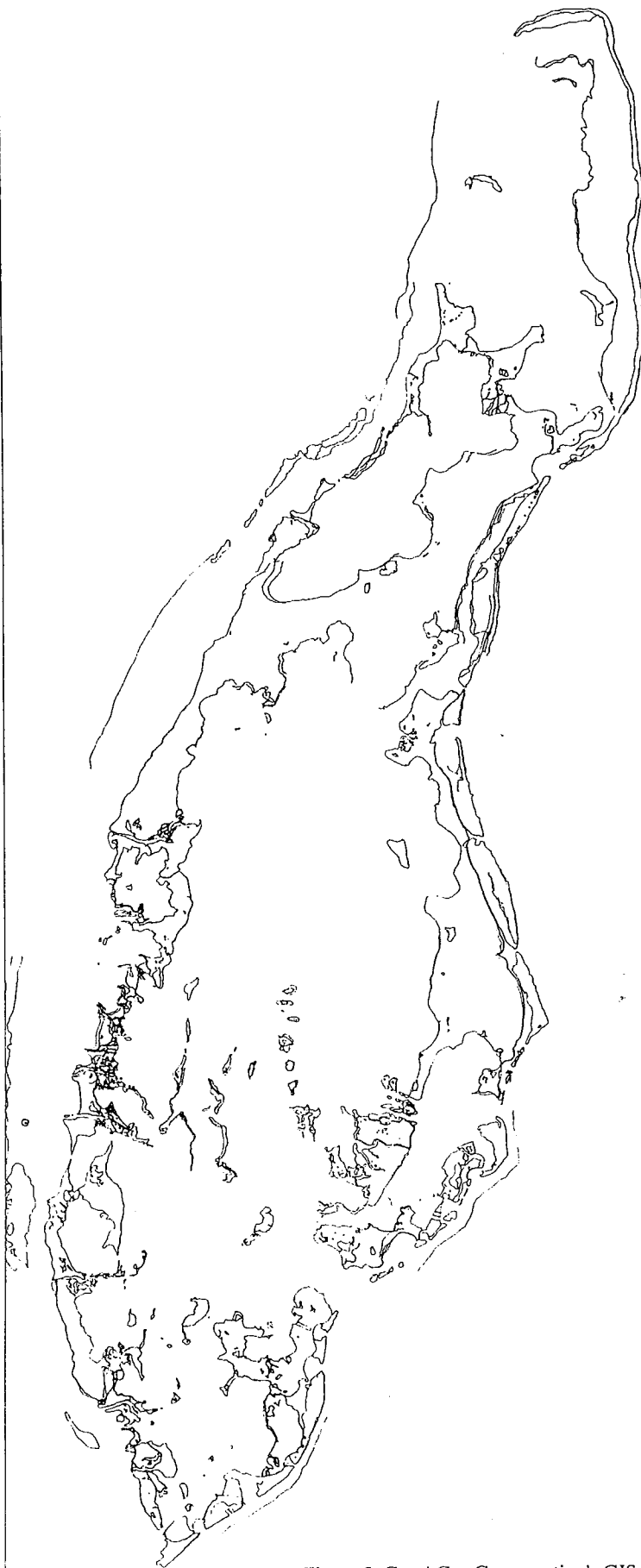


Figure 3. Coral Cay Conservation's GIS map in its preliminary stages. There is still some geo-referencing and editing required to remove the inconsistencies and overlap.

3.3. BASELINE MARINE SURVEYS

3.3.1. INTRODUCTION

Volunteer research programmes are applied to a wide variety of scientific disciplines. The British Trust for Ornithology uses volunteers to census bird species, Earthwatch organise discrete academic projects to assist professional researchers and volunteers participating on the Florida Sea Grant Program are trained to monitor artificial reefs built by recreational fishermen throughout the Florida Keys. The Marine Conservation Society's SEASEARCH programme utilizes volunteers to gather data in preparation for the synthesis of a temperate marine habitat inventory. Volunteer divers and snorkellers also contribute to the REEFWATCH programme that was established by the Tropical Marine Research Unit (York University) to gather broad scale information on the health of coral reefs. Similarly, the Coral Watch Environment Monitoring Program encourages volunteers to assist in efforts to gather information on the health of coral reefs throughout the Florida Keys (National Oceanic and Atmospheric Administration and The Nature Conservancy). Self-funding volunteer labour can be a valuable resource to a host country operating under financial, manpower and training constraints.

The survey methodology developed by CCC (Raines *et al.*, 1992) is based on semi-quantitative techniques adopted by the Marine Nature Conservation Review (MNCR) who are charged with describing the temperate marine communities of the British Isles (Hiscock, 1990). The ordinal data collected by CCC are used to classify reefal habitats, describe species distributions and provide semi-quantitative analyses of biological communities. These data have also provided ground information for remotely sensed satellite imagery (Mumby *et al.*, 1994).

The data itself is entered into a specially designed DBase IV database to allow manipulation and interrogation of the information. This latest database, which is currently undergoing final revisions, is compatible with Geographical Information Systems (GIS).

3.3.2. MARINE SURVEY METHODOLOGY

3.3.2.1. Summary

Typically, a survey team comprises of three biological recorders who make semi-quantitative abundance assessments of 'fish', 'corals and sponges' and 'macroalgae and other invertebrates' respectively. In addition, a fourth diver describes the topographic and

bathymetric profile, substrate composition and natural or anthropogenic impacts. Fish, Scleractinia and macroalgae are recorded at a species level whilst octocorals and Porifera are classified by growth form. A habitat description is given in terms of substrate composition and biological coverage and is conducted by eye using ranks of 0-5.

3.3.2.2 Training Programme

In order to effectively use the survey methodologies developed by CCC, survey teams must first undergo a comprehensive training course in marine life identification and marine survey skills. The programme includes lectures, practical exercises (snorkel/Scuba), one-to-one tuition, video and slide components.

Overview of course syllabus:

- * identification of marine organisms: fish, corals and other marine invertebrates, mangroves, seagrass and algae;
- * training in marine survey techniques: assessment of biological cover and topographical features;
- * aspects of relevant ecological issues: species interactions; taxonomy; classification; physiology.
- * consideration of current coastal zone management issues and practises: requirements for an integrated approach; importance of coastal habitats; baseline- and resource-mapping (including use of GPS and GIS); buffer zone management.

The course is designed to run over a seven-day period with an optional eighth day to cover more advanced aspects of coastal zone ecology and management. Integral to the training programme is testing for minimum standards in species identification before surveying can be undertaken.

3.3.2.3 Survey Techniques

Baseline marine surveys aim to identify and classify the distinct geomorphological zones visible in remotely sensed imagery. To describe patterns of habitat zonation, individual survey transects are orientated perpendicularly to the habitat of interest. For example, in order to survey a stretch of reef that runs in a North-South direction, it would be necessary to adopt a series of East-West transects.

For convenience, the reef bathymetric profile is subdivided into zones (Figure 4). Each reef transect begins at the 30m depth contour of the Drop-off zone, and extends shorewards to either the Reef Crest or Mangrove Fringe. However, several individual surveys are needed to record the physical and biological characteristics of a complete transect. These discrete surveys are primarily arranged to survey distinct topographical zones along the transect. In some areas, an individual reef zone may be too extensive to adequately survey in a single dive. For example, the Inner Forereef to the east of Calabash Cay usually requires several individual, consecutive surveys along the same transect. Within the lagoon, since there is no clear zonation, 300m transect are used.

The extent of each survey is marked with buoys, with the limit of each dive recorded using both global positioning system (GPS) technology and transect marks to features visible in aerial imagery. GPS coordinates are accurate to within 100m and allow data to be spatially referenced on GIS. To facilitate the process of relating transect data to aerial photography, surveys are, where possible, orientated between conspicuous points (eg. "survey extends from northern end of mangrove island 'A' to southern end of mangrove range 'B'").

An individual survey team comprises four divers. The dive is led by a 'physical surveyor' whose responsibility is to navigate in the desired direction and record the depth profile, topography, substrate types and human/natural impacts noted on the survey. This data is transferred to a Physical Recording Form (Appendix 3). A second diver semi-quantitatively records all fish species and takes four representative photographs of the habitat surveyed. Photographs are also taken of any unusual species, coral diseases and signs of reef damage. The remaining two divers semi-quantitatively assess 'scleractinian corals, gorgonians and porifera' and 'macroalgae and other invertebrates' respectively. A habitat assessment of substrate composition and biological coverage is also made and entered onto a Biological Recording Form (Appendix 4).

To obtain good spatial resolution, each survey is conducted in 10m stages, with the 'physical' and 'fish' surveyors leading a 10m floating line.

In essence, a Biological Recording Form can be thought of as a semi-quantitative summary of a particular habitat and its associated species. However, in order to retain habitat integrity on a multiple-habitat survey, the species within each major geomorphological zone (habitat) are recorded separately. By way of example, if surveying a seagrass bed and patch reef on the same dive, it would be nonsensical to include data from both habitats on the same Biological Recording Form. In this example, a single Physical Recording Form would detail the location and description of both habitats and the species recorded within each

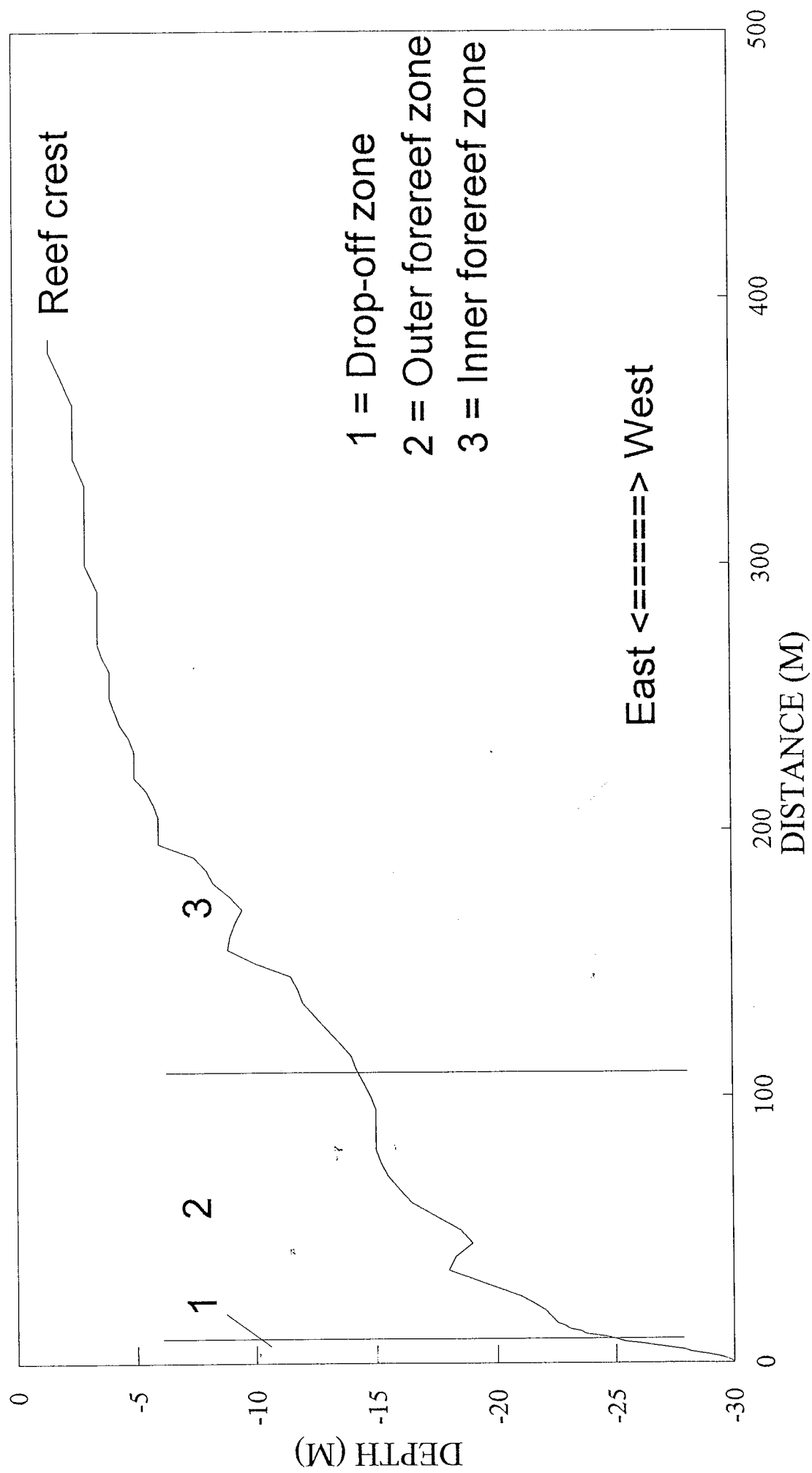


Figure 4. Schematic diagram of a typical reef profile of the reef east of Calabash Cay. This diagram is derived from transect 24 (see figure 4 for actual position).

habitat would be summarized by separate Biological Recording Forms. Major discrete habitats include; sand gully (> 10m wide), *Montastrea* reef, gorgonian plain, high relief spur and groove, *Acropora palmata* zone, Reef Crest, *Turbinaria turbinata* and *Porites* spp. zone, mixed seagrasses and algae, algae dominated (*Udotea* spp. and *Pencillus* spp.), algae dominated (*Lobophora variegata*), sand bore and patch reef (Figure 5).

