SUMMARY OF CORAL CAY CONSERVATION'S ATLANTIC AND GULF RAPID REEF ASSESSMENT DATA FROM TURNEFFE ATOLL, BELIZE

- by -

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This report is part of a series of working documents detailing CCC's science programme on Turneffe Atoll (1994-1998). The series is also available on CD-Rom.

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EXECUTIVE SUMMARY

The coastal waters of Belize consist of a complex set of reefal resources which are economically important for industries such as tourism and fishing. Effective management of these resources can be assisted by data from self-financing volunteer divers. This technique has been used in Belize by Coral Cay Conservation (CCC) to provide data to the Department of Fisheries and Coastal Zone Management Project.

Between 1994 and 1998 CCC collected baseline data on the benthic and fish communities of Turneffe Atoll. In addition to this work, CCC undertook Atlantic and Gulf Rapid Reef Assessment (AGRRA) surveys during September and October 1998. The AGRRA Programme is an initiative by an international collaboration of scientists and managers aimed at determining the regional condition of reefs in the Atlantic and Gulf of Mexico. Undertaking AGRRA surveys at Turneffe Atoll provided an opportunity to (1) provide quantitative data on individual coral heads (e.g. size-frequency information, amount of dead tissue and incidents of disease), algal cover and fish communities and (2) provide a gross comparison of the health of Turneffe Atoll with the rest of the Caribbean. The study also incorporated a critical assessment, published elsewhere, of the ability of non-professional researchers to utilise the AGRRA protocol accurately and consistently.

AGRRA surveys were carried out at a site known as Harry Jones Reef, which is close to Blackbird Cay and just north of Calabash Cay (site of CCC's base camp). Benthic surveys were carried out by CCC's field science staff and fish surveys were undertaken by volunteers following an intensive training period. The AGRRA protocol surveys the benthos via ten 10 m transects along which divers: estimate total live coral cover; assess each coral head (> 25 cm wide) by species for width, height, percent of 'recently dead' coral, percent of 'long dead' coral, presence of any diseases and presence of bleaching. Algal abundance (percentage cover of macroalgae, turf algae, coralline algae and 'other') is assessed via five quadrats directly below each transect line. Finally a belt transect is swum along the 10 m transect line to count *Diadema* spp. Fish are assessed by (a) a series of 30 m belt transect surveys for a defined species list (abundance and sizes) and (b) rover diver censuses where all fish species are recorded along with their density on a logarithmic scale. Data were summarised by via univariate statistics and a series of bar-charts and further analysed using the non-parametric Kruskal-Wallis test.

The AGRRA data collected during this study are limited both spatially and temporally and, therefore, it is not possible to assess fully the health of the fringing reef at Turneffe Atoll. Further surveys are needed at sites around the atoll for comparison with other areas of Belize and with surveys from throughout the Caribbean and Gulf of Mexico. However, the data do provide a baseline for gross comparisons with future surveys, for instance to assess the long-term affects of Hurricane Mitch, and for gross comparisons with surveys from other parts of the region.

Live coral cover was relatively high (20.6-36.9%) and the site was dominated by *Montastraea annularis*. Areas of coral colonies where the tissue had been long dead were almost ubiquitous but values were comparable with the low to moderate level found in the region. Newly dead tissue was much less common and likely to have been caused by coral bleaching. Of the colonies surveyed during this study, over 87% had evidence of bleached tissue but further data are required to assess actual coral mortality. Disease was relatively common at the Turneffe Atoll site and seems slightly greater than many Caribbean reefs surveyed with the AGRRA protocol. Most colonies were generally less than 60 cm with the exception of *Montastraea annularis, Colpophyllia natans, Acropora cervicornis* and *Siderastrea siderea*.

Algal cover is an important independent indicator of, for example, decreased water quality. Data from this study show that most quadrats had abundant macroalgae and algal turf (> 30%) but less coralline algae (< 15%), consistent with data from south central Belize, Honduras, Bahamas, Mexico and Cuba where macroalgae were reported as 'moderate to high'. There were no *Diadema* spp. recorded during the survey at Turneffe Atoll and their low population, similarly to the whole Caribbean, is a contributing factor to the substantial coverage of macroalgae and algal turf.

The fish species list used by the AGRRA protocol was developed to focus on ecologically and commercially important groups. Details of fish abundance are generally not included in existing qualitative reports for AGRRA sites so comparisons are difficult but the data are useful as a baseline for future research and can provide some qualitative conclusions. Data from this study are consistent with Belize having relatively healthy fish communities since, for example, numerous scarids (parrotfish) and acanthurids (surgeonfish) were recorded. The size-frequency data for all species shows that the modal size is 10-20 cm with only groupers and snappers larger than 40 cm. Interpretation of data from the rover surveys is even more difficult than information on size and abundance but the results largely reflect results from the transects. Fish data from the CCC AGRRA survey must also be analysed in the context of known inconsistency of non-professional researchers.

Results from all Turneffe Atoll data indicated that the reef is in reasonable condition compared to the 'average' Caribbean reef, probably because of the low population density of Belize and relatively low fishing pressure. This study leads to the following recommendations:

?? Additional Belizean personnel to receive training on AGRRA techniques during either international or national workshops.
?? UCB, the Coastal Zone Management Project or the Fisheries Department to undertake further AGRRA surveys at both shallow and medium depths at Harry Jones Reef.
?? AGRRA surveys to be extended to other sites on Turneffe Atoll, particularly the western (leeward) reef and data submitted to the regional database. This will also improve the spatial scale of the local data set and provide further evidence for any apparent trends.
?? Additional AGRRA surveys should include surveys of coral recruits and ideally corals less than 25 cm to provide detailed size-frequency data.
?? Continue to aim to establish a multiple use marine protected area at Turneffe Atoll, with an integrated monitoring programme to measure its efficacy.

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Lands Information Centre (Ministry of Natural Resources)
Ministry of Tourism and the Environment
Trimble Navigation

ABBREVIATIONS

AGRRA	Atlantic and Gulf Rapid Reef Assessment
CARICOMP	Caribbean Coastal Marine Productivity
CCC	Coral Cay Conservation
CZMP	Coastal Zone Management Project
CZMU	Coastal Zone Management Unit
GEF	Global Environment Facility
GOB	Government of Belize
GPS	Global Positioning System
IUCN	World Conservation Union
KS	Kruskal-Wallis test
MOU	Memorandum of Understanding
MRC	Marine Research Centre
NGO	Non-government Organisation
n.s.	Not significant
PS	Project Scientist
REEF	Reef Environmental Education Foundation
SCUBA	Self-contained underwater breathing apparatus
SO	Science Officer
UCB	University College of Belize
UNEP	United Nations Environment Programme
UNDP	United Nations Development Programme

FIGURES, TABLES AND APPENDICES

1. INTRODUCTION

1.1 Belize

The coastal waters of Belize (Central America) consist of a complex set of reefal resources, including the largest barrier reef in the western hemisphere (Figure 1). Belize also has three major atolls of the Caribbean, numerous patch reefs, lagoons, sand and mangrove cays and forests. The coastal waters of Belize are economically important for industries such as tourism and fishing. In 1990, aware of a growing conflict between the preservation and human exploitation of the reef environment, Government of Belize (GOB) established a Coastal Zone Management Unit (CZMU) under the Ministry of Agriculture and Fisheries. The CZMU was then superseded by a Coastal Zone Management Project (CZMP), funded by the UNDP Global Environment Facility (GEF). In 1998, a Coastal Zone Management Bill established a Coastal Zone Management Authority and Institute to provide overall management of the coastal zone.

1.2 Coral Cay Conservation

Effective management, including conservation of coral reefs and tropical forests, requires a holistic and multi-disciplinary approach. This is often a highly technical and costly process which many developing countries cannot adequately afford. With appropriate training, non-scientific, self-financing volunteer divers have been shown to be able to provide useful data for coastal zone management at little or no cost to the host country. This technique has been pioneered and successfully applied by Coral Cay Conservation (CCC), a British non-profit organisation.

CCC is an international NGO committed to providing resources for the protection and sustainable use of tropical coastal environments. CCC does not charge the host country for the service it provides and is primarily self-financed through a pioneering participatory scheme. Within the scheme, members of the public are given the opportunity to join a phase of each project in return for a financial contribution to the CCC programme. At the expedition site, volunteers are provided with suitable training and collect data under the guidance of project scientists. Finances generated from the volunteer programme allow CCC to provide conservation education, technical skills training and capacity building, contributing to a strong policy of collaboration with government and non-government organisations within the host country.

Data and technical assistance have been provided to both the Department of Fisheries and CZMP under the remit of a Memorandum of Understanding (MOU). The MOU was signed in 1990 and updated and extended in both 1994 and 1998. Since 1990, CCC has provided data for six proposed or established marine protected areas at South Water Cay, Bacalar Chico, Sapodilla Cays, Snake Cays, Laughing Bird Cay and Caye Caulker. These projects have generally provided habitat maps, the associated databases and management recommendations to assist reserve planning (for example McCorry et al., 1993; Gill et al., 1995; Gill et al., 1996).

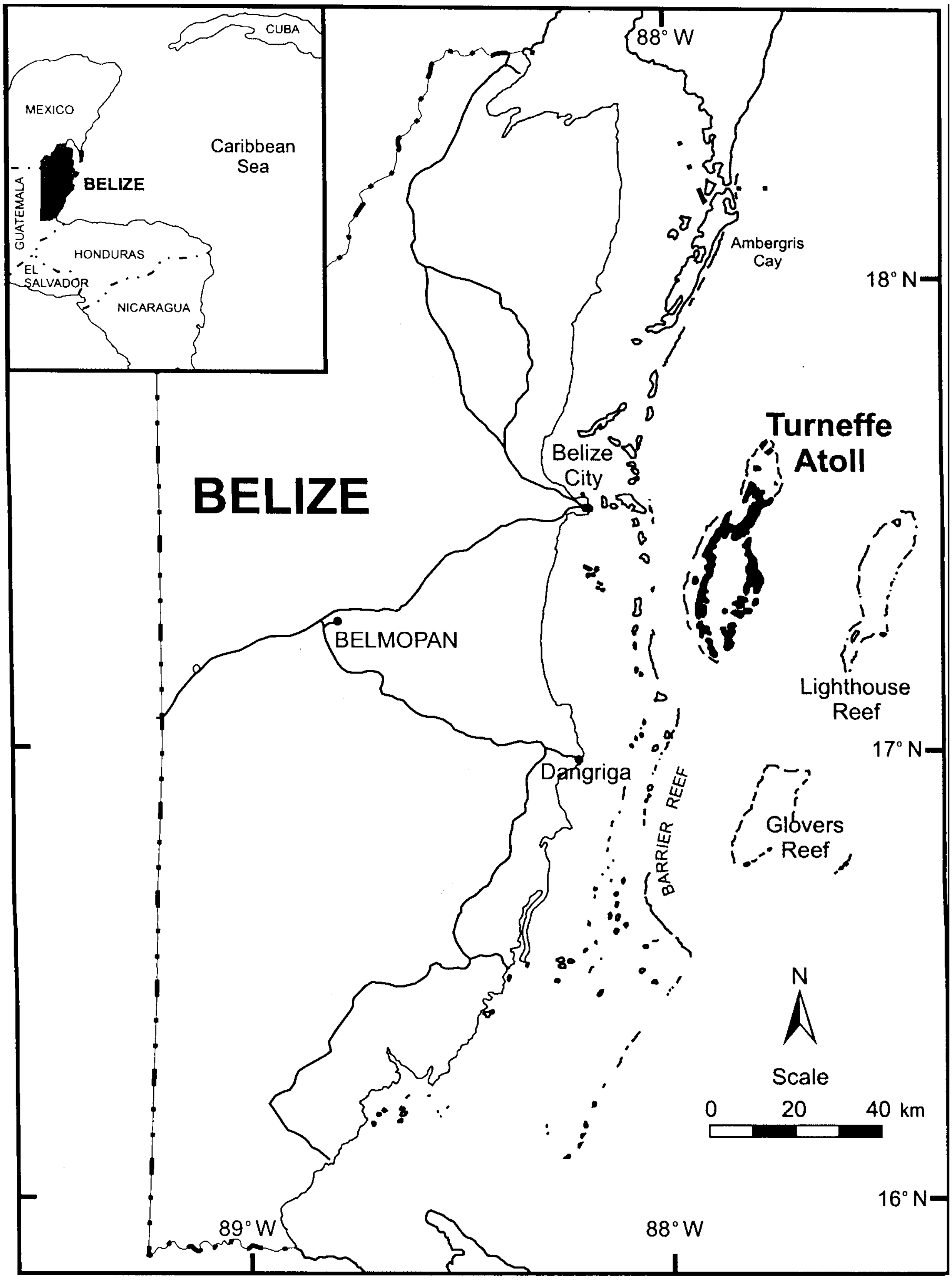

Figure 1. Map of the coastal resources of Belize. Source: modified from Murray et al. (1999).

1.3 Turneffe Atoll project

In 1993 the University College of Belize (UCB) entered into a working agreement with CCC to collaborate towards the establishment of a permanent, self-financing Marine Research Centre (MRC) of both regional and international standing. The field site was selected as Calabash Cay on Turneffe Atoll (Figure 2), the largest atoll in the Caribbean at approximately 330 km^2 (UNEP/IUCN, 1988). Turneffe Atoll is completely surrounded by an extensive reef system which encompasses a complex central lagoon and extensive mangrove forested cays. The principle objectives of the MRC project were identified as protection of the terrestrial and marine resources of Turneffe Atoll, strengthening the capacity of UCB to undertake coastal marine research and training and providing technical assistance to the Department of Fisheries. In August 1994, the agreement between CCC and UCB was endorsed by the GOB through the signing of a MOU between the three lead agencies. A core component of this MOU was establishing and monitoring a management plan for Turneffe Atoll.

Between January 1994 and early 1997, CCC volunteers carried out surveys around the whole atoll which have resulted in an extensive database of baseline information. Analysis of these data and combination with aerial photographs has led to a Turneffe Atoll Habitat Map, the first draft of which was completed in August 1998. Between March 1997 and December 1998 this baseline database was complemented by surveys to quantitatively document the abundance of commercially important fish species.

CCC’s survey work at Turneffe Atoll was designed to obtain sufficient data from which comprehensive habitat and additional resource maps could be created in order to assist the planning of sustainable management initiatives. However, in addition to this primary aim, CCC has also initiated basic assessments of reef health close to Calabash Cay via Reef Check and Atlantic and Gulf Rapid Reef Assessment surveys.

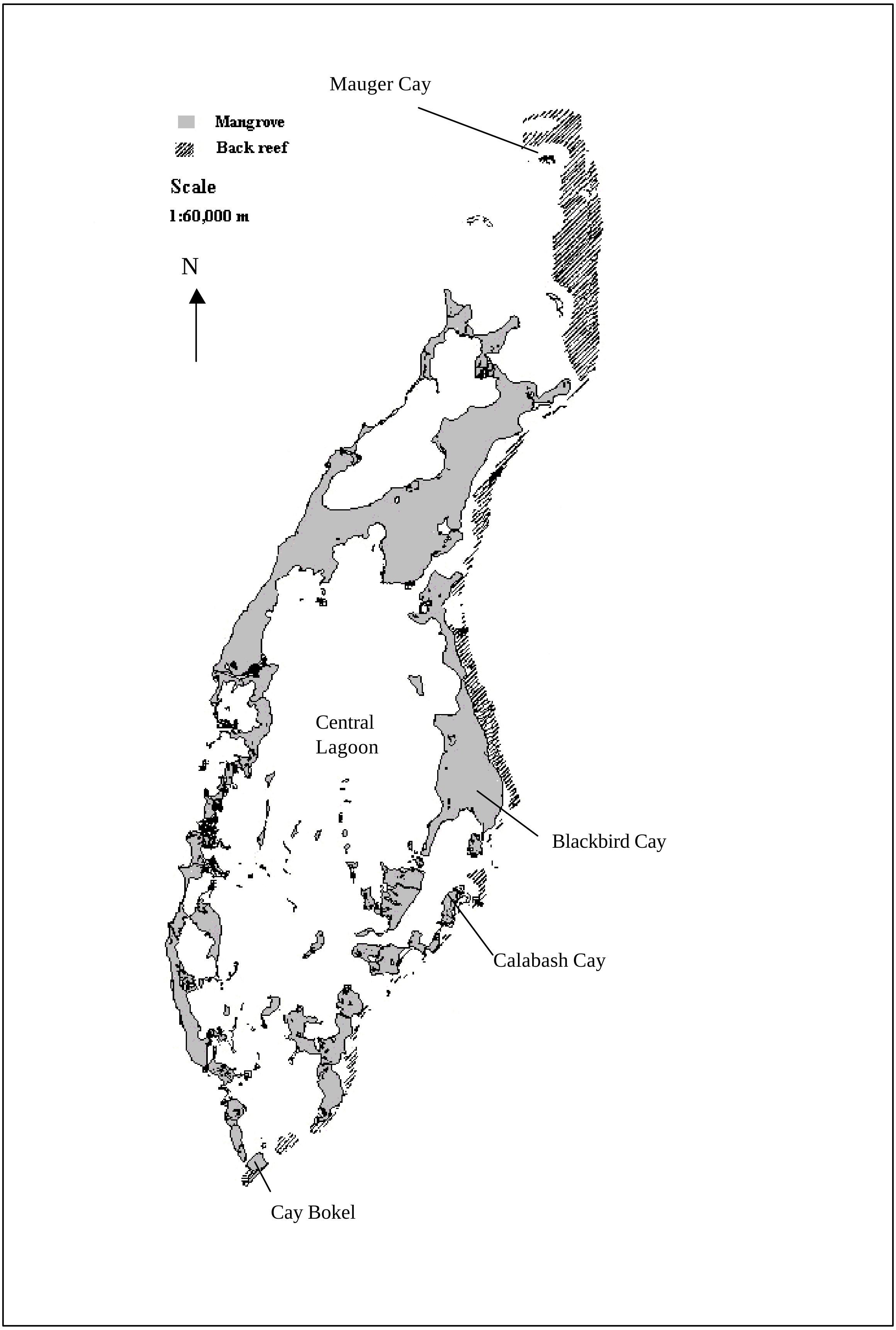

Figure 2. Map of Turneffe Atoll, showing the location of Calabash Cay which is the site of the UCB / GOB / CCC Marine Research Centre.