3.3.3. VALIDATION OF SURVEY TECHNIQUE

Quantitative reef sampling techniques have undergone rigorous testing (e.g. Weinberg, 1981). However, there is a dearth of literature devoted to the quality of data obtained using volunteers to conduct marine biological surveys, and the precision of semi-quantitative marine survey techniques. Although the general assumption that the field scientist consistently assigns ordinal ranks to species is widely accepted, supporting evidence is largely restricted to anecdotal confirmations of confidence and unpublished field tests.

Attempts have been made to assess the data generated by volunteers undertaking coral reef fish censuses. The voluntary organisation "Frontier Tanzania" has studied the relationship between the fish count and length estimates made by volunteers and the data collected by their staff (Darwall, pers. comm.). Similarly, The Nature Conservancy and the Florida based "Reef Environment Education Foundation" studied the consistency of fish census data obtained from volunteers and the changes in accuracy following greater survey experience (Akins, pers. comm.). Both organisations have found encouraging preliminary results to support the use of volunteer reef survey programmes.

In February 1993, a study was designed to validate the marine survey techniques employed by CCC and investigate the quality of semi-quantitative ordinal data on sessile coral reef communities. To achieve these aims, the accuracy and inter-group consistency of coral, macroalgal and habitat classification data were critically assessed. The individual sources of data inaccuracy were investigated with a view to identifying bathymetric, habitat, experience and species related trends. The specific species-level results have enabled CCC to refine the volunteer training programme and provide a measure of confidence which can be incorporated into data analyses. The general conclusions of this study should apply to any organisation that uses volunteers to conduct surveys of the marine environment.

The results of this analysis were presented at the First European meeting of the International Society for Reef Studies, Vienna 16-20th December, 1993. The resulting paper is currently under review for publication in the Bulletin of Marine Science (Appendix 5).

Mixed Seagrasses & Algae	Sand	Sand Cay	Mixed Seagrasses & Algae	Zonal Rubble & Acropora on carbonate pavement	Acropora reef	Agalicia / Acropora / Millepora reef	Gorgonian rich Montastraea reef	Montastraea reef	Sand	Montastraea reef
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depth (m)



Figure 5. Schematic diagram of a typical reef profile east of South Water Cay including a detailed habitat classification.
(Source: McCarthy *et al.*, 1993)

4. SURVEYS COMPLETED AND PRELIMINARY ANALYSIS OF DATA

4.1. SURVEYS COMPLETED

Between the 6th January and the 22nd March 1994, CCC has completed 37 full transect across the reef and 17 in the lagoon. The reef transects have been carried out directly east of CCC's base on Calabash Cay and are sited 100m apart (Figure 6). Each transect was based on initial exploratory work carried out during early January 1994. The lagoon transects are situated west of Calabash Cay and represent a preliminary exploration of a series of important habitats. The completed transects represent a total of 225 individual survey dives, 175 on the reef and 50 in the lagoon. These dives have been carried out at a wide variety of depths, from 2 to 30m and involve linear distances of up to 300m.

4.2. ZONE ASSESSMENT

Data for 24 of the reef transects have been assimilated into CCC's database (the coordinates of which are provided in Appendix 6). An initial analysis of this data has been performed for each of the major reef zones, which are a Drop-off, an Outer Forereef area and an Inner Forereef zone (Figure 6). Within the lagoon, data has so far been gathered from a single habitat, namely mixed seagrass beds.

Preliminary analysis has mainly been by univariate methods, such as the median values of the substratum and biological coverage scores assigned to each zone (Table 1) along with other qualitative information from the survey forms. However, the advantage of the CCC database is that it is compatible with multivariate statistic packages which enable more detailed examination of the data. Using the powerful capabilities of UNISTAT, it is possible to generate dendrograms in order to examine any distinct clusters within the surveys. Currently this has only been done for substrate types in the lagoonal habitats, but will eventually be extended to the biological cover, reef habitats and species information.

4.2.1. SPECIES LISTS

A preliminary species list compiled from the survey records for each of the reef zones and the seagrass beds is shown in Appendix 7 and act as a useful indicator of biodiversity.

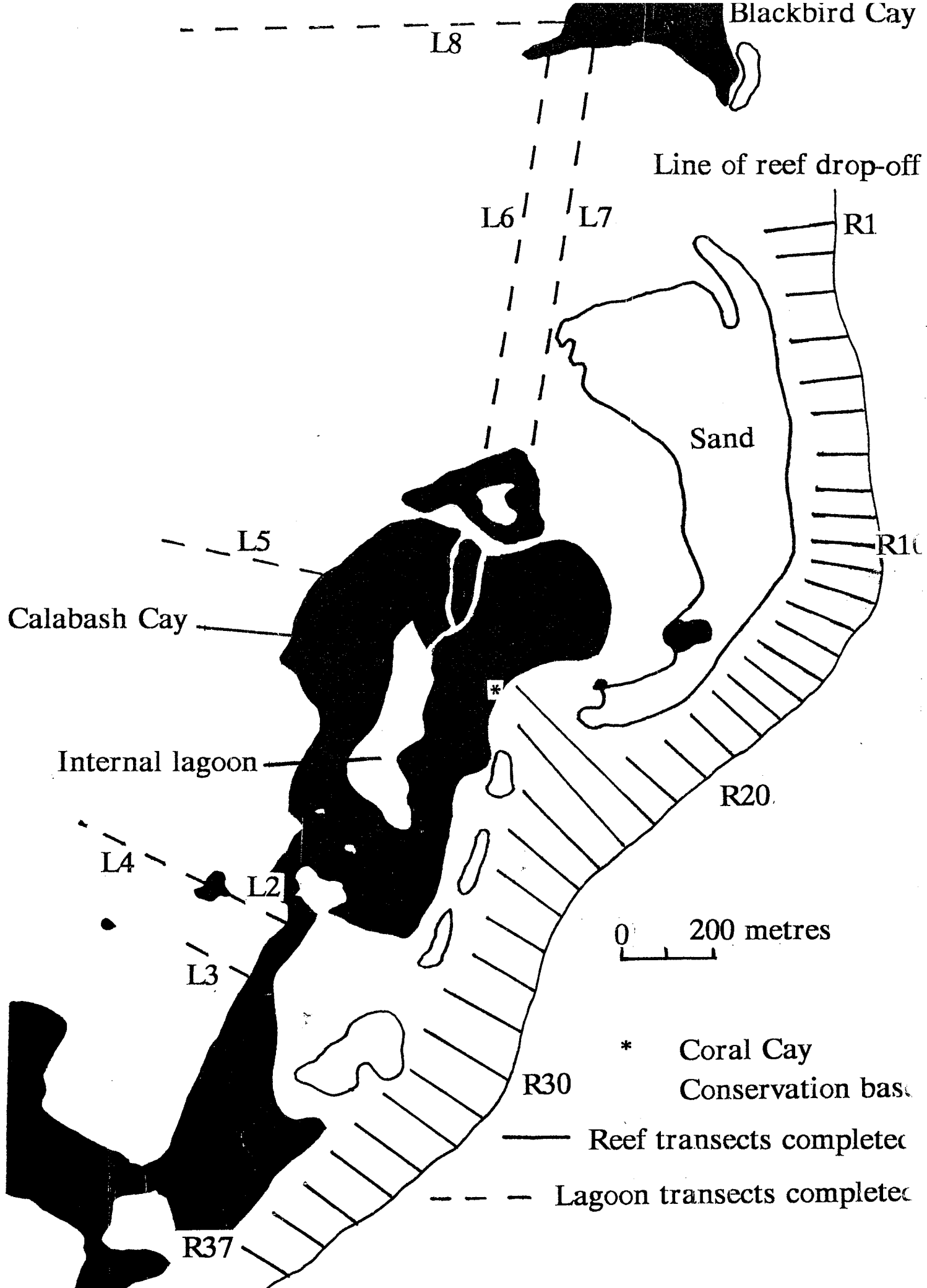


Figure 6. Diagram showing the reef and lagoon transects surveyed around Calabash Cay. The position of the Coral Cay Conservation base is also highlighted.

		Inner forereef	Outer forereef	Drop-off	Seagrass bed
Number of habitats examined		91	33	24	46
S	Live coral	2	2	2.5	0
U	Deadcoral	1	0	0	0
B	Bedrock	0	1	2	0
S	Sand	3	3	2	4
T	Mud	0	0	0	0
R	Rubble	2	1	0	0
A	Mangrove	0	0	0	0
T					
U					
M					
B C	Live hard coral	2	3	2	0
I O	Soft corals	2	2	2	0
O V	Sponges	1	2	2	1
L E	Invertebrates	0	0	1	1
O R	Algae	2	3	3	2
G	Seagrass	0	0	0	4
I	Mangrove	0	0	0	0
C					
A					
L					

Table 1. Table showing the median values for the substratum and biological cover variables in the three reef zones seen east of Calabash Cay and the seagrass beds. (Data collected before March 1994.)

4.2.2. DROP-OFF ZONE

The spectacular Drop-off is the deepest and most easterly part of the reef that has been surveyed by CCC to date. The boundary between the Drop-off and Outer Forereef is reflected by a shallowing of topographical gradient at an average depth of 20.8m. The lateral distance between the shallowest section of the Drop-off and the 30m depth contour (the maximum depth surveyed) varies from 1-2m up to 30-40m. There is no pattern to this variation, with the lateral distance fluctuating between the maximum and minimum values on adjacent transects. The substrate is mainly live coral, bedrock and sand. The steep topography of this zone is reflected by the median value of sand, which is lower than for the forereef (Table 1). It may also be caused by the increased upwelling action of local currents.

The biological and species diversity (Table 1) includes hard and soft corals, sponges, algae and other invertebrates. More detailed analysis of the data reveals the dominant species to be mountainous star coral (*Montastrea annularis*), smooth starlet coral (*Siderastrea siderea*), leaf coral (*Agaricia agaricities*), sheet coral (*Agaricia grahamae*), common sea fans (*Gorgonia ventalina*) and branching octocorals. Algal coverage is mainly by the genus *Halimeda* and *Lobophora variegata*. A high diversity of fish species is found within this zone (Appendix 7), including the larger pelagic species such as jacks (Carangidae) and planktivores such as the blue chromis (*Chromis cyanea*). The high abundance of the latter may reflect high levels of plankton resulting from nutrients from upwelling water.

4.2.3. OUTER FOREREEF ZONE

The boundaries of the Outer Forereef zone are the shallowest part of the Drop-off (approximately 20m) and continuing for between 50 and 100m to the eastern boundary of the Inner Forereef zone at approximately 15m depth (Figure 4). The zone is quite complex and the bedrock and live coral substrate is often broken by sand gullies and large patches of sand.

The sandy habitats are predominately found in the shallower part of the zone and support only limited coral growths, such as heads of mountainous star coral (*Montastrea annularis*). However, diverse hard and soft coral growth is abundant away from these sandy areas with the dominant species being mountainous star coral (*Montastrea annularis*), smooth starlet coral (*Siderastrea siderea*), leaf coral (*Agaricia agaricities*), common sea fans (*Gorgonia ventalina*) and branching octocorals. These are interspersed with many sponges and considerable algal coverage, particularly from the genus *Halimeda* and *Lobophora variegata*. Most fish families can also be found in this zone.

4.2.4. INNER FOREREEF ZONE

The Inner Forereef is the widest and most physically diverse of the reef zones surveyed, often extending for a distance up to 300m. It is contiguous from the Outer Forereef to shallow Reef Crest (Figure 4). The substrate of the Inner Forereef is particularly varied, encompassing sub-zones of live and dead coral, patches and gullies of sand and rubble (Table 1). Of the three reef zones, the median value for rubble is highest in the Inner Forereef zone (Table 1) reflecting the high wave energy characteristic of this zone. The topography of the Inner Forereef also includes limited spur and groove development, with coral spurs, perpendicular to the line of the reef, separated by sandy grooves.

The topographic complexity of the Inner Forereef is matched by the biological diversity found in this zone. The Inner Forereef contains a large range of hard and soft coral species, sponges, algae and fish. The dominant species are mountainous star coral (*Montastrea annularis*), smooth starlet coral (*Siderastrea siderea*), leaf coral (*Agaricia agaricites*), common sea fans (*Gorgonia ventalina*) and branching octocorals. However, in addition there are species particularly adapted to high wave energy, such as the rapidly growing ribbon coral (*Agaricia tenuifolia*), elkhorn coral (*Acropora palmata*) and the robust, massive heads brain corals (*Diploria* spp.). The dominant algae are the genus *Halimeda* and *Lobophora variegata*.

4.2.5. LAGOONAL SEAGRASS BEDS

The lagoon habitats so far examined are primarily seagrass beds occurring at depths less than 5m. These habitats are dominated by turtle grass (*Thalassia testudinum*) and to a lesser extent manatee grass (*Syringodium filiforme*). Interspersed within the seagrasses are significant amounts of algae, mainly from the genera *Caulerpa*, *Penicillus* and *Halimeda*. Corals are rare and fish are scarce, except within the fringing mangroves where many juvenile fish occur. Sponges are common, and can be abundant in certain areas, possibly relating to past commercial planting.

The substrate as observed from univariate median values (Table 1), is mainly sand. However, multivariate clustering shows that there are two discrete substrate types: sand and mud (Figure 7).

4.3. ANCILLARY ANECDOTAL INFORMATION

The following anecdotal information has been compiled by CCC research scientists who are currently overseeing the survey work at Calabash Cay and who have worked on numerous

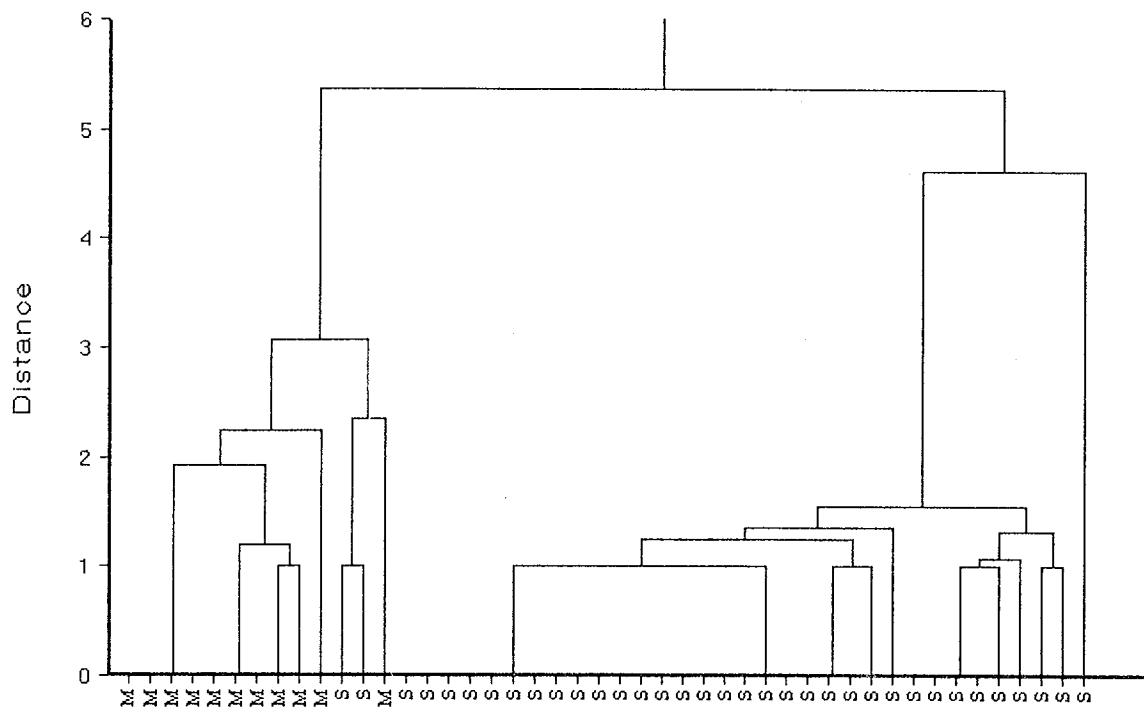


Figure 7. Dendrogram showing the clustering of the lagoonal substrate types. Two clear clusters can be seen, one incorporating the mud (M) substrates and the other including the sand (S) substrate. Only two habitats can be seen in the wrong cluster (4%).

previous CCC projects in Belize.

- a) There is a high degree of spatial variation in reef topography in the vicinity of Calabash Cay.
- b) Sponge abundance and diversity appears to be particularly high compared to the area surveyed by CCC in other areas of the Belize reef. For instance within the lagoon, surveys have revealed high concentrations of sponges just west of Blackbird Cay.
- c) There appears to be a reasonable population of the long spined sea urchin (*Diadema antillarum*) near the Reef Crest. *Diadema* is an important reef herbivore and plays a key role in maintaining the ecological balance between coverage of algae and coral. In 1983/4, a poorly understood plague decimated populations of this urchin throughout the entire Caribbean region, with serious repercussions for coral health (Carpenter, 1990). There are recent reports of sea urchin population recovery, possibly emanating from the southern Caribbean. *Diadema* surveys have recently been incorporated into the Caribbean Coastal Marine Productivity programme (CARICOMP) and plans to study the population of *Diadema* at Calabash Cay are underway.
- d) Observations by CCC staff suggest that reasonably large populations of elkhorn coral exist in the vicinity of Calabash Cay and perhaps throughout the Turneffe Atoll. The elkhorn coral (*Acropora palmata*) has been severely afflicted by another poorly understood phenomenon known as White Band Disease (WBD). In many areas of the Caribbean, *A. palmata* has been reduced from the dominant shallow water coral species to barely an 'incidental' member of the reef community. There is a possibility that some kind of pathogen (or conditions required for a pathogen) may be distributed throughout the central and eastern Caribbean by the Orinoco river (Bythell, pers.comm.). If this is true, Belize should, to a large extent, avoid the worst of the disease. To date, incidences of WBD have not been fully studied in Belize.
- e) The Turneffe Islands are believed to support the largest population of crocodile in the region (Perkins, 1983). This suggestion will need verification but should make for some very important studies (see section 4.6.)

5. PROPOSED RESEARCH PROGRAMMES FOR APRIL '94 - MARCH '95

5.1. SATELLITE REMOTE SENSING

Remote sensing provides rapid, cost-effective and efficient means of assessing natural resources within large areas of reef systems and, therefore, has great potential as a management tool. Although satellite remote sensing is widely used for terrestrial resource mapping, its application to marine environments is often constrained by light scattering and attenuation in water. The image analysis must attempt to accommodate for two major variables: spatial difference in habitat and bathymetric variation. The isolation of these variables is an important research priority for the application of this technique in coastal resource management.

The most widely used sources of imagery are those from Landsat Multispectral Scanner (MSS), Landsat Thematic Mapper (TM), and SPOT High Resolution Visible (HRV), which use both multispectral and panchromatic sensors.

The resource data obtained by CCC is ideally suited to the classification of remotely sensed imagery and CCC has recently applied SPOT Panchromatic imagery to map coral reefs in the Sapodilla Cays (Mumby *et al.*, 1994).

Two Landsat Thematic Mapper (TM) scenes of the Turneffe Atoll are held at the LIC. The images were recorded in March and April 1993 and though they possess some cloud cover, much of the scenes are of high quality. Analysis of these remotely sensed data will take place once sufficient ground truthing data has been obtained by CCC.

5.2. QUANTITATIVE HABITAT ASSESSMENT AND PERMANENT MONITORING

The CARICOMP methodologies for seagrass and mangrove monitoring studies will be included in the schedule of research undertaken by CCC once the latest guidelines are published (Appendix 8). The CARICOMP methodology for monitoring coral reefs uses chain transects and this technique is under consideration for inclusion in the CCC science programme. However, it is unlikely to be adopted by CCC volunteers since the technique requires the chain to be repeatedly laid in the same fashion. It is, therefore, preferable for the survey to be repeated over time by a single person. Furthermore, deploying the chain is potentially damaging to corals, sponges and gorgonians.

Quadrats can be used to estimate percent cover of each species and obtain information

about density, abundance, diversity and colony size. Tests are currently underway to investigate the precision of quantitative quadrat data generated by CCC volunteers. Pending the results of these tests, CCC plan to carry out quantitative permanent monitoring studies based on this technique.

5.3. WATER QUALITY ASSESSMENT

CCC proposes to incorporate water quality analysis into its routine survey work, to allow more detailed analysis of the physical parameters governing the area. The variables to be measured will include:

- * temperature
- * salinity
- * turbidity (Secchi depth)
- * sedimentation rate
- * nutrient analysis (dissolved and sediment-bound)

It is also hoped that the water quality programme will be extended by collaboration with the National Oceanographic Data Center via data exchange and the use of other equipment to enable measurement of a wider variety of parameters. CCC is also exploring the use of a side-scan sonar to gather detailed topographical information.

Detailed water quality assesment will also play an integral role in the permanent monitoring programme outlined in section 4.2. In this case the data will give a vital clue to causes of any changes observed in the benthic communities.

5.4. ASSESSMENT OF COMMERCIAL SPONGE RESOURCES OF THE TURNEFFE ATOLL

A potentially valuable project is the assessment of commercial sponge resources of the Turneffe Atoll. The Turneffe sponge industry was based on Calabash Cay throughout the nineteenth century but was eventually destroyed by disease in the 1930s (Section 1.). A sponge survey (conducted using quadrat stratified random sampling) will need to address the following questions:

- * What is the diversity and abundance of Porifera in the region?
- * Are these levels regionally significant and are there local centres for diversity and/or abundance?

- * What is the potential for a revived sponge industry on the Turneffe Atoll?
- * How effective was the previous replanting programme?

The major difficulty with surveying sponges is identification: many species require detailed spicule examination for accurate identification which is beyond the scope of routine CCC work. However, provided that the commercially important species are readily distinguishable, the study could potentially take place in the absence of absolute diversity estimates, for example, sponge abundance can be categorised by growth form rather than species. Specific sponge identification techniques are currently under investigation.

5.5 TERRESTRIAL STUDIES OF CALABASH CAY

An important part of the work on the Turneffe Atoll will be mapping, assessment and monitoring of terrestrial habitats. This will include a species inventory and production of geo-referenced GIS base maps. It is proposed that mangrove mapping techniques undertaken by Zisman (Tropical Forestry Action Plan, Belize), using satellite imagery, will be utilised.

5.6 CROCODILE CENSUS

A population study of the american crocodile (*Crocodylus acutus*) and morelets crocodile (*Crocodylus moreleti*) on the Turneffe Atoll will commence in May 1994. Crocodile census takes place at night by travelling a measured distance along a predetermined survey route and recording all crocodiles observed. Spotlights are used to locate the crocodiles and classify them according to size. Mr. Steven Platt, a crocodile researcher from the Department of Biological Sciences at Clemson University, USA, will be collaborating with this project. The project also has the support of the IUCN Crocodile Specialist Group.

5.7 MARINE TURTLE NESTING STUDIES

Monitoring of turtle nesting will take place in late spring/summer 1994. Although the hawksbill (*Eretmochelys imbricata*) and loggerhead (*Caretta caretta*) turtles nest in many coastal areas of Belize, the status of nesting at Calabash Cay is uncertain (Perkins, 1983) although the expansive shore at Calabash Cay provides a suitable substrate for nesting activities.

5.8 FISH CENSUSING

In May 1994, CCC will commence a comprehensive survey of fish species at Turneffe Atoll. The objective of this fish census are:

- * To produce species inventories of the fish communities in different lagoonal habitats and reef subzones.
- * To quantitatively assess the fish communities in different lagoonal habitats and reef subzones.
- * To investigate the possibility of stock assessment for fish species of commercial importance.
- * To permit the monitoring of fish populations with particular reference to providing comparative data of fish stocks in marine protected areas and fished areas.
- * To supply quantitative data in support of dynamic management planning.