1.4 Atlantic and Gulf Rapid Reef Assessment Programme

The Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program is an international collaboration of scientists and managers aimed at determining the regional condition of reefs in the Atlantic and Gulf of Mexico (Ginsburg et al., 1998). Coral reefs in the region are widely accepted to have been affected by a range of anthropogenic factors such as overfishing (Koslow et al., 1988; Bohnsack, 1993), decreasing water quality (Lapointe, 1989; Porter et al., 1999), coral and *Diadema* diseases (Lessios, 1988; Gladfelter, 1982; Aronson et al., 1998) and bleaching (CARICOMP, 1997; McField, 1999). Current and future management initiatives will be assisted by access to a wide scale assessment of reef health

Over the past four years, a rapid assessment protocol has been developed and tested to assess the condition of a large number of coral reefs throughout the western Atlantic. The goal of AGRRA is to provide a regional perspective of coral condition in the Atlantic and Gulf Region by the year 2001. The results aim to highlight the extent of serious declines in remote reefs and comparisons with those close to centres of populations, possible locations for marine protected areas and hypotheses to explain declines in remote reefs (Ginsburg et al., 1998).

Reef health has been assessed by a range of indices including percentage coral cover (for example Aronson et al., 1994), number of colonies, coral diversity and evenness (Dustan and Halas, 1987), the degree of stress experienced by coral heads (reviewed by Brown and Howard, 1985) and fish populations (Sale, 1991; Reese, 1977). However, the AGRRA programme is the first attempt to develop a standardised, rapid protocol to study a range of health parameters for use throughout the Caribbean and Gulf of Mexico and contributing to a central database. Although primarily designed for marine scientists, the protocol was intended to be useable by a range of organisations, including those using non-specialists.

The rapid assessment protocol focuses on assessing three main factors as signals of decline: corals, fish and algae. The vitality of a reef depends on complex relationships between these reef taxa and when changes occur in the community dynamics of one of these components the others are also affected. Therefore, to evaluate the condition of a reef from a one-time assessment, it is critical that multiple indicators of the corals-algae-fishes relationships are examined. The indicators of the AGRRA protocol are: the partial or total mortality of major reef-building corals by species and size; the relative abundance of major algal types (turf, macroalgae and crustose corallines); fish diversity and the abundance and size of key fish species. Following examination of a large number of reefs, it will be possible to develop a scale of reef condition and allow regional comparisons. Although the approach does not attempt to distinguish between cause and effect of reef condition, the data gathered can be used to develop hypotheses on trends of reef decline, particularly across large spatial scales.

CCC undertook AGRRA surveys in October and November 1998 to provide both data on reef health at Turneffe Atoll and to assess the accuracy and consistency of information collected by non-professional divers using the protocol. The validation exercise, published elsewhere (Harborne and Turnbull, in prep.), compared volunteer data for benthic surveys against those collected by field science staff. This reference data set, known to be correct, is used in this study as an assessment of reef health at Turneffe and is supplemented by fish data collected by the volunteers. Field science staff were not able to collect fish data because of time constraints. The AGRRA survey has also provided UCB, CCC and the MRC with increased publicity and heightened awareness of the work on Turneffe Atoll.

1.5 Report outline

This report aims to present the results of the AGRRA surveys on Turneffe Atoll, an indication of reef health and management recommendations. Data are also summarised for comparison with future surveys. The specific aims of the report are to:

?? Provide quantitative, species and size specific data on tissue mortality on reef building coral colonies;
?? Provide quantitative data on algal abundance;
?? Provide quantitative data on fish diversity and the size and abundance of target species;
?? Provide a comparison of reef health at Turneffe Atoll with other sites in the region.

2. METHODS

2.1 Site selection

The target reef for assessment was the fringing reef of Turneffe Atoll at a site directly adjacent to the Marine Research Centre on Calabash Cay known as Harry Jones Reef (Figure 3). This section of reef was thought to be representative of a coral rich forereef on the atoll. It is also known to be a popular dive area and suspected of being degraded by diver damage (R. Malone, pers. comm.). According to the official protocol the dives were carried out within the coral rich area at depths between 8 and 15 m. However, because of time constrictions the surveys were not repeated at the shallower depth of between 1 and 5 m as recommended. GPS co-ordinates of the survey site were approximately 17^0 17" 40.6' N and 087^0 47" 54.8' W.

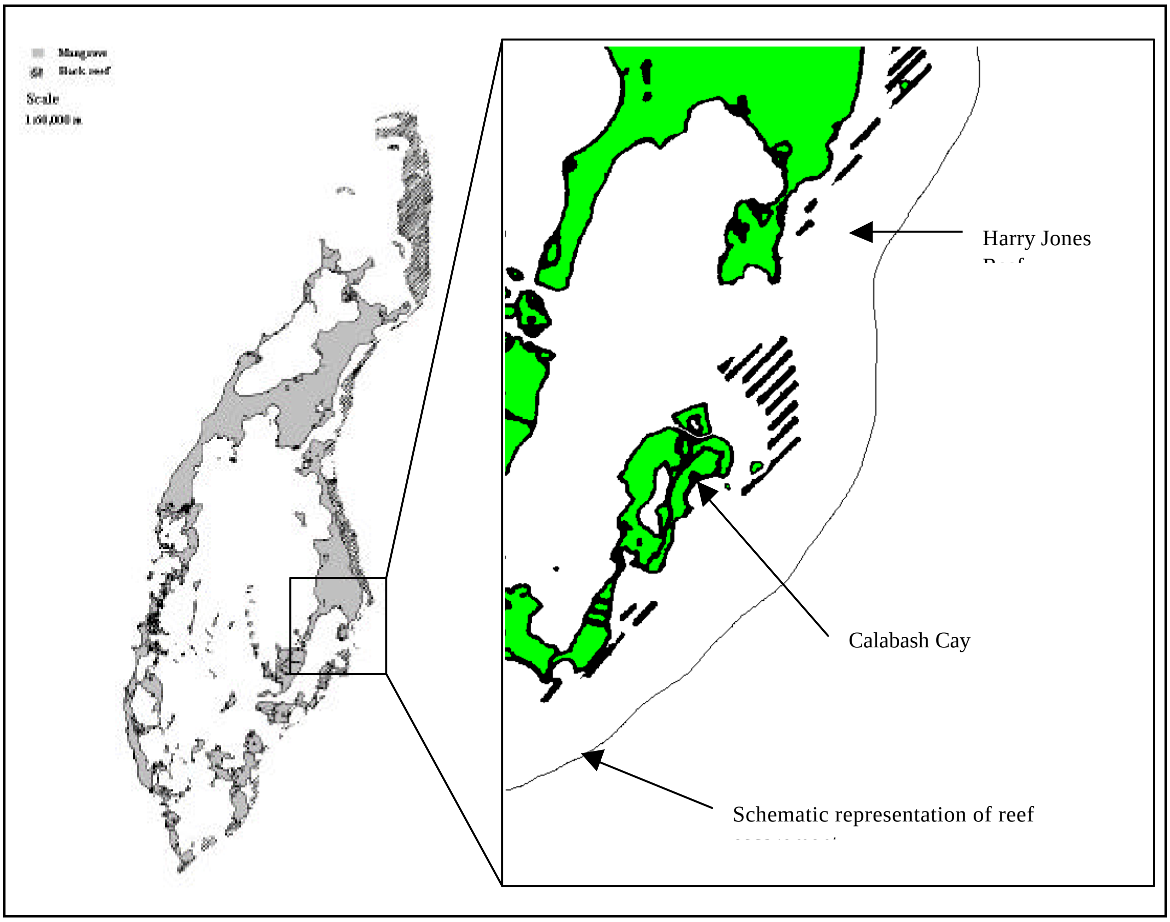

Figure 3. Location of the AGRRA study site at Harry Jones Reef on Turneffe Atoll.

2.2 Surveyors

Volunteer divers in Belize are co-ordinated by a Project Scientist (PS) and Science Officer (SO). The primary responsibilities of the PS and SO are to train CCC volunteers in marine life identification, survey techniques and other supporting skills. The PS and SO also co-ordinate and supervise subsequent surveys and data collection. Volunteers have a week of intensive science training and testing (see Harborne, 1999) which enables them to identify species accurately, therefore ensuring precise and consistent data collection (Mumby et al., 1995).

All data collected using the AGRRA protocol were CCC field science staff (benthic data) or volunteer divers who had successfully undertaken CCC's marine ecology training course (fish data).

2.3 AGRRA protocol

The following sections provide a summary of the AGRRA protocol followed at Turneffe Atoll. Full details of the protocol are given in Appendix 1 and further updates can be found on the website[1].

2.3.1 Benthic survey

Ten 10 m transects were laid on the reef in a direction that is parallel to the long axis of the reef. The transects were not overlapped and areas with abrupt changes in slope, deep grooves, large patches of sand or unconsolidated coral rubble were avoided. Five main assessments were carried out along each transect.

Live coral

An estimation of total live coral cover (cm) along the length of the transect was taken including all living stony corals regardless of size or species. This was then converted into live coral cover as a percentage of the total length.

Coral heads

Along the transect line, coral heads (both living and dead) directly underneath the transect line that were at least 25 cm wide and attached to the substratum were assessed according to the following criteria:

(a) coral name (genus and species);
(b) width (including live and dead areas);
(c) height (including live and dead areas);
(d) percent of coral that was 'recently dead' (non-living parts where the corallite structures were white and either intact or covered by a layer of fine mud);

[1] http://coral.aoml.noaa.gov/agra/rap-revised.html

(e) percent of coral that was 'long dead' (any non-living parts where the corallite structure was gone or covered by organisms that were not easily removed);
(f) presence of any diseases (black band, white band, yellow blotch, red band and unknown);
(g) presence of bleaching as a percentage of the live tissue that was affected.

Only reef-building corals were included in the survey (Appendix 1). The categories of bleaching (pale, partly bleached and bleached) and the additional diseases (white plague and white spots) documented in the recently revised AGRRA protocol were not used in this study.

Algal abundance

Five 25 x 25 cm quadrats were placed at two metre intervals directly below the transect line. Conspicuous patches of sand, macroalgae and benthic animals were avoided. Where the site for the quadrat did not lie on a suitable area the quadrat was placed 1 m from the mark either along or beside the line. If there was no suitable area then the site was not assessed. The following were noted for each quadrat:

(a) substratum type;
(b) percentage cover of macroalgae;
(c) percentage cover of turf algae;
(d) percentage cover of living crustose coralline algae,
(e) percentage cover of any other element (e.g. invertebrates or sand).

Finally, a plastic ruler was used to approximate the average canopy height of the macroalgae present within the quadrat.

Diadema count

A belt transect was swum along the 10 m transect line and every individual of *Diadema* spp. counted within 0.5 m of each side of the transect line.

2.3.2 Fish survey

Two distinct methods for surveying fish were employed at the site.

Belt transect counts

Belt transect counts for a defined species list were conducted along a straight 30 m transect line which was measured whilst conducting the survey to minimise disturbance. The belts were located randomly within the survey site and were estimated at 2 m wide using a 1 m wide T-bar. Belt transects were repeated at the site commencing at least 5m laterally away from a previous position. Fish were counted slightly ahead of the divers position whilst swimming along the transect so as to record fish before they were disturbed. The approximate length (<5, 5-10, 10-20, 20-30, 30-40 and >40 cm) of the fish was recorded as well the abundance of each species. Juvenile fish (<5 cm) were not recorded for fish from the families Scaridae or Haemulidae. The defined species list was biased towards those species most likely to be affected by human impacts (Appendix 1).

Rover diver census

Rover diver censuses were conducted in the vicinity of the fish belt transects. Surveys were conducted by divers swimming continuously around the site for approximately 30 minutes and recording all fish (genus and species). Divers were encouraged to check under overhangs and other hiding places. The density of each species was estimated using the following logarithmic scale: Single (1 fish); Few (2-10); Many (11-100) and Abundant (>100).

2.4 Data analysis

All data were transferred to field recording sheets and then to standard Microsoft Excel spreadsheets in the field.

Both benthic and fish data were summarised using univariate statistics. Some results were also represented graphically to highlight particular trends. Percentage cover data were treated as non-parametric and statistical differences were examined using the Kruskal-Wallis test (Kruskal and Wallis, 1952).

Data analysis was carried out using Unistat 4.7 for DOS.

3. RESULTS

Raw data from benthic surveys (corals and algae) are appended in Appendix 2. Fish data are not appended because of the known inaccuracies of data collection (see Discussion).

3.1 Coral heads

3.1.1 Coral head health

From a survey of 10 transects the mean live coral cover for the site was 28.4% (SD 9.3). These data indicate that the site can be classified as 'Dense massive and encrusting corals' within the classification scheme for marine habitats of the Caribbean (Mumby and Harborne, 1999). The characteristics of this benthic class are a diverse, hard coral cover of greater than 5%. Since the site is on the forereef, the AGRRA site can be classified as being within a 'Forereef + Dense massive and encrusting coral' habitat (Mumby and Harborne, 1999).

The frequency of each coral condition observed on coral heads at the site can be seen in Table 1, along with Kruskal-Wallis analysis of variance between species.

Table 1. Frequency and abundance of tissue conditions on coral heads of each species seen during the study. Standard deviations given in parentheses and frequency of occurrence in italics. KS shows result of Kruskal-Wallis test: n.s. = not significant (p>0.05), * = p<0.05, ** = p<0.01.