In 1993, CCC investigated current fish census techniques which utilize divers to identify and record the number of individuals of each species. Various existing techniques were considered, and led to the use of a novel technique, known as "discrete group fish censusing" (Greene and Alevizon, 1989). The technique was refined over an initial two months trial period at South Water Cay (April-June, 1993). CCC is currently reviewing the success of the technique with a view to making several refinements, principally in limiting the scope of species surveyed to those considered to be the most ecologically significant and commercially important. Limiting the observations in this way should improve the accuracy of the data gathered.

6. ACKNOWLEDGEMENTS

Coral Cay Conservation would like to thank the following for their support and guidance:

Government of Belize: Coastal Zone Management Unit & the Fisheries Department
(Ministry of Agriculture & Fisheries)

The Lands Information Centre & the Forestry Department
(Ministry of Natural Resources)

Department of the Environment
(Ministry of Tourism & the Environment)

British Government: Darwin Initiative for the Survival of Species
(Department of the Environment)

University College of Belize

The Belize Centre for Environmental Studies

The Belize Audubon Society

Trimble Navigation (UK) Ltd

Ray Lightburn (Blackbird Cay Resort, Belize)

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APPENDIX 1

MARINE RESEARCH CENTRE, CALABASH CAY, TURNEFFE ATOLL

DRAFT DISCUSSION DOCUMENT

APPENDIX 2

CORAL CAY CONSERVATION: STATUS REPORT

CORAL CAY CONSERVATION: STATUS REPORT

AWARDS/GRANTS

Darwin Initiative for the Survival of Species.

Funding approved in 1993 by the Department of the Environment (UK) for a 2 year project to assist with surveys and training programmes for the establishment of a management plan for the Turneffe Atoll.

Commission of the European Communities

Funding approved by DGVIII in 1993 for a 2 year collaborative project between CZMU/CCC/ITCF/IUCN to establish a marine reserve at Bacalar Chico.

British Airways 'Tourism for Tomorrow Award'

Overall winners of the 'Global Award' for 1993.

First International Marine Environmental Award

Award by Dr. Frederico Mayor, Director UNESCO, in 1992 at the headquarters of UNESCO, Paris. Mrs Janet Gibson, CZMU Belize, was present to accept the award with CCC. Dr. Mayor stated that the award was given to CCC on account of "the professionalism of the conservation work; the fact that the funds are raised by civic efforts; the involvement of both amateurs and professionals from the UK and Belize in diving, conservation and other technical fields; the work undertaken in developing local expertise to protect the irreplaceable resource; the high quality public education programmes, and a demonstration of the determination of people from developed and developing countries in combating environmental problems which observe to national bounds".

RECENT PUBLICATIONS

Mumby, P.J., Baker, M.A., Raines, P.S., Ridley, J.M. & Phillips, A.T.

The potential of SPOT Panchromatic imagery as a tool for mapping coral reefs.

2nd Thematic Conference on Remote Sensing for Marine & Coastal Environments, New Orleans, Louisiana, 1994.

Mumby, P.J., Raines, P.S. & Ridley, J.M.**

Coral Cay Conservation: A critical assessment of volunteer-derived data.

1st European Meeting of the International Society for Reef Studies, Vienna, 1993.

Bull. marine Sc. (in press).

Gray, D., Mumby, P.J., Gibson, J. & Raines, P.S.

GIS: A tool for integrated coastal zone management in Belize.

In prep.

Raines, P.S. & Cleator, B.C.

Coral Cay Conservation: Isles of Scilly Expedition Report, 1993.

McCorry, D., Mumby, P.J., Raines, P.S. & Ridley, J.M.

South Water Cay Marine Reserve Management Plan, CCC Report, 1993.

Mumby, P.J.

The application of Geographical Information Systems (GIS) in marine resource management. Special Symposium on GIS, Royal Geographic Society (London), 1993.

Raines, P.S., Ridley, J.M., McCorry, D. & Mumby, P.J.
Coral Cay Conservation: Survey techniques and their application in Belize.
7th International Coral Reef Symposium, Guam, 1992.
(Cited by Dr. Grahame Keller, Chairman Great Barrier Reef Marine Park Authority, in a report to the World Bank on the status of marine protected areas worldwide).

Raines, P.S., Ridley, J.M. & McCorry, D.
The role of Coral Cay Conservation in Marine Resource management in Belize.
IUCN 4th World Congress on National Parks & Protected Areas, Caracas, 1992.

Raines, P.S., Nunny, R. & Cleator, B.C.
Coral Cay Conservation: Isles of Scilly Report, 1992.

***The positive reception to this paper was such that CCC has subsequently been asked to organise a workshop entitled 'Volunteer Programmes in Applied Marine Research and Coastal Zone Management' at the Second European Regional Meeting of the International Society for Reef Studies to be held in Luxembourg in September 1994. CCC has also been invited to organise the 'Volunteer Workshop' during the International Year of Coral Reefs in 1996.*

Following the Vienna meeting, Dr. John Ogden (Co-chairman and Director of the Florida Institute of Oceanography) invited CCC's Science Co-ordinator to travel to the Site Directors Meeting of Caribbean Coastal Marine Productivity (CARICOMP) to present the findings of the CCC paper; this is the only regional programme concerning the health of coral reefs throughout the Caribbean. CCC/UCB/GOB have been invited by Dr. Ogden to attend the next meeting.

Professor Robert Ginsburg (University of Miami) presented CCC's paper to a USA Federal Government meeting on the environment as an example of what can be achieved through the use of volunteer surveyors).

SUMMARY OF PROJECTS UNDERTAKEN IN BELIZE

Since 1989, CCC has assisted the CZMU with the collection, analysis and synthesis of data in support of the development of Special Area Management Plans for selected regions of the Belize barrier reef. Work undertaken by CCC includes:

UCB/GOB/CCC Marine Research Centre (Turneffe Atoll)

1994 onwards: Development of Marine Research Centre on Calabash Cay (Turneffe) to strengthen institutional capacity at UCB for a marine Studies Programme. Survey of marine/terrestrial resources of Turneffe and production of an environmental database for the establishment of a management plan for Turneffe.

South Water Cay Marine Reserve

1990-93: Detailed surveys covering an area of over 180km². Output included production of accurate (+/- 5m, DGPS) geo-referenced base maps (from aerial photography & remote sensed images), GIS resource description maps and a management plan. Production of fish census data from discrete group methods for the region.

Sapodilla Cays

1991-93: Detailed surveys covering an area of over 300km². Output included production of accurate geo-referenced base maps (aerial photography and SPOT imagery), classification of Landsat TM image, sediment analysis, and establishment of an regional environmental database.

Laughing Bird Cay

1992: Baseline surveys and investigation of coral bleaching incidents and anchor damage.

Cay Caulker

1993: Rapid ecological assessment and production of geo-referenced base maps in support of the Siwa Ban Marine Reserve.

SUMMARY OF COLLABORATIVE PROJECTS WITH FOREIGN AGENCIES

CCC/UCB/Dr. Alasdair Edwards, Centre for Tropical Coastal Management Studies, Newcastle University

1995: Evaluation of the uses and cost-effectiveness of remote sensing for coastal resources assessment and mapping.

CCC/UCB/Dr Anthony Jensen, Oceanography Department, Southampton University.

1995: Oceanographic survey of Turneffe Atoll

CCC/UCB/GOB/National Oceanographic Data Centre (NOAA)

1994: Data exchange and CDROM publication of CCC databases.

CCC/UCB/World Conservation Monitoring Centre (UK)

1994: Data exchange agreement.

CCC/UCB/International Centre for Living Aquatic Resources & Management

1993: Data exchange and inclusion of CCC databases into Reefbase database.

CCC/UCB/Dr. Peter Spencer-Davis, University of Glasgow

1994: Investigation of rapid method for assessing growth rates of corals in relation to water pollution.

CCC/UCB/Dr Richard Warwick, Plymouth Marine Laboratory (UK)

1994: Analysis of CCC data utilising PRIMER (Plymouth Routines in Multivariate Ecological Research).

CCC/UCB/Stephen Platt (IUCN Crocodile Specialist Group), Dept. of Biological Sciences, Clemson University.

1994: Survey of crocodiles at Turneffe Atoll.

CCC/Natural Resources Institute of the Overseas Development Agency (UK)

1992: Investigation of the application of remote sensing techniques to the study of coral reef habitats in Belize

CCC/Dr. Rob Nunny

1992: Investigation of the impact on the Belize barrier reef of changing mainland fine sediment discharge regimes.

CCC/Silsoe College, Cranfield University.

1991: Investigation of the potential of spot panchromatic imagery as a tool for mapping coral reefs.

PATRONS

Prof. David Bellamy	-	Conservation Foundation (UK)
Jonathon Porritt	-	Friends of the Earth
Sir John Chapple	-	President, Zoological Society of London
Prof. Stewart Sutherland	-	Vice-Chancellor, University of London
Prof. Eric Sunderland	-	Vice-Chancellor, University of Wales
Prof. Struther Arnott	-	Vice-Chancellor, University of St. Andrews

ASSOCIATE SCIENTIFIC ADVISORS/REFEREES

- | | | |
|------------------------------|---|--|
| Dr. Andrew Price | - | Special Advisor, Coastal and Marine Programme, IUCN; co-author of "Guidelines for Developing a Coastal Zone Management Plan for Belize" (IUCN Report). |
| David Gray, MA | - | GIS Expert; Special Advisor to the Lands Information Centre, Belize. |
| Dr. Nicholas Flemming | - | Coordinating Committee, Marine Science and Technology, International Oceanographic Committee. |
| Prof. Paul Ryan | - | Lecturer, University College, Ireland: Chairman, Technical Committee, World Underwater Federation. |
| Dr. John Davies | - | Head of Marine Survey Unit, Joint Nature Conservation Committee. |

NON-ASSOCIATE ADVISORS

- | | | |
|------------------------------|---|--|
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| Dr. Nick Polunin | - | Centre for Tropical Coastal Resource Management, Newcastle University. |
| Dr. Rupert Ormond | - | Tropical Marine Research Unit, York University. |
| Prof. Robert Ginsburg | - | University of Miami. |
| Dr. Joe Halusky | - | Florida Seagrass Programme |
| Dr. Mary Enstrom | - | Coral Watch - Environmental Monitoring Programme |
| Dr. Callum Roberts | - | University of Rhode Island |
| Prof. Steve Bortone | - | University of West Florida. |

EDUCATION & TRAINING

Each year, CCC Charitable Trust (Charity number: 1025534) makes available over 30 scholarships for young Belizeans in tropical marine ecology, SCUBA diving and marine survey techniques. Scholars have included personnel from the Fisheries Department, Forestry Department and the Ministry of Tourism and the Environment as well as teachers and students from many of Belize's schools and colleges.

APPENDIX 3

CCC PHYSICAL RECORDING FORM

Physical Recording Form/Photography

Site No: _____ Transect No: _____ Date: ____ / ____ / ____
Start time: ____ : ____ End time: ____ : ____ Underwater vis: _____ m

First: _____ Last: _____ No. dives/snorkels in Belize: _____
Recorders: _____
names _____
Depth limits: Upper _____ m
Lower _____ m
Repeat visit? Y/N

TYPE OF SURVEY

Spot dive ☐
Transect ☐
General ☐
Mapping ☐
Photography ☐
Sounding ☐
Other ☐

ZONE

Barrier reef: ☐ Back Reef ☐ Sediment
☐ Reef Crest ☐ Seagrass
☐ Inner Fore ☐ Patch Reef
☐ Outer Fore ☐ Mangrove
☐ Ridge ☐ Other
☐ Inner Drop Off
☐ Outer Drop Off

IMPACTS

Litter ☐
Sewage ☐
Coral Damage ☐
Lobster Potting ☐
Fish Traps ☐
Other ☐

PHOTOGRAPHY

Film Code _____
Frames Taken _____

YOUR IMPRESSION OF THE SITE

Frame No.	Description (Depth/Metres)

Aesthetic	Biological
Excellent	
V. Good	
Good	
Average	
Poor	
Other Comments:	

SITE DESCRIPTION (Describe general location of the site, topography, main habitats (coral, sand, etc.) and depths, and your impression of the site).