Species	N	Percentage cover (when present)			Percentage cover (all heads)		
		Old death	New death	Bleaching	Old death	New death	Bleaching
Acropora cervicornis	5	45.0 (33.5) *100.0*	10.0 (8.7) *60.0*	-	45.0 (33.5)	6.0 (8.2)	-
Agaricia agaricites	6	20.0 (20.0) *100.0*	-	39.0 (31.0) *100.0*	20.0 (20.0)	-	39.0 (31.0)
Agaricia tenuifolia	2	40.0 (28.3) *100.0*	-	20.0 (0.0) *100.0*	40.0 (28.3)	-	20.0 (0.0)
Colpophyllia natans	5	44.0 (37.1) *100.0*	-	90.0 (-) *20.0*	44.0 (37.1)	-	18.0 (40.2)
Diploria labyrinthiformis	1	-	-	50.0 (-) 100.0	-	-	50.0 (-)
Montastraea annularis	62	35.9 (22.3) *100.0*	10.4 (7.2) *30.6*	45.9 (23.3) *100.0*	35.9 (22.3)	3.2 (6.2)	45.9 (23.3)
Montastraea cavernosa	2	7.5 (3.5) *100.0*	-	10.0 (-) *50.0*	7.5 (3.5)	-	5.0 (7.1)
Porites astreoides	2	25.0 (7.1) *100.0*	7.5 (3.5) *100.0*	20.0 (-) *50.0*	25.0 (7.1)	7.5 (3.5)	10.0 (14.1)
Porites porites	10	50.0 (27.1) *100.0*	10.0 (7.1) *40.0*	33.9 (24.7) *90.0*	50 (27.1)	4.0 (6.6)	30.5 (25.7)
Siderastrea siderea	6	38.0 (32.7) *83.3*	5.0 (0.0) *33.3*	63.0 (37.0) *83.3*	31.7 (33.1)	1.7 (2.6)	52.5 (41.9)
All corals	101	36.6 (24.8) *99.0*	9.7 (6.7) *28.7*	44.4 (25.5) *87.1*	35.9 (25.1)	2.9 (5.8)	38.7 (28.1)
KS test		n.s.	n.s.	n.s.	n.s.	n.s.	**

Table 1 shows that coral tissue which had been dead for a long period of time were common overall and ubiquitous for all *Montastraea* spp. and *Porites* spp. heads which were the dominant coral species at Harry Jones Reef. The presence of long dead tissue was not just constrained to massive coral types with branching corals such as *Acropora cervicornis* also having a high frequency of occurrence. Tissue which was newly dead was also observed on both the massive and branching coral forms, although it was most commonly seen on *Porites astreoides*. Bleaching was common, with 87.1% of all colonies affected and there was significant variation between coral species when all heads were included.

Although tissue which was long dead was very common it did not on average cover more than 50% of the coral head. However, the standard deviations for these figures are large indicating that on some heads the coverage of long dead coral was greater than 50%. Newly dead tissue covered a much smaller proportion of the coral head, but there was one colony of *Colpophyllia natans* which had a large proportion of newly dead tissue.

The incidents of coral disease on each coral head are summarised in Table 2.

Table 2. Frequency of incidents of disease on each coral species seen during the study.

Species	n	Incidents of disease (%)				
		Black band	White band	Yellow band	Red band	Unknown
Acropora cervicornis	5	-	60.0	-	-	-
Agaricia agaricites	6	-	-	-	-	-
Agaricia tenuifolia	2	-	-	-	-	-
Colpophyllia natans	5	-	-	-	-	-
Diploria labyrinthiformis	1	-	-	-	-	-
Montastraea annularis	62	-	6.5	8.1	-	8.1
Montastraea cavernosa	2	-	-	-	-	-
Porites astreoides	2	-	-	-	-	100.0
Porites porites	10	-	-	-	-	30.0
Siderastrea siderea	6	-	-	-	-	33.3
All corals	101	-	6.9	5.0	-	11.9

Coral disease was not widespread with only 23.8% of all coral heads exhibiting any kind of disease. *Montastraea annularis* coral heads were subject to the greatest diversity of diseases. The commonest diseases were those that could not be allocated to one of the main categories and hence were labelled as 'unknown'. Black band disease and red band disease were not seen on any corals during the study.

3.1.2 Size distribution of coral heads

Table 3 and Figures 14 (a) – (k) summarise the size-frequency information generated by the AGRRA surveys during this study. Table 3 includes the normal range of sizes for each species (Humann, 1993) as a comparison. In addition to the size-frequency information, the graphs for *Montastraea annularis* (Figure 4 (f)) and *Porites porites* (Figure 4 (i)) also include the percentage cover of old dead, newly dead and bleached tissue within each size category. Only data for these two species are displayed because too few colonies of all other species were surveyed to provide useful analysis (n < 10). Colonies less than 25 cm are not surveyed by the AGRRA protocol.

Table 3. Summary of mean colony heights and widths for each species seen during the study. Colony widths are compared with the commonly observed range taken from Humann (1993). Standard deviations are given in parentheses.

Species	n	Mean colony height (cm)	Mean colony width (cm)	
			Observed	From Humann
Acropora cervicornis	5	24.0 (8.2)	43.0 (15.7)	30 – 240
Agaricia agaricites	6	25.0 (11.0)	32.5 (4.2)	10 – 90
Agaricia tenuifolia	2	32.5 (10.6)	40.0 (14.1)	90 – 370
Colpophyllia natans	5	31.0 (7.4)	65.0 (15)	50 – 210
Diploria labyrinthiformis	1	25.0 (-)	40.0 (-)	30 – 120
Montastraea annularis	62	52.1 (36.8)	64.6 (35.8)	30 – 300
Montastraea cavernosa	2	37.5 (3.5)	30.0 (7.1)	60 – 240
Porites astreoides	2	25.0 (7.1)	25.0 (0.0)	15 – 60
Porites porites	10	22.0 (9.5)	44.5 (17.9)	30 – 120
Siderastrea siderea	6	20.8 (3.8)	35.8 (16.9)	30 – 180

Coral heads were generally small, with the majority of heads lying between 20 and 80 cm (Figure 4 (k)). However, the mean colony sizes generally lie within the published range (Table 3), with only *Agaricia tenuifolia* and *Montastraea cavernosa* being smaller than the normal limits. The only species which had heads larger than 80 cm was *Montastraea annularis* (Figure 4 (f)). The data for tissue conditions within each size category of *Montastraea annularis* or *Porites porites* do not show any obvious trends, such as greater mortality in smaller colonies. There is no significant variation between the size categories for any tissue condition for either species (KS; $p > 0.05$).

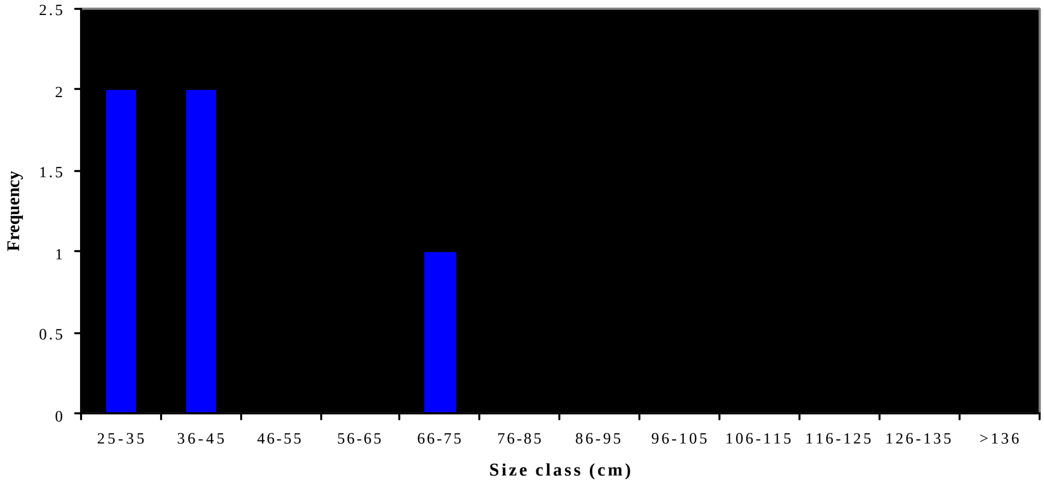

Figure 4 (a). Size-frequency distribution of *Acropora cervicornis* colonies.

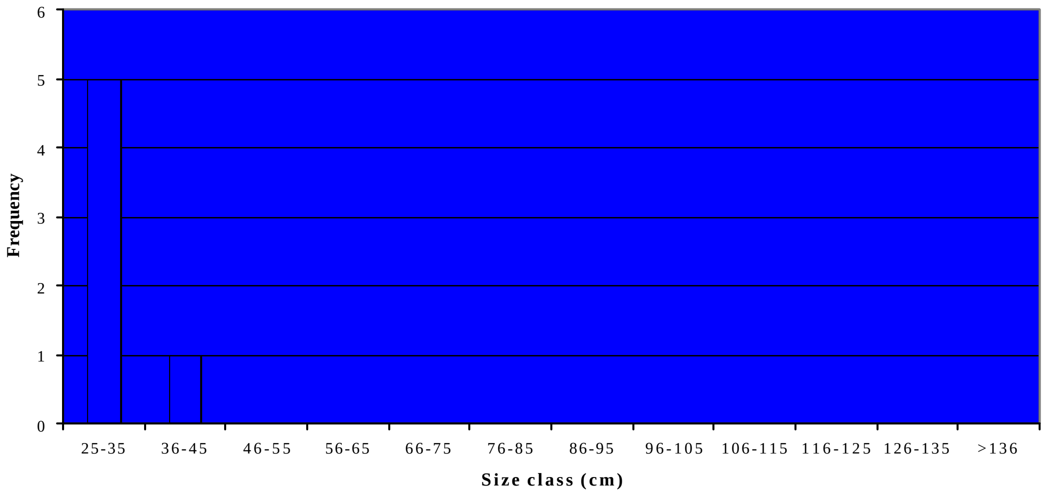

Figure 4 (b). Size-frequency distribution of *Agaricia agaricites* colonies.

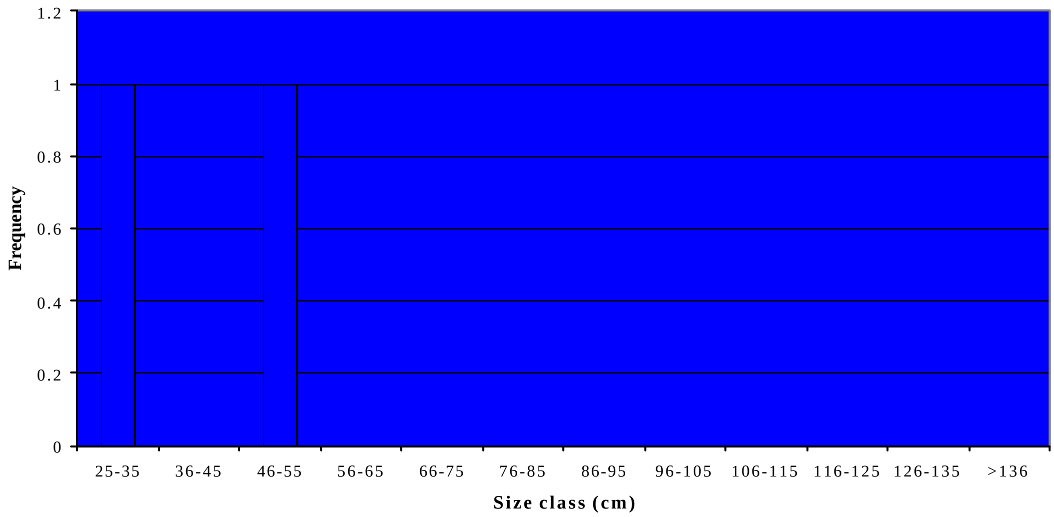

Figure 4 (c). Size-frequency distribution of *Agaricia tenuifolia* colonies.

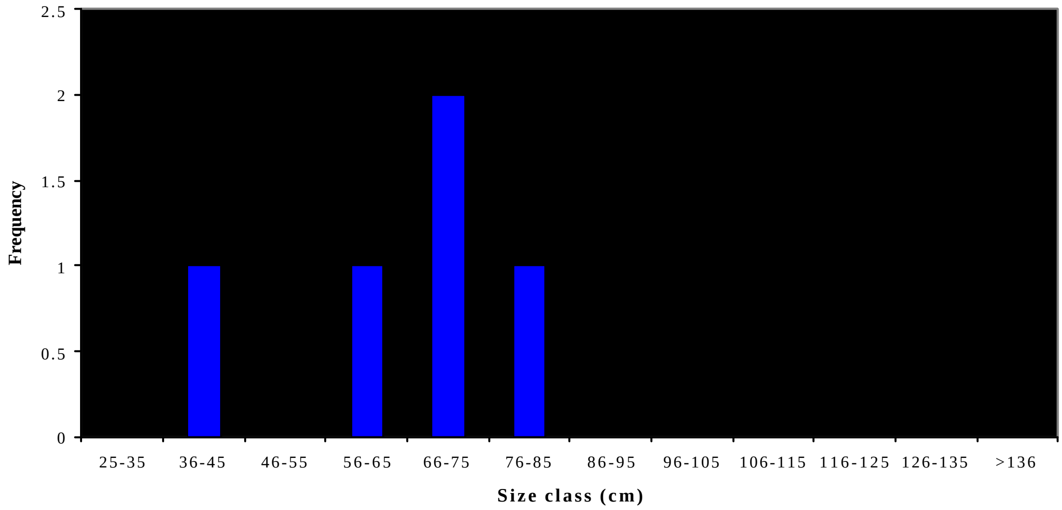

Figure 4 (d). Size-frequency distribution of *Colpophyllia natans* colonies.

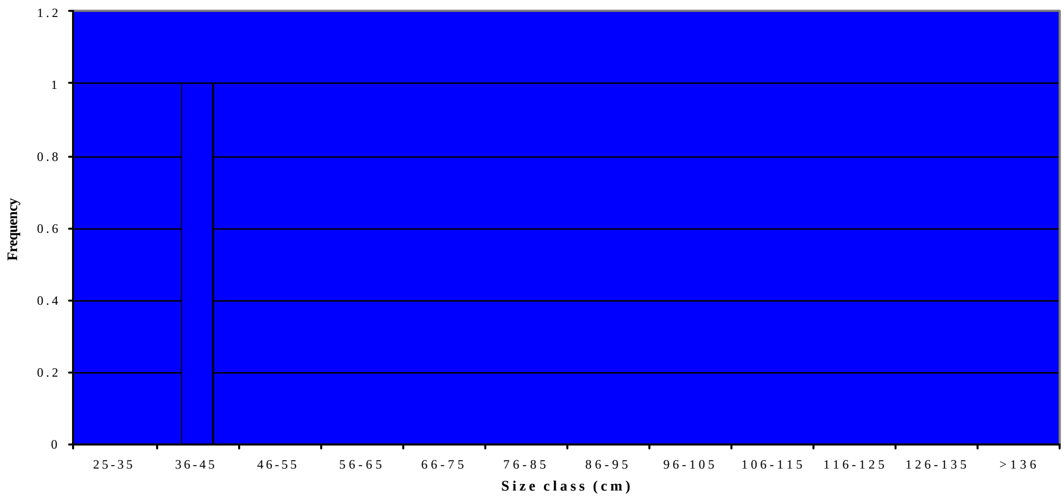

Figure 4 (e). Size-frequency distribution of *Diploria labyrinthiformis* colonies.

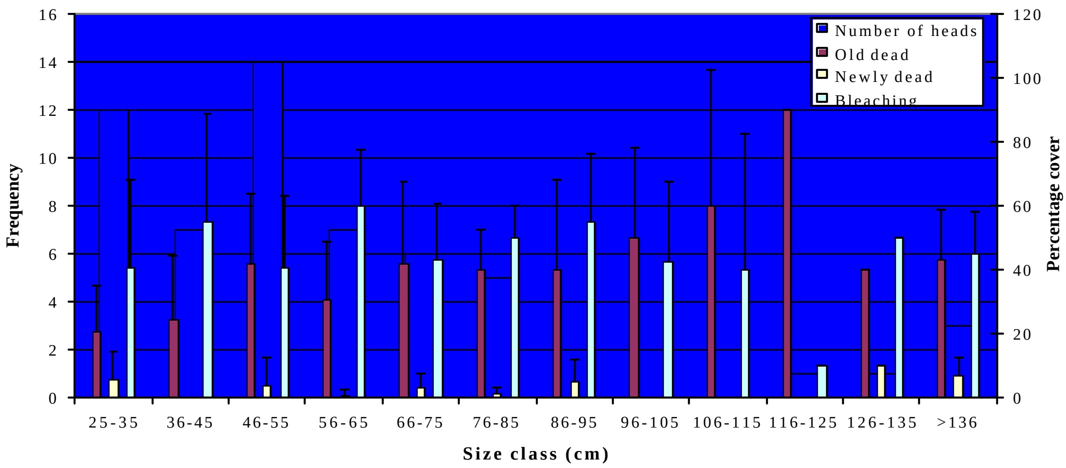

Figure 4 (f). Size-frequency distribution of *Montastraea annularis* colonies. Bars show standard deviation.

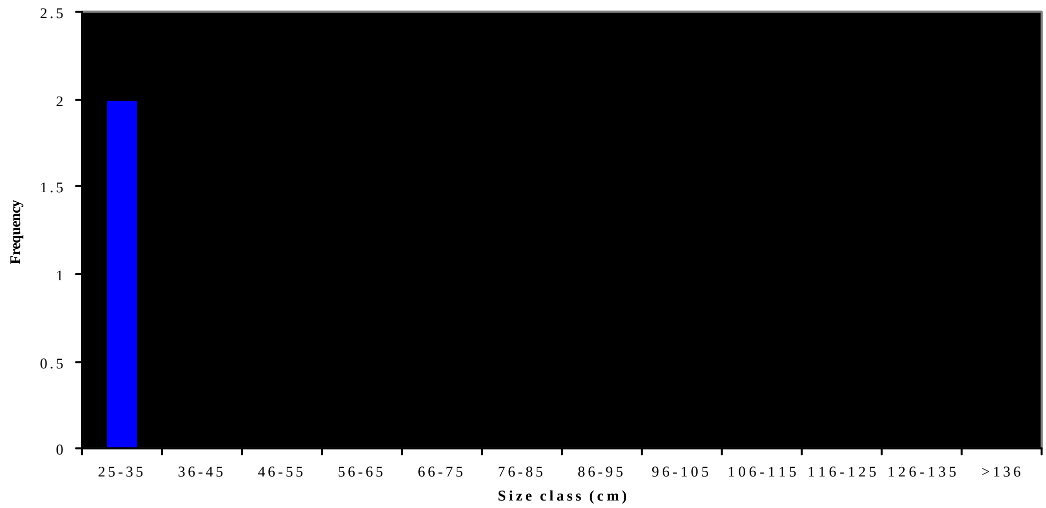

Figure 4 (g). Size-frequency distribution of *Montastraea cavernosa* colonies.

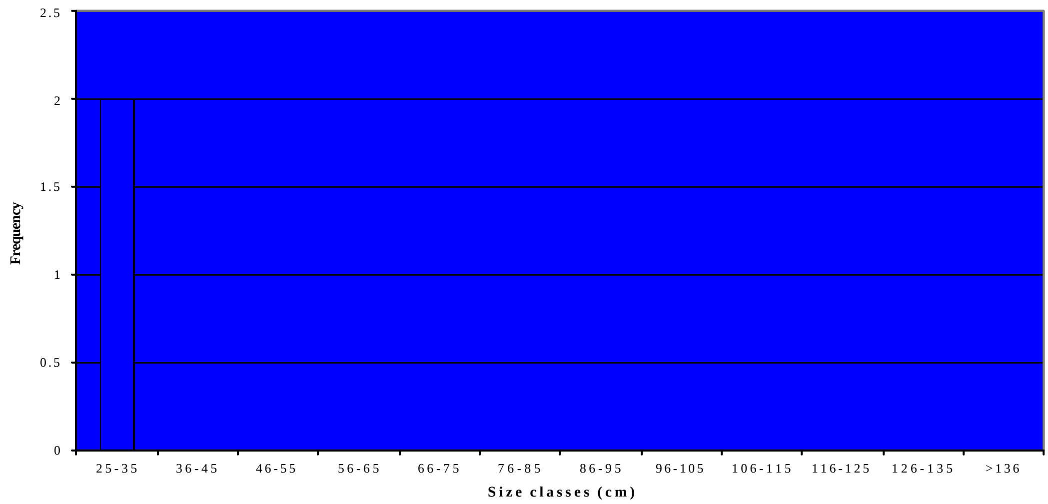

Figure 4 (h). Size-frequency distribution of *Porites astreoides* colonies.

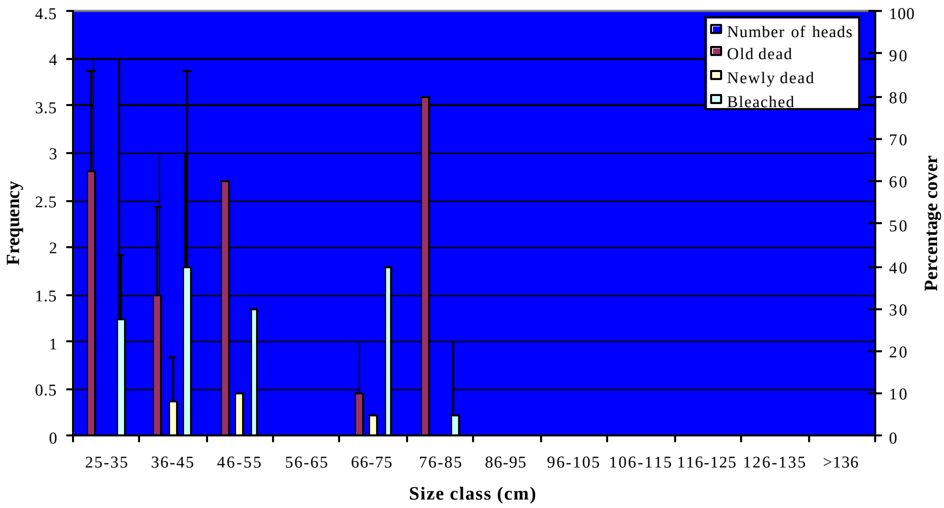

Figure 4 (i). Size-frequency distribution of *Porites porites* colonies. Bars show standard deviation.

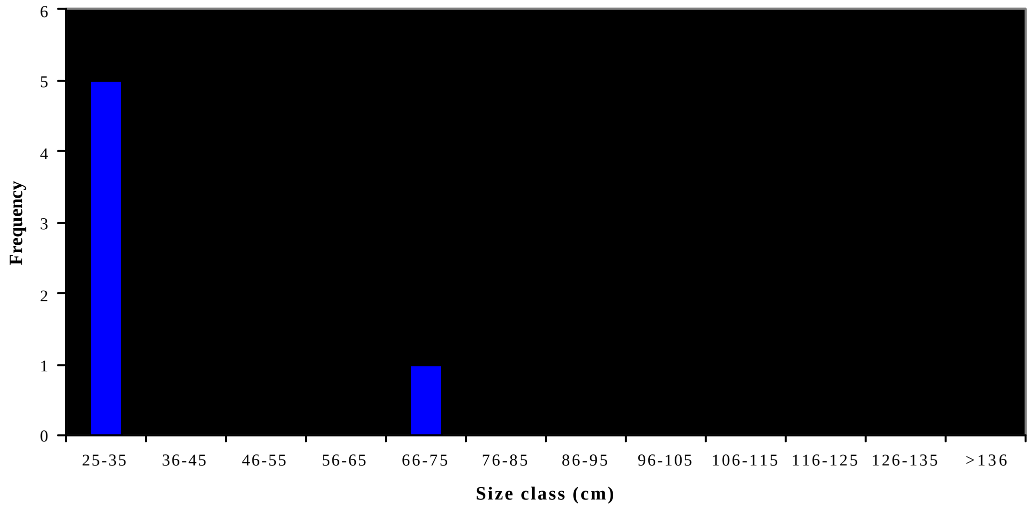

Figure 4 (j). Size-frequency distribution for *Siderastrea siderea* colonies.

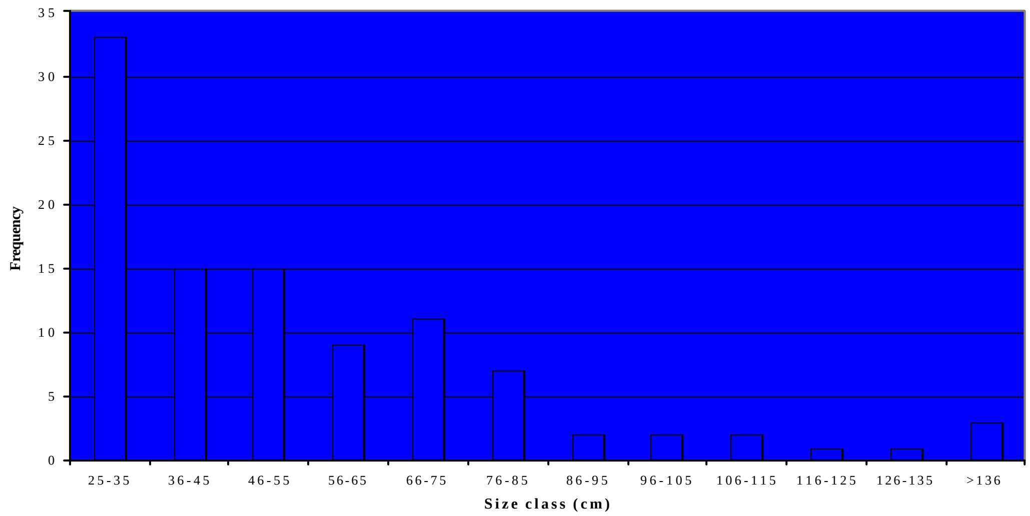

Figure 4 (k). Size-frequency distribution for all coral heads sampled.

3.2 Algal quadrats

A total of 49 algal quadrats were laid under the 10 benthic transects at the study site. Table 4 shows the dominant substrate types which were present within the quadrats. Rubble and dead coral were the dominant substrate types, accounting for over 90% of all quadrats sampled.

Table 4. The frequency of occurrence of dominant substrate types within algal quadrats at the AGRRA study site.

Dominant substrate	n	Frequency of occurrence
Rubble	21	42.9
Dead coral	24	49.0
Sand	3	6.1
Rock	1	2.0
Total	49	-

Table 5 shows the percentage cover of each algal type and the mean canopy height on each substrate type. Table 5 also shows the results of Kruskal-Wallis analysis of variance of each algal type between substrates.

Table 5. Frequency of occurrence and mean percentage cover of each algal category and mean canopy height per quadrat in each substrate type. Frequency of occurrence shown in italics and standard deviation in parentheses. Kruskal-Wallis (does not include 'all quadrats'): n.s. = not significant (p> 0.05), * = p<0.05, ** = p<0.01.

Substrate type	n	Percentage cover (all quadrats)				Canopy height (mm)
		Macro-algae	Algal turf	Coralline algae	Other	
Rubble	21	36.7 (19.3)	45.0 (20.4)	12.4 (10.0)	12.4 (15.4)	27.6
		100.0	*100.0*	*81.0*	*66.7*	(14.5)
Dead coral	24	30.2 (19.8)	48.1 (21.3)	12.5 (10.6)	16.5 (13.8)	19.2
		100.0	*100.0*	*70.8*	*83.3*	(9.9)
Sand	3	23.3 (15.3)	43.3 (20.8)	8.3 (7.6)	28.3 (24.7)	23.3
		100.0	*100.0*	*66.7*	*66.7*	(23.1)
Rock	1	50.0 (-)	30.0 (-)	5.0 (-)	20.0 (-)	20.0
		100.0	*100.0*	*100.0*	*100.0*	(-)
All quadrats	49	33.0 (19.3)	46.1 (20.4)	12.0 (10.0)	15.5 (15.2)	23.1
		100.0	*100.0*	*75.5*	*75.5*	(13.1)
Kruskal-Wallis		n.s.	n.s.	n.s.	n.s.	n.s.

Macroalgae and algal turf were ubiquitous in all quadrat types with coralline algae and 'other' present in only 75% of quadrats. The category of 'other' included bare substrate and invertebrates and this was present in the majority of quadrats and on all substrates. It should be noted that total algal cover does not add up to 100% because some of the algal types were overlapping (e.g. macroalgae on coralline algae). There was no significant variation between any of the algal categories on the different substrate types.

3.3 Regional comparisons

The AGRRA Programme is regional but there is currently no widely available database for detailed comparisons between the data from Belize and the rest of the Caribbean and Gulf of Mexico. However, general reports are posted to the AGRRA website[1]. For comparative purposes, these reports have been summarised in Table 6. Since this information has been taken from the internet it is difficult to determine precisely the parameters which are quoted and what is meant by each qualitative statement but does aid setting the CCC AGRRA surveys in context.

[1] http://coral.aoml.noaa.gov/agra/field-reports.html, (Morisseau-Leroy, 1999).

Table 6. Summary of qualitative results from AGRRA reef surveys around the Caribbean and Gulf of Mexico region. NMS = National Marine Sanctuary.

Location and date	Old death	New death	Live coral	Bleaching	Macro-algae	Turf algae	Incidence of disease
Abaco Island, Bahamas, 9.99	High incidence in *Montastrea* spp. and *Diploria* spp.		Low		High in places		Low
Andros Reef Complex, Bahamas, 97/98	Low to moderate	Patchy incidence	Good		Low to moderate		
San Salvador Island, Bahamas, 6.98	15-35% cover	<1-2% cover		Rare	Low	Dominant algae	Low
South Central Belize, 1.99	Near 100% mortality in *Agaricia tenuifolia*	5% on forereef region		Recovering and moderate	10-40%	Dominant algae	Increased in 4 month period
Bonaire Marine Park, Bonaire, 2.99	28%	<2%	48%	Coral recovering	Low <15%	Dominant algae (50%)	Rare except YBD (>2%)
Cayman Islands, 6.99	Low			Rare <1%			Low, mainly White
Southwest Cuba, date unknown	24-34%	3-10.5%	15-23%		Moderate to high		Present
Cayos Cochinos Biological Reserve, Honduras, 9.99	Moderate	Moderate to high		Low to moderate and pale	Moderate to high		Present
Akumal, Mexico, 3.99	28.2%	4.0%	17.3%	9.2%	28%		White plague 5%
Xcalak, Mexico, 3.99	28.4%	4.7%	16.3%	11.5%	24%		White plague 0.6%
Horseshoe Reef, Tobago Cays Marine Park, 6.99	23-28	1-35	29-44%	Partial bleaching on 5% of colonies	*Halimeda* dominant at deep sites		Low
Turks and Caicos Islands, 8.99	Low	Low	Maximum 30%	Rare <1%	Rare		Low but high diversity
US Flower Garden Banks NMS, 8.99		<2.5%	48.8-53.9%	Rare	Low		Rare
Los Roques National Park, Venezuela, 10.99	<25%	5%	>50%	Low incidence	<5%		Low
This study: Harry Jones Reef, Turneffe Atoll 9/10.98	**35.9%**	**9.9%**	**28.4%**	**87.1% incidence**			**Moderate (23.8%)**

3.4 Diadema surveys

No *Diadema* spp. urchins were found on any of the transects surveyed.

3.5 Fish surveys

3.5.1 Belt transect surveys

The results of the belt transect surveys can be seen in Table 7 (common names for all fish species are listed in Appendix 3). In total, 35 of the different species included in the AGRRA protocol were observed along the 60 m^2 transects. The most abundant species (mean abundance > 1.0 per transect) were *Acanthurus coerulus* (blue tang), *Haemulon flavolineatum* (french grunt), *Ocyurus chrysurus* (yellowtail snapper) and *Sparisoma viride* (stoplight parrotfish). Table 7 also includes comparative data from CCC quantitative surveys for commercially important species which were undertaken around the whole of Turneffe Atoll between 1997 and 1998 (Gardiner and Harborne, 2000). The quantitative surveys have been adjusted from a survey area of 350 m^2 to 60 m^2.

Table 7. Belt transect counts of fish in fixed size classes and comparative data from CCC quantitative surveys around the whole atoll. Values are mean number of fish per 60 m^2 transect. Standard deviation in parentheses. n = 25 for AGRRA surveys and 908 for comparative data.