General location _____

Topography _____

Main habitats _____

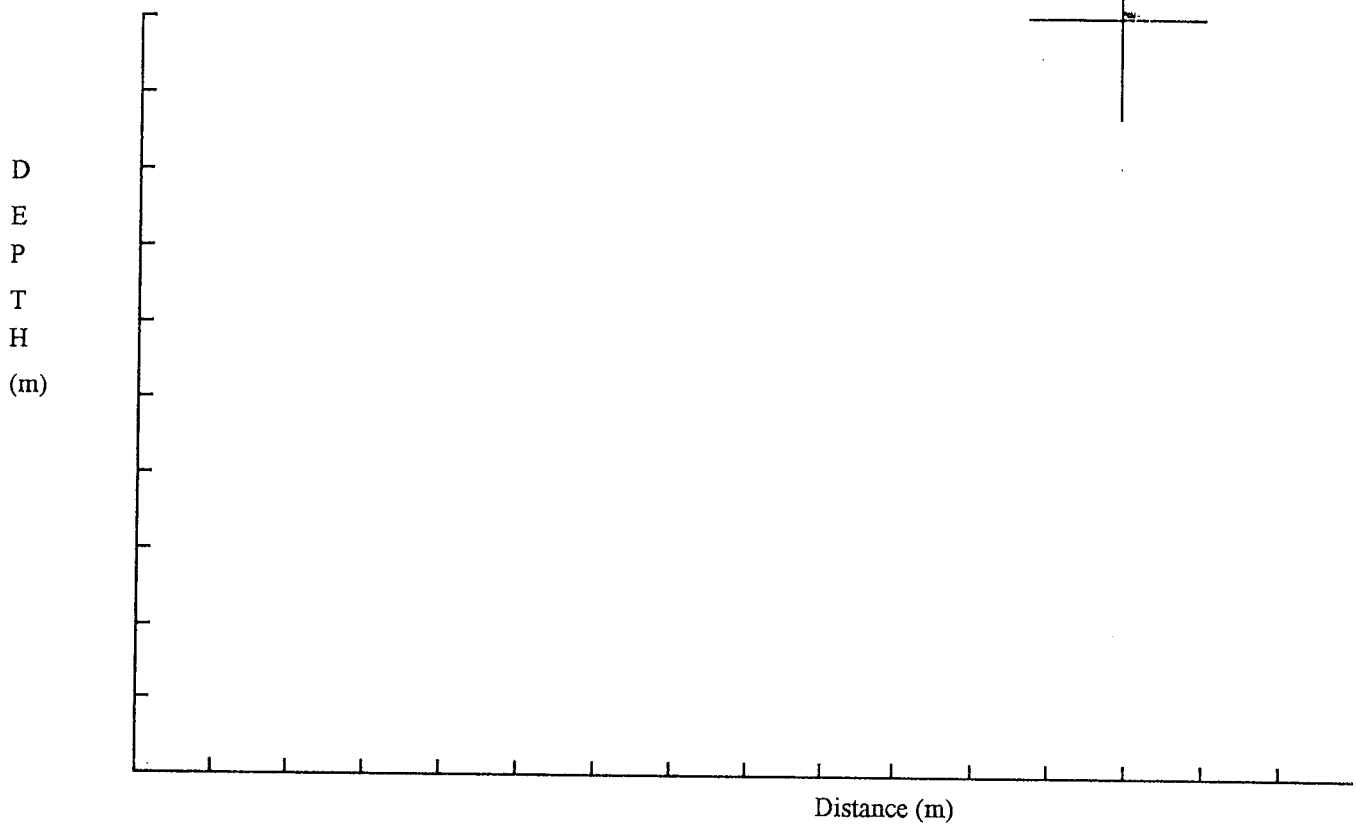
Depth range of dive _____

Your impression of the site _____

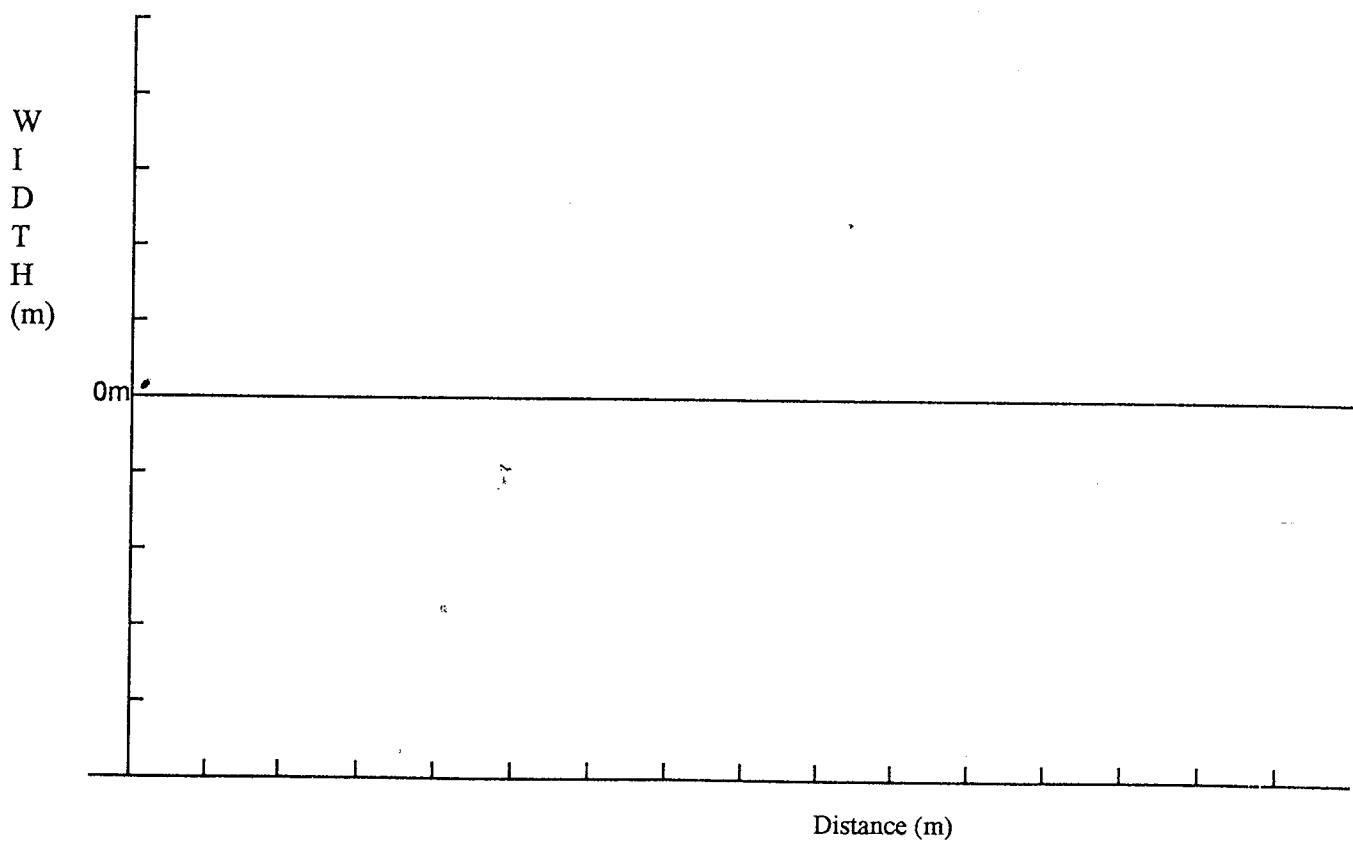
SITE PROFILE /PLAN DRAWING (Note depths, distances and habitats)

SIDE VIEW:

Orientation



AERIAL VIEW



APPENDIX 4

BIOLOGICAL RECORDING FORM

BIOLOGICAL RECORDING FORM

Site No:

Transect No.

Habitat No: _____ of: _____ Date: ____ / ____ / ____

Percentage Cover: _____ %

Start time: _____ :

End time: _____ :

First: _____ Last: _____

No. dives/snorkels
in Belize

Recorders

name(s)

Depth limits: Upper _____ m

Lower _____ m

Underwater visibility _____ m

ZONE**SUBSTRATUM****BIOLOGICAL COVER****Barrier Reef****Lagoon**

(0-5)*

(0-5)*

Back reef
Reef crest
Inner fore
Outer fore
Ridge
Inner drop off
Outer drop off

Sediment
Seagrass
Patch reef
Mangrove
Other

Live corals
Dead corals
Bedrock
Sand
Mud
Rubble
Mangrove

Live hard corals
Soft corals
Sponges
Invertebrates
Algae
Seagrass
Mangrove

*These figures need not add up to 5 total

HABITAT DESCRIPTION

(Describe substratum, depths, main animal/plant groups and growth forms)

1. Substratum types within the Habitat: _____

2. Describe depth range of the Habitat: _____

3. Main animal groups in Habitat: _____

4. Main Plant groups in Habitat: _____

5. Habitat classification (seagrass bed, spur and groove, shallow reef etc): _____

6. Other comments: _____

SPECIES LIST

Score 0-5 Abundance:

None = 0
Rare = 1
Occasional = 2
Frequent = 3
Common = 4
Abundant = 5

MARINE ALGAE

GREEN

Filamentous-loose tufts:

Polyphysa polyphysoides

Enteromorpha flexuosa

Cladophora prolifera

Sheet-like:

Ulva sp.

Cup-like:

Udotea cyathiformis

Disc-like:

Acetabularia sp.

Lacy:

Anadyomene sp.

Marble-like:

Ventricaria ventricosa

Halicystis-Derbesia osterhoutii

Brush-like:

Caulerpa cupressoides

Caulerpa paspaloides

Caulerpa prolifera

Caulerpa sp.

Rhipocephalus phoenix

Penicillus capitatus

Penicillus dumetosus

Penicillus pyriformis

Coarse branched: (eg. Gracilaria sp.)

Fine branched:

Liagora

Calcified:

Amphiroa sp.

Encrusting

Filamentous:

Turf:

Wrangelia argus

BROWN

Pyramid-like:

Turbinaria sp.

Fine branched:

Dictyota sp.

Blade-like:

Lobophora variegata

Padina sp.

Leaf-like:

Sargassum sp.

MARINE PLANTS

Mangroves:

Red

White

Black

Seagrass:

Turtle (blade-like)

Manatee (cylindrical)

Halophila decipiens (leaf-like)

SCLERACTINIA: HARD CORALS

Elkhorn

Staghorn

Fused staghorn

Club finger

Finger

Green cactus

Yellow pencil

Mountainous star

Cavernous star

Rough starlet

Smooth starlet

Flower coral

Solitary disk

Large flower

Blushing star

Elliptical star

Golfball

Lobed star

Smooth star

Rose coral

Ivory tube

Ivory bush

Orange tube

Sheet coral

Leaf coral

Massive leaf

Ribbon

Scroll

Purple leaf

Fragile saucer

Saucer

Giant brain

Smooth brain

Grooved brain

Knobby brain

Butterprint brain

Fungus

Fat fungus

Thin fungus

Grooved fungus

Rough star

Sinuuous cactus coral

Pillar coral

Mustard hill

Ivory Tree

OCTOCORALLIA: SOFT CORALS

Common sea fan

Venus sea fan

Deepwater fan

Branching: rod

plume

Red sea whip

(deep water)

Flat sea whip

(shallow water)

RED

Sheet-like:

Halymenia floresia

Kallymenia limnuthii

PORIFERA: SPONGES

Encrusting
Barrel
Vase
Tube
Branching
Ball
Plate

CNIDARIA

Corallimorphs
Hydroids
Anemones
Zoanthids (eg. Palythoa sp.)
Fire coral (Millepora)

ANNELIDA

Segmented worms:
Fire worms

--

Calcareous Tube:
Christmas tree
Feather duster

CRUSTACEA

Spiny lobster*
Shrimps

Crabs*
Arrow
Coral
Spider
Hermit

MOLLUSCS

Conch*
Bivalves
Cowrie
Topshell
Octopus*
Nudibranchs

ECHINODERMS

Feather stars
Sea stars

Sea urchins:
Short spined*
Long spined*
Sea cucumbers

TUNICATES

Species:

FISH

Butterfly:
Spotfin
Foureye
Banded
Reef
Longsnout

Angel:
Rock beauty
Queen
French
Gray
Cherubfish

Surgeon:
Ocean
Doctor
Blue tang

Jacks:
Barjack
Horse-eye
Yellow
Crevalle

Porgy:

--

Chub/Mojarra/Spadefish:

--

Barracuda/Mackeral:

--

Tarpon/Bonefish/Snook:

--

Needlefish/Bonnetmouth:

--

Cobia/Flyingfish/silverside:

--

Snapper:
Schoolmaster
Mahogany
Dog
Gray
Mutton
Lane
Yellowtail

Grunts:
Blue striped
Spanish
Smallmouth
Striped
White
Caesar
Cottonwick
French

Tomtate
Sailors choice
Margate
Black Margate
Porkfish

Damselfish:
Yellowtail

Dusky
Longfin
Cocoa
Beaugregory
Bicolor
Threespot
Sergeant major
Night sergeant
Blue chromis
Brown chromis

Hamlets:

Barred
Masked
Indigo
Blue
Golden
Yellowbelly
Shy

Grouper:

Jewfish
Nassau
Red
Black
Yellowfin
Comb
Tiger
Marbled
Red hind
Rock hind
Graysby
Coney

Bass:

Chalk
Harlequin
Tobaccofish
Fairy basslet
Blackcap basslet

Parrotfish:

Queen
Rainbow
Princess
Blue
Striped
Midnight
Stoplight
Redband

* Include total number of species seen in left hand box

Wrasse:

Hogfish

Spanish hogfish

Puddingwife

Creole

Yellowhead

Slippery dick

Bluehead

Clown

Rosy razorfish

Cardinalfish:

Belted

Barred

Flamefish

Squirrelfish:

Squirrelfish

Longjaw

Longspine

Dusky

Reef

Blackbar

Bigeye

Gobies:Blennies:Jawfish:Batfish:Flounder:Scorpionfish/Stargazer/Frogfish:Toadfish/Gurnard:Searobin/Hawkfish/Lizardfish:Trumpetfish/Cornetfish/Tilefish:Smooth/Spiny Pufferfish:Triggerfish:

Queen

Black durgon

Filefish:

Scrawled

Whitespotted

Remora:Goatfish:Moray eels:

Green

Goldentail

Spotted

Conger eels:

Garden eel

Snake eels:Sharks:

Nurse

Blacktip

Rays:

Spotted eagle

Southern

Yellowtail

Manta

Turtles:

Green

Hawksbill

Loggerhead

Leatherback

Mammals:

Dolphin (species..)

Manatee

Further Species Information:

APPENDIX 5

**ABSTRACT FROM "CORAL CAY CONSERVATION: A
CRITICAL ASSESSMENT
OF VOLUNTEER-DERIVED DATA"**

MUMBY ET AL., 1994

CORAL CAY CONSERVATION: A CRITICAL ASSESSMENT OF VOLUNTEER-DERIVED DATA

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ABSTRACT

Since 1986, Coral Cay Conservation (CCC) has utilized a workforce of over 600 specially-trained volunteer divers to collect detailed topographic, bathymetric and biological data for the establishment of management plans for selected areas of the Belize barrier reef. The biological data recorded are semi-quantitative and reflect the abundance of reef organisms including fish, macroalgae and hermatypic corals on a scale of 0-5. Substrate composition and biological cover are also visually assessed.

An exercise was carried out to assess the accuracy and consistency of data recorded by volunteers. Transects were laid in each of the major reef zones and in lagoon habitats. Each transect was surveyed independently by six teams of trained volunteers and compared to a standard obtained by experienced CCC staff using extended dive profiles. Analyses were carried out to test the accuracy and consistency of the coral, macroalgal and habitat data. Further analysis sought to quantify the proportion of species correctly identified, the frequency of erroneous species recordings and the variation of abundance ratings.

The overall accuracy of coral surveys varied from 52-70% with the poorer values obtained in deeper outer and inner drop-off reef zones. The trend of reduced surveyor performance in deeper water is discussed in terms of physical, physiological and psychological phenomena. Inter-group consistency exhibited a similar bathymetric trend to that found for coral accuracy. Macroalgae were generally accurately and consistently recorded. No clear trend of improved accuracy and consistency following greater survey experience was apparent. Substrate composition and biological cover were recorded with an accuracy exceeding 90% in seagrass habitats and 70-90% in reef sites. A number of recommendations are made for the improvement of survey methodology and volunteer training.

APPENDIX 6

COORDINATES OF TRANSECTS ON REEF AND LAGOON HELD ON CCC DATABASE

TRANSECT	START	END
CBR1	N 17 17 174 W 87 47 790	N 17 17 284 W 87 47 931
CBR2	N 17 17 114 W 87 47 772	N 17 17 351 W 87 47 953
CBR3	N 17 17 096 W 87 42 762	N 17 17 104 W 87 47 801
CBR4	N 17 17 052 W 87 47 784	N 17 17 216 W 87 47 903
CBR5	N 17 16 995 W 87 47 813	Missing
CBR6	N 17 17 110 W 87 47 796	N 17 17 223 W 87 47 889
CBR7	Missing	Missing
CBR8	N 17 16 977 W 87 47 886	N 17 17 087 W 87 47 936
CBR9	N 17 17 074 W 87 47 935	N 17 17 299 W 87 47 941
CBR10	N 17 17 075 W 87 48 777	N 17 16 988 W 87 48 085
CBR11	N 17 16 852 W 87 48 009	N 17 17 179 W 87 47 857
CBR12	N 17 16 878 W 87 47 995	N 17 16 963 W 87 48 019
CBR13	N 17 16 740 W 87 48 103	N 17 16 875 W 87 48 111
CBR14	N 17 16 824 W 87 47 962	N 17 16 823 W 87 48 095
CBR15	N 17 16 759 W 87 48 239	N 17 16 925 W 87 48 212
CBR16	N 17 16 716 W 87 48 147	N 17 16 759 W 87 48 239
CBR17	N 17 16 879 W 87 47 970	N 17 16 906 W 87 48 089
CBR18	N 17 16 608 W 87 48 268	N 17 16 608 W 87 48 268
CBR19	N 17 16 540 W 87 48 508	N 17 16 784 W 87 48 646
CBR20	N 17 16 505 W 87 48 423	N 17 16 774 W 87 48 548
CBR21	N 17 16 461 W 87 48 528	N 17 16 596 W 87 48 588
CBR22	N 17 16 523 W 87 48 430	N 17 16 716 W 87 48 594
CBR23	N 17 16 479 W 87 48 430	N 17 16 705 W 87 48 515
CBR24	N 17 16 525 W 87 48 399	N 17 16 551 W 87 48 718

TRANSECT	START	END
SG3C	N 17 16 187 W 87 49 337	N 17 16 229 W 87 49 361
SG5C	N 17 16 947 W 87 49 243	N 16 48 480 W 88 04 510
SG6C	N 17 17 462 W 87 48 644	N 17 17 901 W 87 48 373
SG7C	N 17 16 879 W 87 48 671	N 17 17 530 W 87 48 665
SG8C	N 17 18 308 W 87 48 509	N 17 18 703 W 87 49 265
SG9	N 17 18 725 W 87 48 401	N 17 19 220 W 87 48 357
SG10	N 17 18 744 W 87 48 262	N 17 18 872 W 87 43 350
SG11	N 17 18 756 W 87 48 311	N 17 19 009 W 87 48 791
SG12	N 17 18 715 W 87 48 243	N 17 19 380 W 87 48 526

APPENDIX 7

SPECIES LISTS FOR REEF ZONES AND SEAGRASS BED

SPECIES INVENTORY FOR REEF ZONES AND SEAGRASS BEDS

Abbreviations

OD Outer Drop-off

OF Outer Forereef

IF Inner Forereef

SG Lagoonal Seagrass Beds

Species List:

Scleractinia

Octocorallia

Porifera

Cnidaria

Annelida

Crustacea

Mollusca

Echinodermata

Tunicata

Osteichthyes

Chondrichthyes

Reptilia

Mammalia

Rhodophyta

Phaeophyta

Chlorophyta

Angiospermae

	OD	OF	IF	SG
<u>SCLERACTINIA</u>				
Elkhorn coral (<i>Acropora palmata</i>)			X	
Staghorn coral (<i>Acropora cervicornis</i>)	X	X	X	X
Fused staghorn coral (<i>Acropora prolifera</i>)			X	
Club finger coral (<i>Porites porites</i>)	X	X	X	X
Finger coral (<i>Porites furcata</i>)	X	X	X	X
Mountainous star coral (<i>Montastrea annularis</i>)	X	X	X	X
Cavernous star coral (<i>Montastrea cavernosa</i>)	X	X	X	X
Smooth starlet coral (<i>Siderastrea siderea</i>)	X	X	X	X
Rough starlet coral (<i>Siderastrea radians</i>)	X	X	X	X
Flower coral (<i>Eusmilia fastigiata</i>)	X	X	X	
Solitary disk coral (<i>Scolymia lacera</i>)	X	X	X	
Blushing star coral (<i>Stephanocoenia michelini</i>)	X	X	X	
Elliptical star coral (<i>Dichocoenia stokesii</i>)	X	X	X	X
Leaf coral (<i>Agaricia agaricites</i>)	X	X	X	
Purple leaf coral (<i>A. agaricites forma purpurea</i>)	X	X		
Ribbon coral (<i>Agaricia tenuifolia</i>)		X	X	X
Scroll coral (<i>Agaricia undata</i>)	X	X		
Saucer coral (<i>Agaricia fragilis</i>)	X	X	X	

	OD	OF	IF	SG
Sheet coral				
<i>(A. grahamae/lamarcki)</i>	X	X		
Plate coral				
<i>(Helioseris cucullata)</i>				
Giant brain coral				
<i>(Colpophyllia natans)</i>	X	X	X	
Smooth brain coral				
<i>(Diploria strigosa)</i>	X	X	X	X
Knobby brain coral				
<i>(Diploria clivosa)</i>	X	X	X	X
Grooved brain coral				
<i>(D. labyrinthiformis)</i>	X	X	X	
Butterprint brain coral				
<i>(Meandrina meandrites)</i>	X	X	X	X
Butterprint rose coral				
<i>(Meandrina meandrites forma danae)</i>				
Fat fungus coral				
<i>(Mycetophyllia danaana)</i>	X	X	X	
Thin fungus coral				
<i>(Mycetophyllia aliciae)</i>	X	X	X	
Grooved fungus coral				
<i>(Mycetophyllia ferox)</i>	X	X	X	
Fungus coral				
<i>(M. lamamarckiana)</i>	X	X	X	X
Pillar coral				
<i>(Dendrogyra cylindrus)</i>			X	
Mustard hill coral				
<i>(Porites astreoides)</i>	X	X	X	X
Honeycomb plate coral				
<i>(Porites colonsensis)</i>				
Green cactus coral				
<i>(Madracis decactis)</i>	X	X	X	
Yellow pencil coral				
<i>(Madracis mirabilis)</i>	X	X	X	
Smooth star coral				
<i>(Solenastrea bourmoni)</i>		X	X	
Rose coral				
<i>(Manicina areolata)</i>	X	X	X	X

	OD	OF	IF	SG
Rough star coral (<i>Isophyllastrea rigida</i>)			X	X
Cactus coral (<i>Isophyllastrea sinuosa</i>)		X	X	
Golfball coral (<i>Favia fragum</i>)		X	X	
Large flower coral (<i>Mussa angulosa</i>)	X	X		

OCTOCORALLIA

Common sea fan (<i>Gorgonia ventalina</i>)	X	X	X	
Venus sea fan (<i>Gorgonia flabellum</i>)	X	X	X	
Branching rods*	X	X	X	
Branching plumes**	X	X	X	
Flat sea whips (<i>Pterogorgia</i> spp.)			X	X
Corkey sea fingers (<i>Briareum asbestinum</i>)		X		
Encrusting gorgonian (<i>Erythropodium caribaeorum</i>)				
Sea whips (<i>Ellisella</i> spp.)	X	X		
Deepwater sea fan (<i>Iciligorgia schrammi</i>)	X			

* includes species of *Pseudoplexaura*, *Eunicea* & *Plexaurella*

** includes species of *Muriceopsis*, *Pseudopterogorgia*

HEXACORALLIA

Black coral (<i>Antipathes</i> spp.)	X
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	OD	OF	IF	SG
<u>PORIFERA</u> (growth forms)				
Encrusting	X	X	X	X
Vase	X	X	X	
Tube	X	X	X	X
Branching	X	X	X	X
Barrel	X	X	X	
Ball	X	X	X	X
Plate	X	X	X	