Species	Mean number of individuals per size class						Mean abundance	Turneffe Atoll
	<5 cm	5-10 cm	10-20 cm	20-30 cm	30-40 cm	>40 cm		
Acanthurus bahianus	0.0 (0.0)	0.24 (0.6)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.24 (0.6)	-
A. chirurgus	0.0 (0.0)	0.04 (0.2)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.04 (0.2)	-
A. coerulus	0.0 (0.0)	0.84 (1.5)	0.32 (0.6)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.16 (1.4)	-
Anisotremus virginicus		0.0 (0.0)	0.08 (0.3)	0.04 (0.2)	0.04 (0.2)	0.0 (0.0)	0.16 (0.5)	0.10
A. surinamensis		0.0 (0.0)	0.0 (0.0)	0.04 (0.2)	0.0 (0.0)	0.0 (0.0)	0.04 (0.2)	0.003
Balistes vetula	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.04 (0.2)	0.0 (0.0)	0.04 (0.2)	-
Bodianus rufus							0.60 (1.5)	0.14
Caranx ruber							0.84 (1.5)	0.77
Chaetodon capistratus	0.12 (0.4)	0.36 (0.6)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.48 (0.7)	-
C. ocellatus	0.0 (0.0)	0.12 (0.4)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.12 (0.4)	-
Epinephelus adscensionis	0.0 (0.0)	0.04 (0.2)	0.04 (0.2)	0.0 (0.0)	0.0 (0.0)	0.04 (0.2)	0.12 (0.4)	0.02
E. cruentatus	0.04 (0.2)	0.28 (0.5)	0.32 (0.6)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.64 (0.8)	0.12
E. fulvus	0.0 (0.0)	0.0 (0.0)	0.04 (0.2)	0.04 (0.2)	0.0 (0.0)	0.0 (0.0)	0.08 (0.3)	0.19
E. striatus	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.16 (0.4)	0.16 (0.4)	0.07
Haemulon flavolineatum		0.40 (0.8)	0.48 (0.9)	0.20 (0.5)	0.0 (0.0)	0.0 (0.0)	1.08 (1.0)	0.77
H. plumieri		0.12 (0.3)	0.44 (0.8)	0.20 (0.4)	0.0 (0.0)	0.0 (0.0)	0.76 (1.1)	0.31
H. sciurus		0.08 (0.3)	0.28 (0.6)	0.48 (0.7)	0.04 (0.2)	0.0 (0.0)	0.88 (1.1)	0.39
Holacanthus ciliaris	0.0 (0.0)	0.0 (0.0)	0.12 (0.3)	0.12 (0.3)	0.0 (0.0)	0.0 (0.0)	0.24 (0.4)	-
H. tricolor	0.0 (0.0)	0.12 (0.3)	0.16 (0.5)	0.04 (0.2)	0.0 (0.0)	0.0 (0.0)	0.32 (0.6)	-
Lachnolaimus maximus							0.16 (0.5)	0.14
Lutjanus apodus	0.0 (0.0)	0.0 (0.0)	0.04 (0.2)	0.16 (0.5)	0.0 (0.0)	0.0 (0.0)	0.20 (0.6)	0.48
L. mahogoni	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.04 (0.2)	0.0 (0.0)	0.0 (0.0)	0.04 (0.2)	0.10
Melichthys niger	0.0 (0.0)	0.16 (0.5)	0.08 (0.4)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.24 (0.6)	-
Microspathodon chrysurus							0.32 (1.2)	-
Ocyurus chrysurus	0.0 (0.0)	0.04 (0.2)	0.68 (1.3)	0.2 (0.6)	0.04 (0.2)	0.12 (0.6)	1.08 (1.4)	2.88
Pomacanthus arcuatus	0.0 (0.0)	0.04 (0.2)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.04 (0.2)	-
P. paru	0.0 (0.0)	0.04 (0.2)	0.04 (0.2)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.08 (0.4)	-
Scarus coeruleus		0.0 (0.0)	0.04 (0.2)	0.04 (0.2)	0.0 (0.0)	0.0 (0.0)	0.08 (0.3)	-
S. croicensis		0.0 (0.0)	0.0 (0.0)	0.04 (0.2)	0.0 (0.0)	0.0 (0.0)	0.04 (0.2)	-

S. guacamaia		0.0 (0.0)	0.08 (0.3)	0.04 (0.2)	0.0 (0.0)	0.0 (0.0)	0.12 (0.3)	-
S. taeniopterus		0.16 (0.5)	0.52 (0.8)	0.08 (0.3)	0.0 (0.0)	0.0 (0.0)	0.76 (1.2)	-
S. vetula		0.0 (0.0)	0.08 (0.3)	0.08 (0.3)	0.0 (0.0)	0.0 (0.0)	0.16 (0.4)	-
Sparisoma aurofrenatum		0.0 (0.0)	0.20 (0.6)	0.08 (0.4)	0.0 (0.0)	0.0 (0.0)	0.28 (0.9)	-
S. rubripinne		0.0 (0.0)	0.0 (0.0)	0.12 (0.6)	0.0 (0.0)	0.0 (0.0)	0.12 (0.6)	-
S. viride		0.08 (0.3)	0.36 (0.7)	0.44 (0.8)	0.16 (0.5)	0.0 (0.0)	1.04 (1.3)	-

3.5.2 Size-frequency distributions

The size-frequency distribution of each fish family, and all families combined, are shown in Figures 5 (a) – (i).

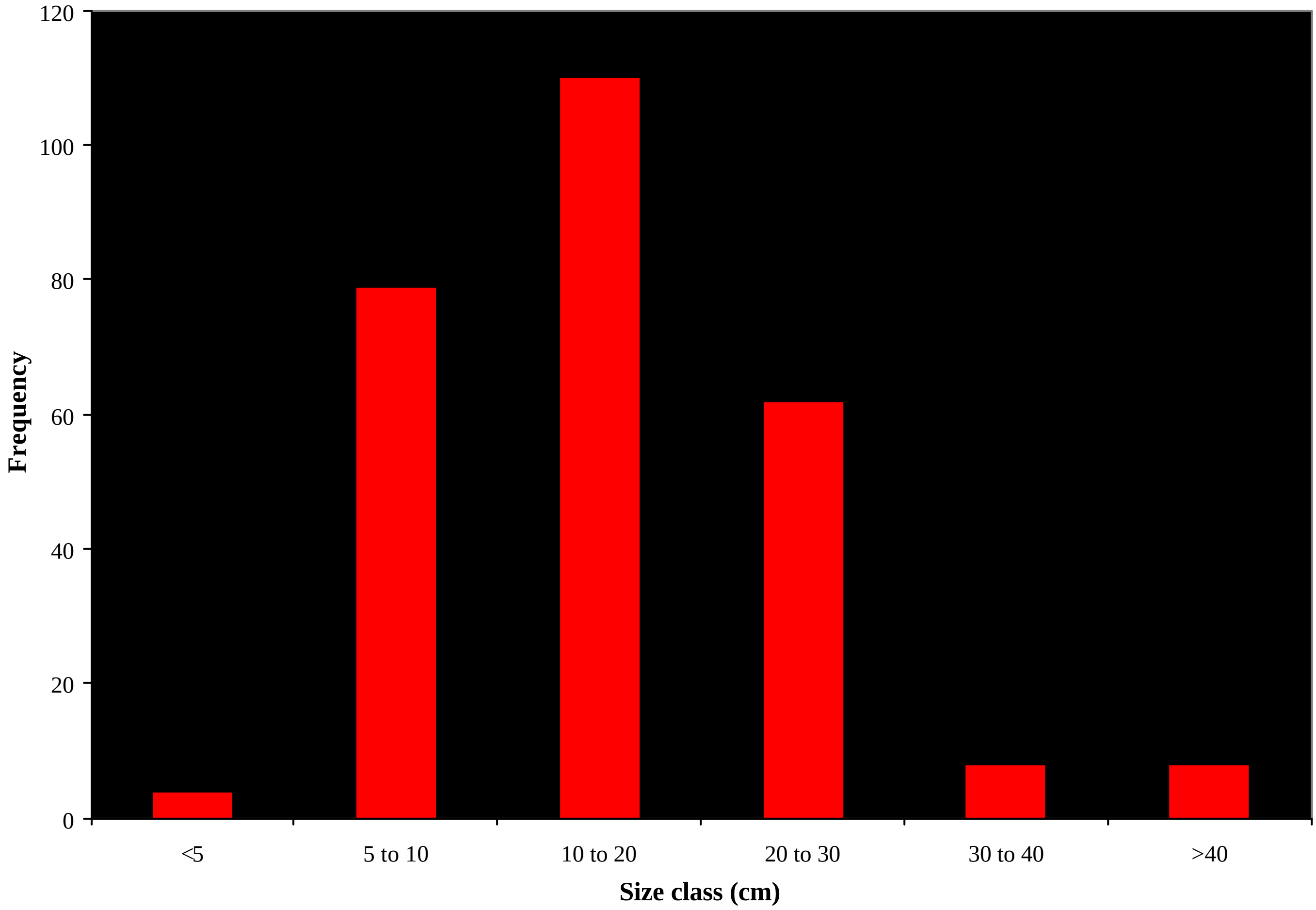

Figure 5 (a). Size-frequency distribution for all fish species

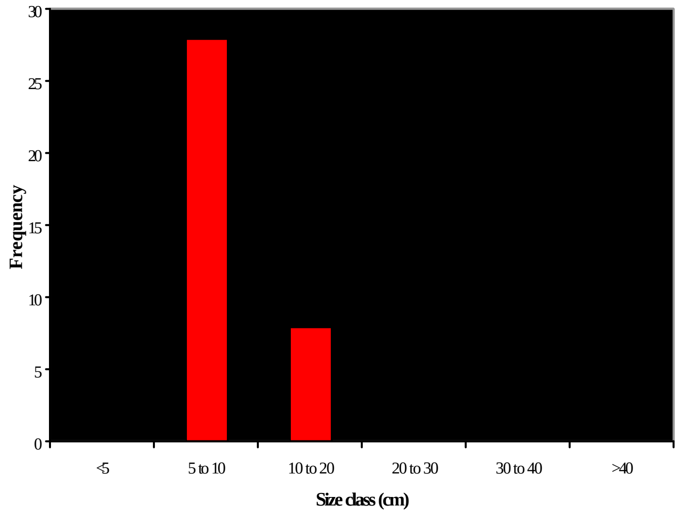

Figure 5 (b). Size-frequency distribution for surgeonfish.

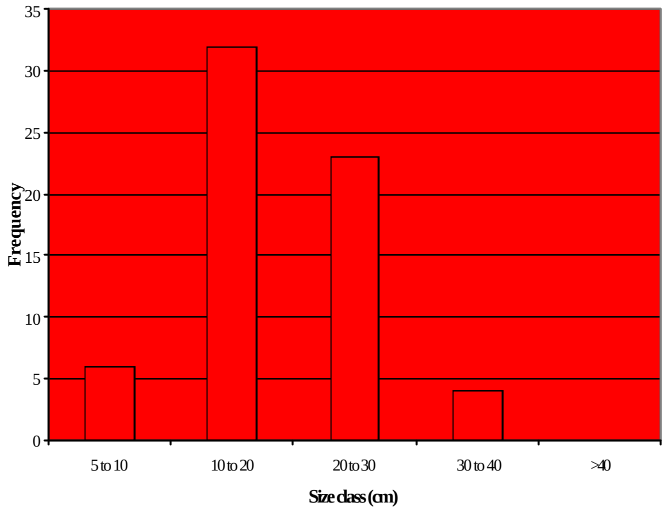

Figure 5 (c). Size-frequency distribution for parrotfish.

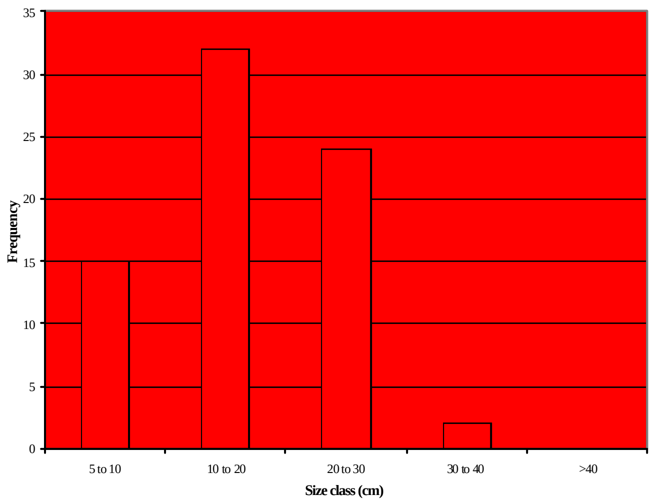

Figure 5 (d). Size-frequency distribution for grunts.

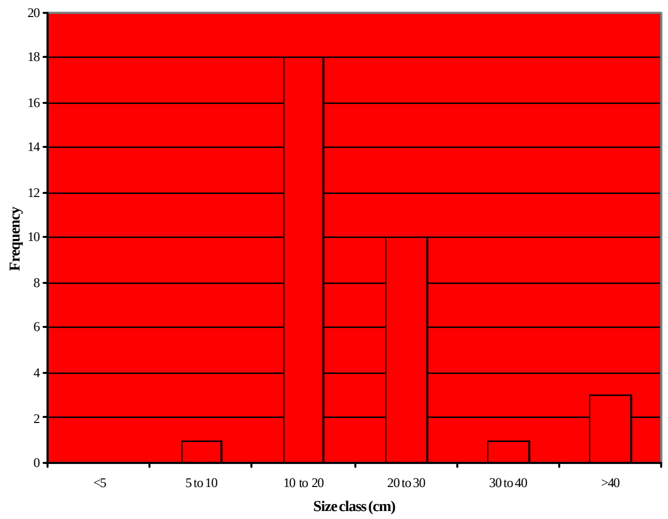

Figure 5 (e). Size-frequency distribution for snappers.

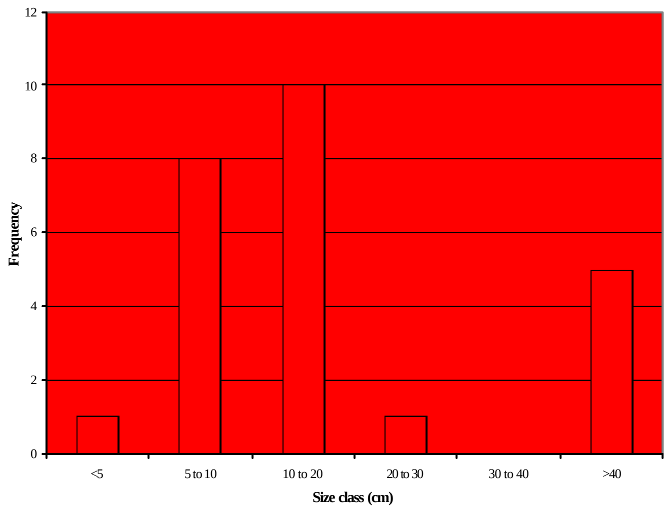

Figure 5 (f). Size-frequency distribution for groupers.

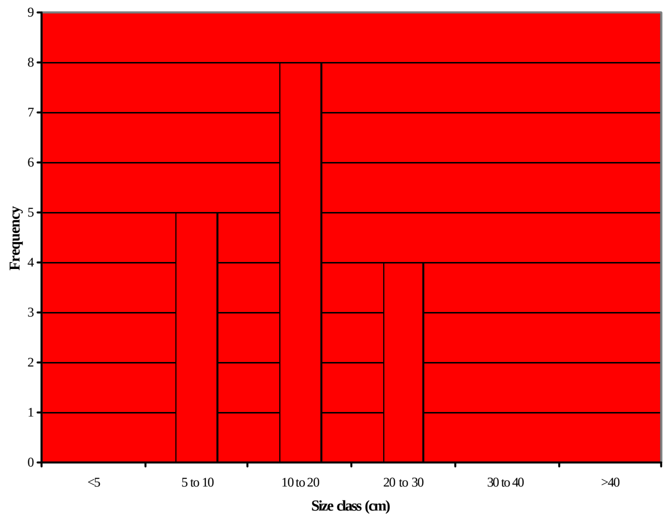

Figure 5 (g). Size-frequency distribution for angelfish.

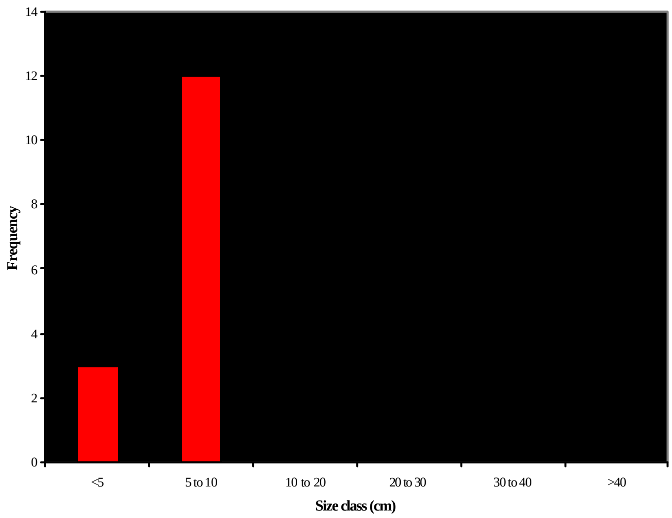

Figure 5 (h). Size-frequency distribution for butterflyfish.

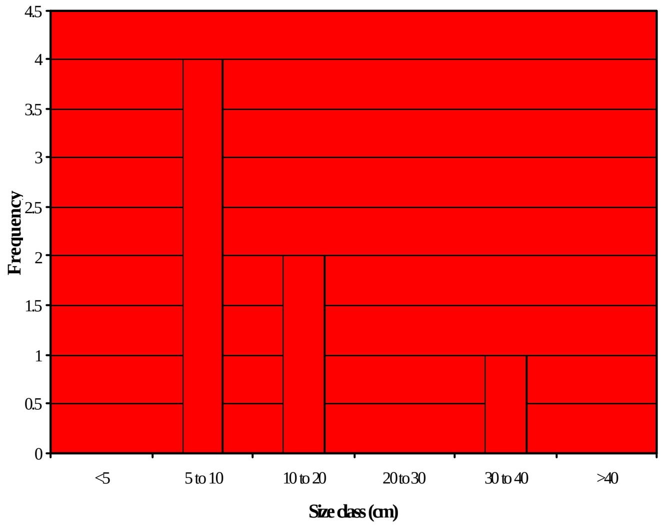

Figure 5 (i). Size-frequency distribution for triggerfish.

Figure 5 (a) shows that the mode size for all fish combined is 10 – 20 cm and this is reflected in all other families, with the exception of butterflyfish and triggerfish which have a mode size of 5 – 10 cm. The only fish larger than 40 cm were in the commercially important families of groupers and snappers. However, the grouper size-frequency distribution also reflects the range of sizes in the family from small species such as the coney (*Ephinephelus fulvus*) to the large groupers such as the Nassau grouper (*E. striatus*).

3.5.3 Rover survey

Six rover surveys were completed by the volunteers during the AGRRA survey and the results are shown in Table 8. Sixty seven species were recorded during the rover surveys with a mean of 33.3 species (SD = 3.1) being recorded per 30 minute dive. The creole wrasse, *Clepticus parrae*, was the most abundant fish with a median abundance of 4 (over 100 individuals). Parrotfish (Scaridae) was the most abundant family with 10 species being recorded.

Table 8. Abundances of fish recorded during the rover survey. Median abundance is calculated from the ordinal 0 – 4 scale used during the survey. Range given in parentheses. n = 6.

Species	Median abundance	Species	Median abundance
Ablennes hians	0.1 (0 – 1)	*H. rufus*	0.3 (0 – 3)
Acanthurus bahianus	0.5 (0 – 2)	*Hypoplectrus chlorurus*	0.1 (0 – 2)
A. chirurgus	1.5 (0 – 2)	*H. guttavarius*	0.1 (0 – 1)
A. coerulus	3.3 (3 – 4)	*H. indigo*	0.3 (0 – 2)
Anisotremus virginicus	0.1 (0 – 1)	*Lachnolaimus maximus*	0.8 (0 – 2)
Aulostomus maculatus	0.3 (0 – 2)	*Lactophrys polygonia*	0.3 (0 – 1)
Balistes vetula	0.3 (0 – 1)	*Lutjanus apodus*	1.5 (0 – 2)
Bodianus rufus	1.5 (0 – 2)	*L. mahogoni*	1.9 (0 – 2)
Caranx bartholomaei	0.3 (0 – 3)	*Melichthys niger*	1.8 (0 – 2)
C. latus	0.1 (0 – 1)	*Microspathodon chrysurus*	0.5 (0 – 2)
C. ruber	2.5 (1 – 3)	*Mycteroperca bonaci*	0.3 (0 – 1)
Chaetodon capistratus	2.0 (2 – 2)	*M. tigris*	0.3 (0 – 1)
C. ocellatus	0.5 (0 – 2)	*Ocyurus chrysurus*	3.0 (3 – 3)
C. striatus	0.1 (0 – 2)	*Opistognathus aurifrons*	0.1 (0 – 1)
Chromis cyanea	0.1 (0 – 3)	*Pomacanthus arcuatus*	1.5 (0 – 2)
Clepticus parrae	4.0 (4 – 4)	*Pseudupeneus maculatus*	0.1 (0 – 2)
Decapterus macarellus	0.3 (0 – 3)	*Scarus coelestinus*	0.3 (0 – 2)
Diodon hystrix	0.3 (0 – 2)	*S. coeruleus*	0.1 (0 – 1)
Epinephelus adscensionis	1.2 (0 – 2)	*S. croicensis*	1.5 (0 – 2)
E. cruentatus	1.9 (1 – 2)	*S. guacamaia*	0.3 (0 – 2)
E. fulvus	0.1 (0 – 1)	*S. taeniopterus*	1.8 (0 – 2)
E. striatus	0.5 (0 – 1)	*S. vetula*	0.1 (0 – 2)
Equetus punctatus	0.3 (0 – 1)	*Scomberomorus regalis*	0.3 (0 – 2)
Gobiosoma horsti	0.1 (0 – 2)	*Sparisoma aurofrenatum*	0.5 (0 – 2)
Gramma loreto	3.0 (0 – 4)	*S. chrysopterum*	0.3 (0 – 2)
Haemulon carbonarium	0.1 (0 – 2)	*S. rubripinne*	2.0 (1 – 3)
H. flavolineatum	2.0 (1 – 3)	*S. viride*	2.8 (2 – 3)
H. plumieri	1.8 (0 – 3)	*Stegastes diencaeus*	2.0 (0 – 3)
H. parra	0.1 (0 – 1)	*S. fuscus*	2.8 (0 – 3)
H. sciurus	1.8 (0 – 3)	*S. leucostictus*	0.1 (0 – 2)
Halichoeres garnoti	0.1 (0 – 2)	*S. partitus*	0.3 (0 – 2)
Holacanthus ciliaris	0.1 (0 – 2)	*S. planifrons*	0.1 (0 – 3)
H. tricolor	1.9 (1 – 2)	*Thalassoma bifasciatum*	0.1 (0 – 3)
Holocentrus adscensionis	2.5 (0 – 3)		

4. DISCUSSION

The AGRRA data collected during this study are limited both spatially and temporally and, therefore, it is not possible to assess fully the health of the fringing reef at Turneffe Atoll. The programme of data collection was designed as a pilot study to generate a baseline data set and examine the ability of non-professional divers to utilise the protocol. Surveys are needed at a shallow site (1–5 m) at Harry Jones Reef, at additional mid-depth and shallow sites around the atoll and at other locations on Glovers Atoll, Lighthouse Reef and the Belize Barrier Reef for comparison. Indeed, the data presented in this report require confirmation since Hurricane Mitch, which affected Turneffe in late 1998, may have significantly altered the health of the reef. Ideally, these surveys would form part of a national long-term monitoring protocol.

Furthermore, for truly rigorous analysis, the results need to be compared with AGRRA surveys from throughout the Caribbean and Gulf of Mexico. Such detailed analysis, accompanied by a widely accessible regional database, is a goal for the AGRRA Program over the next two years (Ginsburg and Kramer, 1999). Similarly, the target date for completing the assessment of the Western Atlantic and Gulf of Mexico region is the end of the year 2001. However, some qualitative reports are already available at the AGRRA website (Morisseau-Leroy, 1999) for 14 locations and a basic summary of trends has been compiled (Ginsburg and Kramer, 1999). The following sections use these reports and additional available data to provide an indication of reef health at Turneffe Atoll.

4.1 Coral health

Live coral cover was relatively high at the study site and is comparable to the mean hard coral cover of 20.6-36.9% found during ‘Reef Check’ surveys in 1997 and 1998 (Taylor and Harborne, 1999) at sites close to Calabash Cay, also on Turneffe Atoll. These values of coral cover are likely to be significantly lower than is typical for ‘natural’ reefs but the region has experienced a phase shift from coral dominated to algal dominated reefs because of factors such as the removal of herbivorous fish and the loss of *Diadema* urchins (Hughes, 1994). Hence Reef Check 1997 found a mean coral cover of 20.5% for the Caribbean region (Hodgson, 1999). Similarly, with the exception of intermediate / deep reefs of the Flower Gardens (US), Los Roques (Venezuela) and Bonaire which had coral cover of 40-50%, values for other AGRRA field sites were 15-30% (Morisseau-Leroy, 1999).

The site was dominated by *Montastraea annularis* (61.3% of all heads) which is the major reef builder in the Caribbean and has been for the past two million years (Budd et al., 1994). In addition to this acknowledged abundance, *M. annularis* may also be a complex of three species (*M. annularis sensu stricto*, *M. faveolata* and *M. franksi*; Weil and Knowlton, 1994) which were not differentiated in this study. However, dominance of the community by one relatively slow growing species (or complex of species) may indicate that the reef is approaching a climax community. The central and southern sections of Turneffe Atoll are sheltered by Lighthouse Reef (Gischler and Hudson, 1998) and there had not been a major hurricane since 1961. Such conditions of limited disturbance can reduce the diversity of a reef community (Connell, 1978).

Areas of coral colonies where the tissue had been long dead were almost ubiquitous and did not vary significantly between species. The AGRRA technique does not differentiate between causes of tissues mortality but these are likely to be varied and include disease, past bleaching events, fish grazing, coral-coral competition and bioerosion. Some mortality is also natural since species such as *Porites porites*, which had the largest percentage cover of old dead tissue, usually has branches which are dead at the base and living nearer the tips (ARH, pers. obs.). Without additional data it is difficult to assess whether the old mortality of reef building corals at Harry Jones is normal, but is comparable with the low to moderate level (approximately 20-30%) reported at most other AGRRA sites (Ginsburg and Kramer, 1999).

Newly dead tissue was much less common than old dead coral since it is rapidly colonised by turf and macroalgae. Much of the newly dead tissue is likely to have been caused by coral bleaching. Large-scale bleaching, the paling of coral tissue from the loss of symbiotic zooxanthellae and / or their pigments linked to increased sea surface temperatures and solar irradiance (Brown, 1997), were not recorded in Belize before 1993 (Glynn, 1993) but since then there have been major events in 1995 and 1998. During late 1998, at the same time as this study, there was a strong El Niño event which caused global coral bleaching, including the wider Caribbean region (Wilkinson, 1998). Temperature induced bleaching is not necessarily linked to mass mortality since following a decrease in seawater temperatures coral polyps can recover their zooxanthellae and return to a normal metabolism.

Coral bleaching was seen on all species during this study with the exception of *Acropora cervicornis*, although only five colonies were surveyed. *A. cervicornis* seems to be less susceptible to bleaching and more likely to recover, possibly because of the symbiotic algal genotypes (Rowan et al., 1997). This conclusion is supported by data from the 1995 bleaching event when all sampled colonies of *Acropora* spp. in Belize recovered fully (McField, 1999). There was further evidence of inter-specific variation in species susceptibility from analysis of the percentage of bleached tissue across all coral heads of each species. *Siderastrea siderea, Diploria labyrinthiformis, Montastraea annularis* and *Agaricia agaricites* had the largest percentage cover of bleached tissue (39-52.5%). This is consistent with the most heavily affected species from the bleaching event in 1995 (CARICOMP, 1997; McField, 1999).

Of the colonies surveyed during this study, over 87% had evidence of bleached tissue. This is higher than the 52% of colonies observed in 1995 (McField, 1999) but further data are required to assess actual coral mortality. However, it seems likely that mortality will be greater than the 10% of colonies in the 1995 event and may reach 20-25% (Wilkinson, 1998). Such levels of mortality have direct consequences to the coral community and previous studies have documented a 13% decrease in coral cover in Belizean patch reefs (Burke, 1996) and 20-35% in Panama following the 1982 event (Lasker et al., 1984). In contrast to Belize, although much of the Caribbean experienced a major coral bleaching event in 1998, the majority of areas surveyed recovered with only minor coral mortality affecting selected species (Ginsburg and Kramer, 1999). The situation on Turneffe Atoll appears to be more similar to the Bahamas, south central Belize (an average of 80% of *Montastraea annularis* and *Diploria* spp. tissue was severely bleached; Peckol et al., 1999) and Honduras where severe coral mortality was observed.

A further effect of elevated sea surface temperatures is that corals stressed by bleaching may become more susceptible to diseases (Williams and Bunkley-Williams, 1990). This will require monitoring since disease was already relatively common at the Turneffe Atoll site, although many of the incidents could not be assigned to a particular type and were recorded as 'unknown'. Of the four actual disease types, which may be complexes of more than one true disease, that are surveyed by the AGRRA protocol only white and yellow band were observed, with the latter restricted to colonies of *Montastraea annularis*. White band was also observed on *M. annularis* but was more common on *Acropora cervicornis*. This is consistent with the pathology of the disease which is known thought to be a bacteria and largely restricted to both *A. cervicornis* and *A. palmata* (Peters et al., 1993). White band disease is known to be an important factor on Belizean reef communities since, for example, large stands of *A. cervicornis* on rhomboid reefs were severely affected in the mid 1980's and caused the community to shift to one dominated by *Agaricia tenuifolia* (Aronson et al, 1998). In contrast, the lack of black band disease (*Phormidium corallyticum*) at the site is encouraging since this disease has been recognised in Belize for over two decades (Antonius, 1973). Its absence is more surprising since it is known to be seen more frequently in massive corals, including *Montastraea annularis* and *M. cavernosa* (Kuta and Richardson, 1996) which accounted for 63.4% of the colonies surveyed at the site.

Incidence of disease at Turneffe Atoll seems slightly greater than many Caribbean reefs surveyed with the AGRRA protocol (Morisseau-Leroy, 1999). However, diseases are known to be 'moderate to high' in Belize, Honduras and areas of the Bahamas and Cuba (Ginsburg and Kramer, 1999). In addition, data from south central Belize indicated that incidents of disease were on the increase in January 1999, possibly as a result of the bleaching event (Morisseau-Leroy, 1999), which could also have been a causative factor in the levels of disease observed on Harry Jones Reef. Further data are required to analyse the patterns of disease in Belize and around Turneffe Atoll, including the identification of the diseases which were affecting the coral heads but were of an unknown origin.

In addition to low levels of tissue mortality and incidents of disease, healthy reefs are considered to have numerous, large reef-building corals, such are seen in the Flower Gardens (US), Los Roques (Venezuela) and Bonaire (Ginsburg and Kramer, 1999). Most of the species sampled during the AGRRA survey had fewer than 10 different colonies greater than 25 cm in width so meaningful analysis is difficult but, of these species most colonies were generally less than 60 cm with the exception of *Colpophyllia natans* and single heads of *Acropora cervicornis* and *Siderastrea siderea*. However, for the more abundant species (*Montastraea annularis* and *Porites porites*) it is possible to examine the size-frequency distributions in more detail. As expected for the major reef-builder, *M. annularis* has a number of large colonies, with a maximum width of 215 cm. Despite these large individuals the mode size is 46-55 cm, indicating a predominance of younger colonies. Similarly, the mode size of *P. porites* is 25-35 cm with two larger colonies of greater than 66 cm. The mode size of all corals combined is also 25-35 cm.

These data reflect both the natural history of different species but also the frequency of major perturbations such as hurricanes. Corals are generally slow growing, for example 1 cm per year for *Montastraea annularis* (Tomascik, 1990) and can take many years to recover from storm damage. The last major hurricane to affect Turneffe Atoll was Hattie in 1961 and this is known to have caused major damage to the eastern reefs and left virtually no living corals (Stoddart, 1963). Stoddart suggested a recovery period of 20-25 years but commented in 1969 (Stoddart, 1969) that recovery was limited by mobile debris, algal competition and increased turbidity. Therefore, it is possible that coral sizes are still a function of this, and other, disturbances and may never reach a community with many large corals such as that seen in Bonaire, which is away from the hurricane belt. However, the mean surface area of *M. annularis* (assuming a semi-spherical shape) is comparable to data from *M. flaveolata* in Curaçao (6630 and 8847 cm^2 respectively; Bak and Meesters, 1998).

Size-frequency statistics have been proposed as important tools for monitoring coral reef health since they include a record of prior history of a coral population (Bak and Meesters, 1998). Such interpretations are, however, limited with AGRRA data since colonies less than 25 cm in size are not surveyed. Bak and Meesters (1998) indicate that partial mortality is correlated to colony size, the modal colony size representing a turning point for damage causing partial as opposed to total mortality and that degraded reefs have fewer small colonies. The lack of variation for amount of long dead tissue between colony sizes and the mean partial mortality being within the range documented by Bak and Meesters (1998) for their largest colony sizes (30-50%) indicates that all the colonies survey by the AGRRA protocol are larger than the modal size for each species. Further data are required to assess the status of small colonies and coral recruits on Turneffe Atoll.