CNIDARIA

Corallimorpharia	X		X	X
Hydroid	X	X	X	X
Anemone	X	X	X	X
Corkscrew anemone (<i>Bartholomea annulata</i>)				X
Giant anemone (<i>Condylactis gigantea</i>)				
Zoanthids (<i>Palythoa</i> spp.)			X	
Fire coral (<i>Millepora</i> spp.)	X	X	X	X
Upsidedown jelly (<i>Cassiopea frondosa</i>)				X
Moon jelly (<i>Aurelia aurita</i>)				
Sea wasp (<i>Carydbea alata</i>)				X

ANNELIDA

Christmas tree worms (<i>Spirobranchus gigante</i>)	X	X	X	X
Feather dusters (<i>Bispira</i> spp.)	X	X	X	X

	OD	OF	IF	SG
Spaghetti worm (<i>Eupolyornia crassicornis</i>)				X
Fanworms (<i>Notaulax</i> spp.)				
Southern lugworm (<i>Arenicola cristata</i>)				
Fireworms (<i>Amphinomidae</i>)		X		

CRUSTACEA

Yellowline arrow crab (<i>Stenorhynchus seticornis</i>)		X	X	X
Banded coral shrimp (<i>Stenopus hispidus</i>)	X	X	X	
Caribbean spiny lobster (<i>Panulius argus</i>)	X		X	X
Isopoda				
Shrimp (<i>Natantia</i> spp.)	X	X	X	
Cleaner shrimps (<i>Periclimenes</i> spp.)				X
Clinging crabs (<i>Mithrax</i> spp.)				
Batwing coral crab (<i>Carpilius corallinus</i>)				
<i>Xanthidae</i> spp.				
Hermit crabs (<i>Paguridae</i>)	X		X	X
<i>Stomatopoda</i> spp.				
Pederson cleaner shrimp (<i>Periclimenes pedersoni</i>)	X		X	

	OD	OF	IF	SG
--	----	----	----	----

MOLLUSCA

Caribbean reef squid (<i>Sepioteuthis sepioidea</i>) <i>Octopoda</i>				
Queen conch (<i>Strombus gigas</i>)		X	X	X
Flamingo tongue (<i>Cyphoma gibbosum</i>)			X	
Frond oyster (<i>Dendostrea frons</i>)				
West Indian Starsnail (<i>Lithopoma tectum</i>)				
Nudibranchia			X	
Bivalvia	X	X	X	X
Amber penshell				

ECHINODERMATA

Long spined urchin (<i>Diadema antillarum</i>)		X		
Slate-pencil urchin (<i>Eucidaris tribuloides</i>)			X	
West Indian sea egg (<i>Tripneustes esculentus</i>)				X
Urchins (<i>Echinometra</i> spp.)	X		X	
Sea cucumbers (<i>Holothuroidea</i>)	X			X
Brittle stars (<i>Ophiuroidea</i>)			X	X
Crinoidea	X			
Golden crinoid (<i>Davidaster rubiginosa</i>)			X	
Cushion sea star (<i>Oreaster reticulatus</i>)				X

	OD	OF	IF	SG
Sand dollar (<i>Cypeaster subdepressus</i>)				
Two-spined sea star (<i>Astropecten duplicatus</i>)			X	X

TUNICATA

Unidentified spp.	X		X	X
Giant tunicate (<i>Polycarpa spongiabilis</i>)				
Reef tunicate (<i>Rhopalaea abdominalis</i>)			X	

ECTOPROCTA

Bryzoans - unidentified spp.

	OD	OF	IF	SG
<i>Padina gymnospora</i>			X	X
<i>Padina stypodium</i>	X	X	X	X
<i>Rosenvingea</i>				
<i>Cystoseira myrica</i>				
<i>Cladosiphon occidentalis</i>				X

CHLOROPHYTA

<i>Ulva</i>				
<i>Acetabularia</i> spp.			X	X
<i>Anadyomene</i> spp.				
<i>Anadyomene stellata</i>				
<i>Caulerpa</i> spp.	X			X
<i>Caulerpa cupressoides</i>				
<i>Caulerpa paspaloides</i>				X
<i>Caulerpa prolifera</i>				X
<i>Caulerpa taxifolia</i>				
<i>Caulerpa mexicana</i>				
<i>Caulerpa racemosa</i>			X	
<i>Rhizocephalus phoenix</i>	X	X	X	X
<i>Penicillus capitatus</i>			X	X
<i>Penicillus dumetosus</i>		X	X	X
<i>Penicillus pyriformis</i>	X	X	X	X
<i>Avrainvillea</i> spp.	X	X	X	X
<i>Avrainvillea nigricans</i>		X		
<i>Avrainvillea elliottii</i>				
<i>Cladocephalus luteofuscus</i>				X
<i>Udotea flabellum</i>	X	X	X	X
<i>Udotea wilsonii</i>			X	X
<i>Udotea occidentalis</i>		X	X	X
<i>Udotea cyathiformis</i>	X	X	X	
<i>Udotea spinulosa</i>				
<i>Halimeda incrassata</i>	X	X	X	X
<i>Halimeda opuntia</i>	X	X	X	X
<i>Halimeda monile</i>		X	X	X
<i>Halimeda goreau</i>	X	X	X	X
<i>Halimeda copiosa</i>	X	X	X	X

	OD	OF	IF	SG
--	----	----	----	----

OSTEICHTHYES

Chaetodontidae

Spotfin butterflyfish (<i>Chaetodon ocellatus</i>)	X	X	X	X
Foureye butterflyfish (<i>Chaetodon capistratus</i>)	X	X	X	X
Longsnout butterflyfish (<i>Chaetodon aculeatus</i>)	X		X	
Banded butterflyfish (<i>Chaetodon striatus</i>)	X	X	X	
Reef butterflyfish (<i>Chaetodon sedentarius</i>)	X	X	X	

Pomacanthidae

French angelfish (<i>Pomacanthus paru</i>)	X	X	X	X
Queen angelfish (<i>Holacanthus ciliaris</i>)	X	X	X	
Rock beauty (<i>Holacanthus tricolor</i>)	X	X	X	
Gray angelfish (<i>Pomacanthus arcuatus</i>)	X	X	X	
Cherubfish (<i>Centropyge argi</i>)	X		X	

Acanthuridae

Ocean surgeonfish (<i>Acanthurus bahianus</i>)	X	X	X	X
Doctorfish (<i>Acanthurus chirurgus</i>)	X	X	X	X
Blue tang (<i>Acanthurus coeruleus</i>)	X	X	X	X

	OD	OF	IF	SG
<u>Carangidae</u>				
Bar jack (<i>Caranx ruber</i>)	X	X	X	X
Horseeye jack (<i>Caranx latus</i>)	X	X	X	
Yellow jack (<i>Caranx bartholomaei</i>)	X			
Crevalle jack (<i>Caranx hippos</i>)	X			
Blue runner (<i>Caranx crysos</i>)			X	
<u>Lutjanidae</u>				
Yellowtail snapper (<i>Ocyurus chrysurns</i>)	X	X	X	X
Schoolmaster (<i>Lutjanus apodus</i>)	X	X	X	
Dog snapper (<i>Lutjanus joco</i>)	X	X	X	
Mutton snapper (<i>Lutjanus analis</i>)				X
Lane snapper (<i>Lutjanus synagris</i>)	X		X	X
Mahogany snapper (<i>Lutjanus mahogoni</i>)	X	X		X
Gray snapper (<i>Lutjanus griseus</i>)				
<u>Pomadasyidae</u>				
Bluestriped grunt (<i>Haemulon sciurus</i>)	X	X		
White grunt (<i>Haemulon plumieri</i>)	X	X	X	X
Caesar grunt (<i>Haemulon carbonarium</i>)		X	X	

	OD	OF	IF	SG
French grunt (<i>Haemulon flavolineatum</i>)	X	X	X	X
Tomtate (<i>Haemulon aurolineatum</i>)		X	X	X
Spanish grunt (<i>Haemulon macrostomium</i>)			X	
Smallmouth grunt (<i>Haemulon chrysargyeum</i>)			X	
Striped grunt (<i>Haemulon striatum</i>)	X		X	
Cottonwick (<i>Haemulon melanurum</i>)		X	X	X
Sailors choice (<i>Haemulon parrai</i>)		X		
White margate (<i>Haemulon album</i>)				
Porkfish (<i>Anisotremus virginicus</i>)	X	X	X	
Black Margate	X			

Pomacentridae

Bicolor damselfish (<i>Stegastes partitus</i>)	X	X	X	
Threespot damselfish (<i>Stegastes planifrons</i>)	X	X	X	X
Beaugregory (<i>Stegastes leucostictus</i>)		X	X	X
Dusky damselfish (<i>Stegastes fuscus</i>)	X	X	X	X
Coco damselfish (<i>Stegastes variabilis</i>)	X	X	X	
Longfin damselfish (<i>Stegastes diencaeus</i>)	X	X	X	
Yellowtail damselfish (<i>Microspathodon chrysurus</i>)		X	X	
Sergeant major (<i>Abudefduf saxatilis</i>)			X	

	OD	OF	IF	SG
Night sergeant (<i>Abudefduf taenus</i>)			X	
Blue chromis (<i>Chromis cyanea</i>)	X	X	X	
Brown chromis (<i>Chromis multilineata</i>)	X	X	X	

Serranidae - hamlets

Indigo hamlet (<i>Hypoplectrus indigo</i>)	X	X	X	
Black hamlet (<i>Hypoplectrus nigricans</i>)	X	X	X	
Barred hamlet (<i>Hypoplectrus puella</i>)	X	X		
Butter hamlet (<i>Hypoplectrus unicolor</i>)	X			
Golden hamlet (<i>Hypoplectrus gummingatta</i>)				
Yellowbelly hamlet (<i>Hypoplectrus aberrans</i>)				
Shy hamlet (<i>Hypoplectrus guttavarius</i>)	X			
Yellowtail hamlet (<i>Hypoplectrus chlonurus</i>)				
Blue hamlet (<i>Hypoplectrus gemma</i>)			X	

Serranidae - groupers

Jewfish (<i>Epinephelus itajara</i>)				
Nassau grouper (<i>Epinephelus striatus</i>)	X	X	X	
Red grouper (<i>Epinephelus morio</i>)				
Red hind (<i>Epinephelus guttatus</i>)	X	X	X	

	OD	OF	IF	SG
Rock hind (<i>Epinephelus adscensionis</i>)	X	X		
Yellowfin grouper (<i>Mycteroperca venenosa</i>)				
Black grouper (<i>Mycteroperca bonaci</i>)	X	X		
Tiger grouper (<i>Mycteroperca tigris</i>)	X			
Yellowmouth grouper (<i>Mycteroperca interstitialis</i>)				
Comb grouper (<i>Mycteroperca nubra</i>)				
Marbled grouper (<i>Epinephelus inermis</i>)	X			
Graysby (<i>Cephalopholis cunctata</i>)	X	X		
Coney (<i>Cephalopholis fulvus</i>)	X	X	X	
<u>Serranidae - seabass</u>				
Harlequin bass (<i>Serranus tigrinus</i>)	X	X	X	X
Chalk bass (<i>Serranus tortugarium</i>)				
Tobaccofish (<i>Serranus tabacarius</i>)			X	
<u>Grammidae</u>				
Fairy basslet (<i>Gramma loreto</i>)	X	X	X	X
Blackcap basslet (<i>Gramma melacara</i>)	X			

	OD	OF	IF	SG
<u>Scaridae</u>				
Princess parrotfish (<i>Scarus taeniopterus</i>)	X	X	X	X
Queen parrotfish (<i>Scarus vetula</i>)	X	X	X	
Rainbow parrotfish (<i>Scarus guacamaia</i>)			X	X
Blue parrotfish (<i>Scarus coeruleus</i>)	X		X	
Striped parrotfish (<i>Scarus iserti</i>)	X	X	X	X
Midnight parrotfish (<i>Scarus coelestinus</i>)	X	X	X	
Stoplight parrotfish (<i>Sparisoma viride</i>)	X	X	X	X
Redband parrotfish (<i>Sparisoma aurofrenatum</i>)	X	X	X	X
Yellowtail parrotfish (<i>Sparisoma rubripinne</i>)			X	
Redtail parrotfish (<i>Sparisoma chrysopterus</i>)				