4.2 Algal cover

Algal cover is an important independent indicator of reef health since, for example, the amount of macroalgae can highlight the effects of decreased water quality and herbivory and coralline algae are a sign of favourable conditions (Ginsburg et al., 1998). Low algal abundance is regarded as an indication of a balanced reef system (reviewed by Done et al., 1996). Abundance of algae is particularly important on Caribbean reefs since most reefs within the region have experienced a dramatic decrease in coral cover and concomitant increase in macroalgae over the last two decades. This pattern has been attributed to a number of factors, particularly the mortality of *Diadema* spp. urchins in the 1980's (reviewed by Lessios, 1988), removal of herbivorous fish and increased nutrients within the water column. Belize has been cited as an undisturbed system but data show algal cover increasing from less than 10% to current levels of over 60% (e.g. McClanahan et al., 1999).

This ecological shift, however, has not been consistent in Belize and suggests a complex set of synergistic factors varying within the coastal zone. For example, on the barrier reef and Glovers Atoll patch reefs the changes paralleled the decimation of *Acropora* from white-band disease and show the role of coral mortality along with putative changes in herbivory and nutrients (McClanahan et al., 1999). The physico-chemical environment must also have an important role since the increased flushing on the forereef at Glovers Atoll seems to have limited disease and the increase in erect macroalgae is less apparent (McClanahan and Muthiga, 1998). In contrast, on the rhomboid reefs close to Carrie Bow Cay the result of *Acropora cervicornis* death is an alternative community state dominated by *Agaricia tenuifolia* (Aronson et al., 1998). Aronson et al. (1998) suggest that this shift seems to have been caused by intense herbivory by the urchin *Echinometra viridis*, reducing macroalgae and facilitating *Agaricia* recruitment.

Data from the AGRRA survey on Turneffe Atoll show that most quadrats had abundant macroalgae and algal turf (> 30%) but less coralline algae (< 15%) and there was no variation between substrate types. Similarly to the coral information, these data are difficult to interpret without additional temporal and spatial surveys. However, the results are consistent with data from south central Belize, Honduras, Bahamas, Mexico and Cuba where macroalgal abundances were reported as 'moderate to high' (generally >25%; Morisseau-Leroy, 1999; Ginsburg and Kramer, 1999). This is in contrast to the Flower Gardens (US), Los Roques (Venezuela) and Bonaire where macroalgal abundance was low (generally < 20%; Ginsburg and Kramer, 1999). Turf algae were also comparable to the highest coverages in the region, although the cover of 50% in Bonaire, which is considered a healthy reef, shows the difficulty of assigning values of reef status. There are less comparative data for coralline algae but the frequency of occurrence in 75% of the quadrats and an abundance of approximately 15% shows there are favourable areas for coral recruitment (Morse et al., 1988). However, more research is required on the interaction of algal abundance, intra and inter-taxa competition, water quality, herbivory and coral recruitment before the AGRRA database can be analysed fully.

Diadema spp. urchins graze algal turf and young specimens of macroalgae and help to keep the algal load on a reef low (Lessios, 1988). There were no *Diadema* spp. recorded during the survey at Turneffe Atoll and their low population, similar to the whole Caribbean, is a contributing factor to the substantial coverage of macroalgae and algal turf. Reef Check 1997 and 1998 conducted on a site to the south of Harry Jones Reef, but at the same depth as this study, did find a small number of *Diadema* spp. urchins (mean of 0.4 and 1.4 individuals per 100 m^2 respectively; Taylor and Harborne, 1999) and a population increase may occur in the future.

4.3 Fish abundance

The fish species list used by the AGRRA protocol was developed to focus on ecologically and commercially important groups such as herbivores and those targeted by fisherfolk. It is hypothesised that reduced abundances and small sizes of key guilds are a sign of over-fishing (Ginsburg et al., 1998). Similarly to the benthic surveys, fish data collected during this study are difficult to interpret without further spatial and temporal replication and comparative information from other areas of Belize and the Caribbean region. In addition, details of fish abundance are generally not included in the existing qualitative reports for AGRRA sites (Morisseau-Leroy, 1999). Furthermore, the effects of over-fishing are so pervasive in the Caribbean it may never be possible to compare data against a truly 'natural' reef (Jackson, 1997). However, the data are useful as a baseline for future research and can provide some qualitative conclusions.

Data from the CCC AGRRA survey must also be analysed in the context of known accuracy and consistency of non-professional researchers. In contrast to the benthic data, which was collected by field science staff, the fish surveys were undertaken by volunteers. A validation exercise, carried out in conjunction with this study, showed that although volunteers are relatively accurate with benthic surveys, they are inconsistent at fish surveys (Harborne and Turnbull, in prep.). Although non-professionals have been shown to be able to undertake accurate fish surveys (Darwall and Dulvy, 1996; Schmitt and Sullivan, 1996) it seems that fish surveys using the AGRRA protocol, which includes identifying species and counting and sizing individuals, is not suitable for collecting consistent data. However, the results presented in this study are averaged over a number of volunteers and, therefore, should be indicative of the status of the site but comparisons with future surveys should be made with caution.

Ginsburg and Kramer (1999) report that abundances of herbivorous fish, such as scarids (parrotfish) and acanthurids (surgeonfish), appear to be moderate to high in most areas. Exceptions are low numbers of herbivores in San Salvador, Bahamas, Cuba and Mexico and low abundances and smaller sizes of commercial fishes in both these areas and with St Vincent. Data from this study are consistent with Belize having relatively healthy fish communities since, for example, there were 11 species of scarids and acanthurids seen during the surveys and *Sparisoma viride* (stoplight parrotfish) was amongst the most common of all fish. Abundances are generally higher than those obtained during CCC's quantitative surveys of the whole atoll but this is to be expected since CCC's surveys included a range of habitats, many of which have fewer fish than the coral rich forereef surveyed during the AGRRA study (Gardiner and Harborne, 2000). The species which were less abundant during the AGRRA study are generally those that are known to prefer habitats not present at the survey site, such as *Ocyurus chrysurus* (yellowtail snapper) which are commonly seen on escarpments (ARH, pers. obs.).

The size-frequency data for all species shows that the modal size is 10-20 cm and this is reflected in the distributions for each family. Surgeonfish, butterflyfish and triggerfish have a modal size of 5-10 cm but this reflects their normal body sizes rather than any effects of over-fishing. The only fish larger than 40 cm were groupers and snappers and this is a sign of relatively good reef health since hook-and-line fishing, which is dominant in Belize, selects for piscivores so the catch is predominantly these two families (Koslow et al., 1994). Healthy fish communities are also predicted by a surplus-production model which indicates that there is capacity for further expansion and current effort seems to be only 10% of levels that would maximise landings (Koslow et al., 1994). However, the authors advise that these results must be used with caution, particularly since it is difficult to model the effects of fishing on spawning aggregations which contributes a significant portion of the catch. At least six spawning aggregations are known in Belize, including the north-east corner of all three atolls (Carter and Sedberry, 1997). Fish are often caught before they spawn and some of the areas are thought to be over-exploited or no longer functional (McField et al., 1996). More surveys around Turneffe's reefs, research on populations of juveniles in mangrove stands and seagrass beds and data on fishing pressure is needed before making a fuller assessment of the effects of fishing.

Interpretation of data from the rover surveys is even more difficult than information on size and abundance. However, the results largely reflect results from the transects, with *Acanthurus coerulus* (blue tang), *Caranx ruber* (bar jack), *Ocyurus chrysurus* (yellowtail snapper) and *Sparisoma viride* (stoplight parrotfish) the most abundant (median rating of ? 2.5). In addition, *Clepticus parrae* (creole wrasse), *Gramma loreto* (fairy basslet), *Holocentrus* *adscensionis* (squirrelfish) and *Stegastes fuscus* (dusky damselfish), which are not surveyed using the transect protocol, were also common. The number of species seen during rover surveys (approximately 33 per dive) shows a diverse community but it is likely that a more experienced surveyor would have seen more species. The total number of species (67) compares to a list of 205 and 241 for the whole atoll (CCC and REEF[2], unpublished data) but these were compiled over a larger spatial scale and involved significantly more time underwater. Finally, a study of exploited fish species in the Hol Chan Marine Reserve compiled a list of 47 species (Polunin and Roberts, 1993). Comparison with the list recorded during both transects and rover surveys at the AGRRA site on Turneffe Atoll showed there were 32 species in common which is encouraging for an area which is not a protected reserve.

[22] Reef Environmental Education Foundation, http://www.reef.org/

5. CONCLUSION AND RECOMMENDATIONS

Collection of AGRRA data during 1998 provides an overview of the health of Harry Jones Reef but the data are difficult to interpret without additional spatial and temporal comparisons from both Belize and the wider Caribbean. However, this study indicates that Turneffe reefs are reasonably healthy, although there are causes for concern. Coral cover is reasonably high with a number of larger colonies but there is significant long dead tissue, bleaching and incidents of disease. With the exception of bleaching, the incidents of each parameter are comparable to all but the best reefs in the Caribbean (e.g. the Flower Gardens (US), Los Roques (Venezuela) and Bonaire). The 1998 bleaching event seems to have been more severe in Belize, along with Honduras and the Bahamas, than the rest of the region but the long-term effects will require further monitoring.

Algal biomass on Turneffe was also comparable to many other reefs in the region and, although higher than 'natural' for the Caribbean, indicates a relatively healthy area. Coverage seems unlikely to be more limiting to coral recruitment in Belize than in any other part of the region but this may alter with, for example, the removal of more herbivores. In contrast, fish populations may currently be healthier on Turneffe than much of the Caribbean because of its remoteness, the low population density of Belize and use of relatively sustainable fishing techniques. Along with a good diversity of smaller species and the ecologically important parrotfish and surgeonfish, a few large groupers and snappers were recorded during the surveys. These results are comparable with a larger study of commercially important species around the whole atoll.

Perhaps more importantly the data provide a baseline for comparison with future surveys. Such repeat surveys are already necessary to establish, for example, long-term mortality from the bleaching event and the effects of Hurricane Mitch. Although AGRRA was not designed as a monitoring tool these major events are certain to have altered the reefs at Turneffe and further data collection at a series of sites is required to provide representative information to the regional database. Data can then also be interpreted locally in conjunction with studies such as the CARICOMP surveys carried out by UCB and Reef Check. Such information will also provide a baseline for detailed assessments of the effects of future natural and anthropogenic factors. Belizean personnel have already attended an AGRRA training workshop in Akumal, Mexico (May 1999[3]) and could carry out additional surveys.

<u>Recommendation 1:</u> Additional Belizean personnel to receive training on AGRRA techniques during either international or national workshops.

<u>Recommendation 2:</u> UCB, the Coastal Zone Management Project or the Fisheries Department to undertake further AGRRA surveys at both shallow and medium depth at Harry Jones Reef.

[3] http://coral.aoml.noaa.gov/agra/mbrs.html

Recommendation 3: AGRRA surveys to be extended to other sites on Turneffe Atoll, particularly the western (leeward) reef and data submitted to the regional database. This will also improve the spatial scale of the local data set and provide further evidence for any apparent trends.

In addition to extra surveys there are a number of important variables that cannot be included with the AGRRA protocol but are included as optional surveys. The standard AGRRA protocol does not include corals less than 25 cm but coral recruits are an important indicator of reef health. One optional extra of the AGRRA protocol is to survey coral recruits.

Recommendation 4: Additional AGRRA surveys should include surveys of coral recruits and ideally corals less than 25 cm to provide detailed size-frequency data.

Turneffe Atoll is more remote than many other reefs in the Caribbean and seems to be in good condition. However, Bryant et al. (1998) estimate the threat to the atoll as ‘medium’. Although this threat is lower than many reefs in Central America, there is some cause for concern and pressure from fishing, development and diving, combined with effects from natural events such as coral bleaching, are likely to increase. A marine protected area for Turneffe Atoll has been proposed (Gibson, pers. com.) and this would help to maintain reef health. Such a reserve would also provide additional ecological and economic benefits, such as increased fish catches and income for local communities (Clark, 1996).

Recommendation 5: Continue to aim to establish a multiple use marine protected area at Turneffe Atoll, with an integrated monitoring programme to measure its efficacy.

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APPENDIX 1

Full details of AGRRA protocol.
Source: http://coral.aoml.noaa.gov/agra/rap-revised.html

1. Background

We know there are serious declines in reef-building corals at a number of locations in the Western Atlantic and Gulf of Mexico. We know that reef fish stocks are depleted at a number of specific sites. What we do not know is the regional extent and severity of these declines, how much of them are natural vs. anthropogenic, and especially the condition of reefs remote from centres of human impacts. The Atlantic and Gulf Reef Assessment (AGRRA) has been developed to provide this much-needed information. It is an international collaboration of reef scientists and their associates to assess the condition of reef-building corals and fishes throughout the Western Atlantic Ocean and Gulf of Mexico. A well-developed and tested Rapid Assessment Protocol (RAP) is being used to evaluate the condition of a large number of reefs. The results will provide new information on the extent and distribution of declines; they can contribute to the distinction between anthropogenic vs. natural impacts, and they can identify those reefs that deserve special conservation efforts.

Rapid assessment of marine communities, like public health surveys, is most successful when it addresses specific questions: incidence of disease, premature mortality, and geography of declines in health. For coral reef communities, RAP is not a substitute for long-term monitoring which aims to identify signs of decline on the decadal scale. Instead, as conceived for AGRRA, RAP is aimed at developing answers to specific questions:

What is the distribution and extent of reefs in serious decline? Serious decline means a high mortality of reef-building corals with apparently little potential for recovery and/or the absence of key elements of the fish populations.
How does the condition of fringing reefs impacted by large populations compare with that of reefs remote from centres of populations?
Where are those reefs whose condition and location makes them special candidates for marine protected areas or parks?

These questions can be answered by a one-time application of RAP to a large number of coral reefs even though no previous data are available.

2. Equipment

The following equipment is required for each diver in addition to basic snorkeling gear and SCUBA gear (including depth gauge):

Corals, Algae, and Diadema*:*

Underwater data templates.
Attach the data template onto an underwater slate or writing cylinder (see below). Section 6 has an example of the datasheet template designed for the benthic surveys. An inexpensive way to use the data template is to photocopy it onto a clear acetate overhead transparency, over which clear contact wallpaper is affixed to preserve the acetate template in the water. Then record data on semi-transparent, frosted (=single matte) plastic, mechanical drafting paper (e.g., 'Mylar') that you attach to the template with electrical tape. Alternatively you can photocopy the data template onto both sides of white underwater paper (contact J.L. Darling

Corporation, phone: 206-922-5000, fax: 206-922-5300; address: 2614 Pacific Hwy East, Tacoma, WA 98424-1017). This approach is more expensive (about $52.00 U.S./100 sheets), but data are more likely to be entered in the correct column since the template is reproduced on every data sheet.

A 10 m long transect line.
A 10 m polypropylene line marked at the 1, 3, 5, 7, and 9 m intervals (with cables-ties, electrical tape or permanent ink) to which a small dive weight has been attached at each end.

A 1 m long measuring device.
A polypropylene line marked at 10-cm intervals (as above), plus a loop at one end to go around the wrist of your non-writing hand. Alternatively, a short metric measuring tape or a PVC stick marked in 10-cm intervals can be used.

A 25 x 25 cm quadrat (for algae and small corals).
Construct quadrats using metal material such as stiff, 12 gauge copper wire, which works well, packs well and only requires a pair of wire cutters to construct; or alternatively use 1/2" PVC water pipe and elbows (with holes drilled in them to let the air out). String can be used to make a grid on the quadrat.

A small plastic ruler tied to the slate or writing cylinder (for algae).
Trim the ruler to have a narrow, tapered point, but still be legible, at the basal 5 cm.

Fish

Underwater data templates.
An underwater slate or writing cylinder on which the date template has been accurately transferred. Section 6 has an example of the datasheet designed for the fish transect surveys and the roving diver census.

At least two 30m fibreglass transect lines with a 3 lb. weight attached at one end of each line. Commercially available PVC surveying tapes are suitable for the transect line, or a 30 m nylon cord attached to a home-made reel will work. A clip can be attached to the reel and suspended from the diver's belt, which allows for the tape to deploy freely as the diver swims.

A graduated T-bar or other measuring device (for fish community counts).
Construct a T-bar using 1" diameter PVC pipe and a T connector available at hardware stores. It has a 60 cm long handle and two equal length arms providing a total width across the top of 1 m. Use PVC electrical tape or paint to create a scale along one of the arms showing 5, 10, 20, 30, 40 cm lengths.

Writing cylinders

A writing cylinder is a "thick walled" (1/4" thick) PVC pipe that is 4" internal diameter x ~18 cm long, and may have 3 holes drilled near one end through which surgical tubing can be strung to fit over your wrist. The advantage of the writing cylinder is that it keeps hands free to hold other surveying equipment and to hold on in strong surge or waves. A data template is usually attached to the cylinder with tape.