Labridae

Hogfish (<i>Lachnolaimus maximus</i>)	X	X	X	
Spanish hogfish (<i>Bodianus nufus</i>)	X	X	X	X
Clown wrasse (<i>Halichoeres maculipinna</i>)	X	X	X	X
Yellowhead wrasse (<i>Halichoeres garnoti</i>)	X	X	X	X
Puddingwife (<i>Halichoeres radiatus</i>)			X	
Slippery dick (<i>Halichoeres bivittatus</i>)	X	X	X	X

	OD	OF	IF	SG
Bluehead wrasse (<i>Thalassoma bifasciatum</i>)	X	X	X	X
Creole wrasse (<i>Clepticus parrai</i>)	X	X	X	
Dwarf wrasse (<i>Doratonotus megalepis</i>)			X	
Rosy razorfish (<i>Xyrichtys martinicensis</i>)	X	X	X	X
Green razorfish (<i>Xyrichtys spendens</i>)				X

Holocentridae

Squirrelfish (<i>Holocentrus adscensionis</i>)	X	X	X	X
Longspine squirrelfish (<i>Holocentrus nufus</i>)	X	X	X	
Longjaw squirrelfish (<i>Neoniphon marianus</i>)	X		X	
Dusky squirrelfish (<i>Sargocentron vexillarius</i>)	X	X	X	
Reef squirrelfish (<i>Sargocentron conus</i>)				
Blackbar soldierfish (<i>Myripristis jacobus</i>)				
Bigeye (<i>Priacanthus aeneus</i>)				

Diodotidae

Web burrfish (<i>Chilomycterus antillarum</i>)				
Bridled burrfish (<i>Chilomycterus antennatus</i>)				
Balloonfish (<i>Diodon holocanthus</i>)				X
Porcupinefish (<i>Diodon hystrix</i>)		X	X	

	OD	OF	IF	SG
<u>Apogonidae</u>				
Belted cardinalfish (<i>Apogon townsendi</i>)	X			
Barred cardinalfish (<i>Apogon binotatus</i>)				
Flamefish (<i>Apogon maculatus</i>)				
<u>Mullidae</u>				
Yellow goatfish (<i>Mulloidichthys martinicus</i>)				
Spotted goatfish (<i>Pseudupeneus maculatus</i>)	X	X	X	
<u>Sciaenidae</u>				
Spotted drum (<i>Equetus punctatus</i>)				X
Jackknife fish (<i>Equetus lanceolatus</i>)				
<u>Ostraciidae</u>				
Honeycomb cowfish (<i>Lactophrys polygonia</i>)			X	X
Smooth trunkfish (<i>Lactophrys triqueter</i>)		X		X
Spotted trunkfish (<i>Lactophrys bilcaudalis</i>)		X	X	
<u>Balistidae</u>				
Queen triggerfish (<i>Balistes vetula</i>)	X	X	X	X
Ocean triggerfish (<i>Canthidemis sufflamen</i>)	X		X	

	OD	OF	IF	SG
Black durgon (<i>Melichthys niger</i>)	X	X	X	
<u>Muraenidae</u>				
Green moray (<i>Gymnothorax funebris</i>)			X	
Spotted moray (<i>Gymnothorax moringa</i>)		X	X	
<u>Congridae</u>				
Garden eel (<i>Heteroconger halis</i>)		X		
<u>Monacanthidae</u>				
Scrawled filefish (<i>Aluterus scriptus</i>)		X		
Orange filefish (<i>Aluterus schoepfi</i>)				
Orangespotted filefish (<i>Cantherhines pullus</i>)			X	
<u>Sparidae</u>				
Saucereye porgy (<i>Calamus calamus</i>)		X	X	
<u>Gerreidae</u>				
Yellowfin mojarra (<i>Gerres cinereus</i>)			X	
<u>Ephippidae</u>				
Atlantic spadefish (<i>Chaetodipterus faber</i>)				

	OD	OF	IF	SG
<u>Sphyraenidae</u>				
Great barracuda (<i>Sphyraena barracuda</i>)	X	X	X	X
Southern sennet (<i>Sphyraena picudilla</i>)				
<u>Elopidae</u>				
Tarpon (<i>Megalops atlanticus</i>)		X		
<u>Centropomidae</u>				
Snook (<i>Centropomus undecimalis</i>)				
<u>Albulidae</u>				
Bonefish (<i>Albula vulpes</i>)				
<u>Belonidae</u>				
Houndfish (<i>Tylosurus crocodilus</i>)				X
<u>Rachycentridae</u>				
Cobia (<i>Rachycentron canadum</i>)				
<u>Silversides</u>				
				X
<u>Gobiidae</u>				
Goby	X	X	X	X

	OD	OF	IF	SG
Goldspot goby (<i>Gnatholepis thompsoni</i>)				
Neon goby (<i>Gobiosoma oceanops</i>)				
<u>Clinidae</u>				
Diamond blenny (<i>Malacoctenus boehlkeri</i>)	X	X	X	
Palehead blenny (<i>Labrisomus gobio</i>)				
Blackhead blenny (<i>Emblemaria bahamensis</i>)				
<u>Echeneididae</u>				
Sharksucker (<i>Echeneis nautcrates</i>)				
<u>Bothidae</u>				
Peacock flounder (<i>Bothus lunatus</i>)				X
<u>Aulostomidae</u>				
Trumpetfish (<i>Aulostomus maculatus</i>)		X	X	X
<u>Malacanthidae</u>				
Sand tilefish (<i>Malacanthus plumieri</i>)		X	X	X
<u>Tetraodontidae</u>				
Sharphouse puffer (<i>Canthigaster rostrata</i>)	X	X	X	X

	OD	OF	IF	SG
Bandtail puffer (<i>Sphoerodes spengleri</i>)				X

Synodontidae

Sand diver (<i>Synodus intermedius</i>)			X	
Bluestriped lizardfish (<i>Synodus saurus</i>)		X		

CHONDRICHTHYES

Nurse shark (<i>Ginglymostoma cirratum</i>)	X	X	X	
Lemon shark (<i>Negaprion brevirostris</i>)				
Southern stingray (<i>Dasyatis americana</i>)				
Yellow stingray (<i>Urolophus jamaicensis</i>)			X	
Spotted eagle ray (<i>Aetobatus narinari</i>)				

OD OF IF SG

REPTILIA

Green turtle
(*Chelonia mydas*)

MAMMALIA

Bottlenose dolphin
(*Delphinus delphis*)

X

APPENDIX 8

RECENT CONFERENCES AND MEETINGS

RECENT CONFERENCES AND MEETINGS

1. First European Meeting of the International Society for Reef Studies (ISRS), Vienna 16-20th December 1993.

The largest and undoubtedly most prestigious coral reef conference, the International Coral Reef Symposium, is held every four years and is organized by the International Society for Reef Studies (ISRS). At the last symposium (Guam, 1992) Coral Cay Conservation presented and published a paper entitled, "Coral Cay Conservation - Survey Techniques and Their Application in Belize". The next symposium is scheduled to be held in Panama 1996. Since there is a wealth of work being generated by coral reef scientists worldwide, the society decided that regional interim meetings should take place on an annual basis. The meeting in Vienna was the first of such European meetings.

The five day programme allowed scientists to present their work in a diverse range of topics. Palaeontology featured quite prominently since many European coral reef scientists study the fossil record of corals: unlike live corals, fossil corals are scattered throughout most of Europe.

Peter Mumby, CCC's Project Scientist, presented a paper entitled, "Coral Cay Conservation: a critical assessment of volunteer-derived data" in the plenary session for coral reef monitoring and management. The presentation discussed the importance of using specially trained non-professionals to survey marine resources which, of course, is an essential pre-requisite for sound management planning. Although several volunteer-based organisations exist, none have published a critical assessment of the quality of data obtained using non-professionals. CCC's presentation statistically described the accuracy and consistency of data in light of experience, ecosystem (ie. coral reef versus seagrass bed) and depth. The results were then analysed to highlight the quality of data on an individual species basis (a copy of the abstract is enclosed).

The proceedings of the meeting are being published in the Austrian Journal of Palaeontology. Like many other coral biologists, CCC are not submitting the paper for publication in this journal: Our work is not in any way related to fossils and the journal has a limited distribution. However, CCC are very pleased announce that the editor of the Bulletin of Marine Science has accepted the paper and disseminated it for peer review.

Following the presentation, CCC were invited to attend the site directors meeting of the CARICOMP project (see section 2).

The second European Meeting of the International Society for Reef Studies will be held in Luxembourg, September 1994. The organizers are keen to promote several special interest workshops throughout the meeting. CCC's proposal for a workshop entitled, "The Use of Non-Professionals in Applied Marine Science and Coastal Zone Management" has recently been gazetted and interest promises to be high.

The proceedings from workshops will be published and this provides a golden opportunity for CCC to publish an all-encompassing paper on our work in Belize.

2. Site Directors meeting of the Caribbean Coastal Marine Productivity (CARICOMP) network. Organized by Dr John Ogden (Co-chairman and Director of the Florida Institute of Oceanography), St. Petersburg, Florida, 25-30th January 1994.

CCC were invited to attend the Site Directors meeting of the CARICOMP network. 21 countries from the wider Caribbean are involved in this programme to monitor coastal productivity on a regional scale. CARICOMP is currently the only working regional programme dealing with the status of coral reefs and it promises to be exemplary for other projects that require regional cooperation and institutional support.

Conceptually, CARICOMP was established to standardize and collect detailed information on the health of coral reefs, seagrass productivity and the status of mangroves throughout the entire Caribbean. Data are collected in 21 countries and regularly submitted to a central database in Jamaica. The complete data set (with summary statistics) is then returned to each contributor, providing the scientist with a regional overview of marine systems. UNESCO and the MacArthur Foundation have provided the funds to supply each laboratory with sampling equipment, software requirements and funds for annual meetings. Further monies are being sought to provide institutional support.

The workshop was aimed to refine the monitoring techniques and to discuss their execution in specific detail. CCC made a presentation on our scientific approach and institutional collaboration in Belize which was well received. We also contributed to the revision of monitoring techniques and advised on aspects of handling large data sets.

The Belize representatives are Hol Chan and the Smithsonian Institute (Carrie Bow Cay). It was suggested (John Ogden) that CCC/UCB/GOB attend the next meeting and consider joining the network once the infrastructure at the marine research center is in place. In the meantime, CCC intend to adopt these standardised techniques so that data on the marine resources of the Turneffe Islands are comparable to those of the whole region.

3. Second Thematic Conference on Remote Sensing of Marine and Coastal Environments, New Orleans 31st Jan - 2nd February, 1994.

Technological advances and improved analytical procedures are increasingly rendering satellite remote sensing as a key tool for assessing marine habitats. For example, it is possible to measure the primary productivity of phytoplankton, sea surface temperature and salinity using satellites. Remote sensing is widely applied to terrestrial studies: Mapping mangrove and land use is carried out at the Land Information Center, Belmopan using Landsat TM imagery. However, its use for sensing submerged habitats is restricted by the difficulty of accounting for light attenuation through water. There is therefore much interest in addressing this problem so that coral reefs, seagrass beds etc can be periodically mapped using satellites. The advantages to doing so are numerous;

- (i) a satellite image is of the order of a hundred kilometers wide and thus covers a large area.
- (ii) the amount of field work required is minimal.
- (iii) the extent of marine resources can be mapped and monitored accurately and recorded as digital information within a geographical information system (GIS).

This international conference is dedicated entirely to the use of satellite imagery for studying marine environments.

The Sapodilla Cays, at the southern point of the barrier reef are widely considered to warrant urgent protection on account of the extent of illegal fishing and recent growth of tourism in the area. At the request of the Coastal Zone Management Unit (CZMU), CCC has undertaken several months survey work in this region. This culminated in last summers two month expedition to classify a SPOT Panchromatic satellite image of the Sapodilla Cays. This sensor gives very high spatial resolution (10m) but has limited spectral properties (a single band of reflectance analagous to a black and white photograph).

CCC presented the paper entitled, "The Potential of SPOT Panchromatic Imagery as a Tool for Mapping Coral Reefs"; which is published in the proceedings (enclosed). The work created much interest from the audience and the presenter was nominated for Best Presentation Award.

The classified image is currently at the Land Information Center and will form the primary base map of the Sapodilla Cays for use by the CZMU.