3. Field methods for AGRRA-RAP

Selection of reefs and sites

For the purposes of AGRRA, a REGION is defined as the coarsest scale category (100-km scale); followed by an AREA (10-km scale); a REEF (1-km scale); and a SITE (0.1-km scale). We recognise that reefs vary greatly in size, complexity, depth, profile, and coverage per km of coastline throughout the region. What follows are our recommended procedures for selecting survey sites, however we fully understand that it will be necessary to modify these procedures to accommodate the special conditions at any single site. It is vital for the success of AGRRA that these procedures be followed as closely as possible, and that all modifications to them be carefully noted when the data are compiled.

Reef Selection

For the purposes of AGRRA, a REGION is defined as the coarsest scale category (100-km scale); followed by an AREA (10-km scale); a REEF (1-km scale); and a SITE (0.1-km scale). We recognise that reefs vary greatly in size, complexity, depth, profile, and coverage per km of coastline throughout the region. What follows are our recommended procedures for selecting survey sites, however we fully understand that it will be necessary to modify these procedures to accommodate the special conditions at any single site. It is vital for the success of AGRRA that these procedures be followed as closely as possible, and that all modifications to them be carefully noted when the data are compiled.

Depending on the methods and resources available for your use, REEFS that are selected will generally fall into one of three categories:

1. Unbiased - chosen without local knowledge or published reports;
2. Representative- chosen with the aid of local knowledge to be representative of reefs in that area;
3. Strategic - chosen with local knowledge because they are threatened, suspected to be degraded, or in particularly good condition.

For regional comparisons, it is best to have REEFS that are chosen by either (1) or (2). REEFS that are chosen by (3) can still be assessed, however, they should be clearly flagged as such.

Site Selection

A SITE is defined as an area of habitat that is more or less homogeneous and accessible from a boat anchored or moored in one place. In this initial phase, we are suggesting that you concentrate your efforts on areas of maximum reef development. Generally, this will be in the 1-5 m depth interval (shallow *Acropora palmata* zone) and in the 8-15 m depth interval (shallow fore-reef of maximum coral growth).

Beyond these general depth intervals, it is up to the assessors to locate their SITES. For each REEF that is chosen, you should try to survey one SITE within each chosen depth interval.

A SITE description should be prepared for each site surveyed. It is critical to explain how your site was selected and an explanation of if and, if so, why you needed to deviate from the recommended selection protocol. The site description should also include information on:

location (GPS co-ordinates)
approximate size and shape
relief features (e.g., spur and groove)
position relative to shoreline
orientation as to windward or leeward (or both, if wind direction changes seasonally)
depth range corrected for tidal variations
where possible, an outline map of reef showing location of SITES, nearby land, etc.

Corals, algae, and Diadema

1. At each SITE, haphazardly lay the 10-m transect line just above the reef surface in a direction that is parallel to the long axis of the reef. Make sure the line is taut.

Note: Be sure to avoid any other transects that are being set by your companions, and stay away from the edges of the reef. Also try to avoid areas with abrupt changes in slope, deep grooves, large patches of sand or unconsolidated coral rubble. Unusual reef features should only be included to the extent appropriate to their relative abundance at the site. If the reefs are too small for you to avoid sandy patches, record how much of the transect line crosses sand, to allow a later calculation of the number of coral heads encountered/m of reef surface.

2. Approximate live coral cover by swimming along the transect line with your 1 m measuring device and roughly estimate how many meters of the line is underlain by living coral (to the nearest 10 cm). Be sure to include all live stony corals below the line, regardless of size or species density. Record this total.

3. Swim towards the other end of the transect and stop at the first coral head, cluster, or thicket of the appropriate species that is located directly beneath the transect line, is at least 25 cm wide, and which is either in original growth position or which has fallen and become reattached to the substratum. Record each of the following:

A. Name (genus and species)

B. Record the water depth at the top of the corals at the beginning and end of each transect. In cases where bottom topography is very irregular, or the size of the individual corals is very variable, record the water depth at the top of each coral beneath the transect line at any major change in depth (>1 m).

C. Using a measuring device, measure to the nearest 10 cm, its maximum projected diameter (live + dead areas) in plan view and maximum height (live + dead areas) above the substratum. The diameter should be measured perpendicular to the axis of growth. The height should be measured parallel to the axis of growth. Plan view is assessed from an angle that is parallel to the axis of growth.

D. Estimate the percent (%) of the coral that is "recently dead" and the % of the coral that is "long dead". "Recently dead" is defined as any non-living parts of the coral in which the corallite structures are white and either still intact or covered over by a layer of algae or fine mud. "Long dead" is defined as any non-living parts of the coral in which the corallite structures are either gone or covered over by organisms that are not easily removed (certain algae and invertebrates). Remember to only estimate mortality as viewed from above in "plan" or "map" view. If it is entirely "long dead", indicate this on your data sheet as 100% "long dead".

E. Quickly scan over the surviving portions of the ENTIRE coral colony and note if there are any diseases and/or bleached tissues present. Characterise any diseases by the following colour categories:

BB = Black band
WB = White band
WP = White plague
WS = White spots, patches or pox
YB = Yellow blotch (sometimes called yellow band)
RB = Red band
OT = Unknown

Underline any of these sources of disease (not bleaching) that are visible in plan view and which contributed to your estimate of "% recently dead". For more information about coral diseases see the disease cards (Bruckner 1998) or visit McCarthy and Peter's web site: http://ourworld.compuserve.com/homepages/mccarty_and_peters/coraldis.htm

Characterise any bleaching as approximate severity of discoloration:

P = Pale (discoloration of coral tissue)
PB = Partly Bleached (patches of fully bleached or white tissue)
BL = Bleached (tissue is totally white, no zooxanthallae visible)

Severely bleached coral tissues in many species are translucent, but you can still see the polyps above the skeleton. Bleached tissues should not be included with the "recently dead" estimates.

Note: Some surveyors may want to decrease the minimum size of measured corals to 10 cm (max. diameter) on reefs on which large colonies are scare. They are encouraged to do so on a subset of the transects used to located the 100 large (>25 cm) corals.

F. Whenever possible, record any other sources of recent mortality that can still be unambiguously identified: possibilities include sediments, storm damage, parrotfish bites, damselfish bites and/or algal gardens, predation on the soft tissues by snails like *Coralliophila abbreviata* or the bristle worm *Hermodice carunculata*, various effects of adjacent benthic algae, and any other spatial competitors (e.g., *Erythropodium caribaeorum*, other stony corals). Underline any of these sources that contributed to your estimate of "% recently dead".

G. While examining the entire coral head, count and record the number of damselfish or the total number of damselfish algal gardens on each head.

4. Go to the next appropriate coral and repeat the measurements above. Continue evaluating each coral head (>25 cm) until you reach the other end of the transect.

5. Reswim the transect with the 25 X 25 cm quadrat to estimate relative algal abundance. Place the quadrat every two meters directly below the transect line starting at 1 m (1, 3, 5, 7, 9 m). If a suitable area is not available at this mark, place it on the nearest available space within in a 1m radius of the mark (generally, a suitable place is considered to have greater than 80% of the area covered by algae). Avoid conspicuous patches of sand, macroalgae and benthic animals (other stony corals, gorgonian holdfasts, sponges, ascidians, etc.). If there are still no suitable areas available, draw a line through the space on your data sheet. Use your hands to lightly "wave away" any thin layers of sediment that could cover crustose coralline algae (do not scrape). For each quadrat, record each of the following:

A.
i. Substratum type (as pavement or dead coral).
ii. The % of macroalgae (all larger erect algae, >1 cm in height, both fleshy and calcareous; essentially any alga that you can pick up with your fingers).
iii. The % of turf algae (mostly tiny filaments, <1 cm in height). Include any that are below the canopies of macroalgae.
iv. The % of living crustose coralline algae (solid, calcareous encrusters that are pink or reddish in colour; Include any that are visible below turf algae, macroalgae, or a thin layer of sediment even though your total will exceed 100%).
v. The % other (e.g. invertebrates, sand, or bare areas)
Note: For those who find it easier to measure relative algal percentages, draw a line through the "% other" category and simply record the relative (rather than absolute) % of each of the three algal groups.

B. Use the plastic ruler to approximate the average canopy height of the macroalgae present within the quadrat.

C. Optional: Count and record the number of small (up to 2 cm maximum diameter) corals in the quadrat (see Coral recruitment in Optional Components). Identify any as you can to the genus level.

6. Continue placing and assessing quadrats until you reach the other end of the transect. Under usual conditions, 5 quadrats should be measured along each 10 m transect. If you will be setting more than 10 transects/site, you may want to scale back on the number of quadrats per transect so that you don't end up with more than 50 quadrats/SITE.

7. Using the 1 m measuring device for scale, swim a belt transect along the 10 m line. Count every Diadema that you can see within 1/2 m of each side of the transect line. Because this

species is cryptic, you must inspect all shelter-providing spaces along the transect. (Be prepared to poke your head under the bases of large corals or into crevices.)

8. After you complete a transect, collect the line and haphazardly reset the next transect line, at least 1 m laterally away from its previous position. Remember to avoid other lines, and whenever possible, abrupt changes in slope, large areas of sand and rubble, and any other unusual reef features. Try to ensure that the transects are distributed around the SITE, not concentrated together.

9. Repeat the above steps for each transect.

10. You can continue to reset transects in new positions as many times as safe diving practices permit during any given dive. However, a bare minimum of 50 quadrats and 100 coral heads should be assessed at each SITE. Obviously, appropriate sample sizes will depend on the variance in the local habitats--so we cannot prescribe "a one size fits all protocol".

Note: In some cases, coral density extremes will require modifying the number of transects laid. If coral density is low, lay enough transects to evaluate 100 individual corals (you may have to conduct additional dives). For example, if a site averages 2 corals per 10-m transect line, you need to set 50 transects at that site. If coral density is unusually low, be sure that you are working on a reef rather than an assemblage of corals on a pavement. If coral density is unusually high, set enough transects to evaluate about 200 corals. For example, if you average 20 corals per 10-m transect, you should lay 10 transects per site. Evaluate every coral along the transect (don't skip any). Again, space the transects to ensure that you have a representative sample of the site.

11. After surveying, enter data into a database, then check and verify their accuracy. Back up data regularly and store in a safe place.

Note: We suggest using a standard point-count method to assess large clusters or thickets in which colony boundaries are not distinguishable. There are many point count methods in common use. For example, you can haphazardly lay transects (using either a tape measure or rope with every 25 cm marked off) over the cluster or thicket and identify recent death, old death, or living coral tissue every 25 cm. The maximum diameter and height should be determined for the entire cluster or thicket.

Fish

The AGRRA protocol for fishes includes two distinct methods that should both be applied at each site. All transects used for fish assessment should be located within the same depth intervals specified for the benthic assessment (1-5 m and 8-15 m). Transects for fish will tend to be further apart and may range deeper and shallower than transects for benthic organisms. The integration of fish and benthic sampling, while beneficial, will require close co-ordination between team members for the two parts. It is recommended that the fish observations be conducted between 1000 and 1400 hours if at all possible, when visibility underwater is at a maximum due to overhead sunlight. Many fishes are wary of humans, hence it is necessary to keep away from other people while making these observations.

Method I: Belt transect counts for defined species list.

1. Lay a 30 m transect line by first placing the weighted end of the line on the bottom, and then swimming in a straight line while releasing it from the reel as you count the fish. This minimises the disturbance to the fishes prior to their being counted. Periodically fixing on an object in the distance as you swim will help you swim in a straight line. (You can clip the transect tape to your weight belt to allow for easy release of the tape).

2. As you swim out the full 30 m transect line, count and record fish found within a 2 m wide visually estimated belt transect. Carry a data sheet in standard format, and a 1-m wide T-bar to ensure accurate monitoring of the 2-m wide belt. Hold the T-bar ahead of you angled downward at about 45 degrees, and try to focus your gaze on the several meters of the transect ahead of the T-bar. Count only those SPECIES listed below and do not count juvenile parrotfishes or grunts less than 5cm in total length. This list of species has been chosen to provide coverage of a number of the species most likely to be affected by human impacts, while preserving a relatively consistent search image. This should enhance the precision of transect data.

SELECTED FAMILIES- include EVERY SPECIES within the following families:

Surgeonfish (e.g., *Acanthurus bahianus*, *A. chirurgus*, *A. coeruleus*)
Parrotfish (e.g., *Sparisoma viride*, *S. aurofrenatum*, *S. rubripinne*, *Scarus taeniopterus*, *S. iserti*)
Grunt (e.g., *Haemulon flavolineatum*, *H. chrysargyreum*, *H. sciurus*, *H. plumieri*, *H. aurolineatum*)
Snapper (e.g., *Lutjanus griseus*, *L. apodus*, *L. mahogoni*, *Ocyurus chrysurus*)
Grouper (e.g., *Epinephelus guttatus*, *E. fulvus*, *E. cruentatus*, *E. striatus*, *Mycteroperca bonaci*)
Angelfish (e.g., *Pomacanthus paru*, *P. arcuatus*, *Holocanthus tricolor*, *H. ciliarus*)
Butterflyfish (e.g., *Chaetodon capistratus*)
Triggerfish (e.g., *Balistes vetula*, *Melichthys niger*)

ALSO COUNT the following five species:

Yellowtail damselfish (*Microspathodon chrysurus*)
Hogfish (*Lachnolaimus maximus*)
Spanish hogfish (*Bodianus rufus*)
Barracuda (*Sphyraena barracuda*)
Bar jack (*Caranx ruber*)

3. Estimate the size of each fish and assign them to the following size categories (<5 cm, 5-10, 10-20, 20-30, 30-40, >40cm) using a 1 m T-bar with 5 cm increments to assist in estimating sizes. Large groups of individuals of a species will be classified by attempting to put them into one or more size categories as necessary. By remembering to keep effort equivalent on all segments of the transect, you can limit the tendency to count all members of a school crossing

the transect, instead of just those members which happen to be within the transect as counting of that segment takes place.

Note: Sample the transect belt giving uniform attention to each successive 2-m segment. This requires swimming at a more or less constant rate, while looking consistently about 2 m ahead of your current position. You may pause while recording data, and then start swimming again. It is important to swim in a uniform manner at a speed that covers each 30-m transect in 6-8 minutes should be attempted. High densities of counted species will slow this rate in some cases. The diver will be tempted to count all members of a school as they swim across the transect unless he/she concentrates on giving equal effort to sampling each successive portion of the transect. Only those school members that are actually within the 2 m wide strip of that segment of the transect at a given time is included in the census. Fish observers should be trained to estimate fish lengths by using consistency training methods both on land and underwater.

4. When you reach the end of the transect line, stop the survey and recoil the transect tape.

5. Continue conducting haphazardly-positioned 30 m transects at least 5 m laterally away from the previous position. Repeat the above steps for each transect.

Modifications: Some workers may want to census other species of fish. This is encouraged, provided that these other species are counted on a SEPARATE pass over the transect, after the AGRRA run. Otherwise the census method is substantially changed, and your data may not be directly cross-comparable with other AGRRA assessments.

Method II. Rover Diver census

After finishing the belt transects (or concurrently depending on the number of surveyors), conduct a roving diver census of ALL SPECIES of fishes following the methodology of Reef Environmental Education Foundation (REEF) (http://www.reef.org/) and briefly explained below.

1. The Rover diver census is conducted in the same general area as the belt transects are set.

2. Swim around the reef SITE for approximately 30 minutes (preferably 45-60 min - the longer the better) and record ALL fish species observed. Use all knowledge you have of fish habits, and search under overhangs, in caves, and so on. The objective is to find the maximum number of species that you can in during your search time.

3. Estimate the density of each species by using logarithmic categories: Single (1 fish), Few (2-10 fishes), Many (11-100 fishes), or Abundant (> 100 fishes).

4. Record your observations on the standardised REEF data entry sheet.

5. Contact REEF to submit your datasheet for the regional database.

Species list of major Caribbean reef-building corals

Acropora cervicornis
Acropora palmata
Agaricia agaricites
Agaricia lamarcki
Agaricia tenuifolia
Colpophyllia natans (OR *Colpophyllia amaranthus, C. breviserialis* & *C. natans*)
Dendrogyra cylindrus
Diploria clivosa
Diploria labyrinthiformis
Diploria strigosa
Madracis decactis
Madracis mirabilis
Montastraea annularis
Montastraea faveolata
Montastraea franksi (OR *Montastraea annularis* f. *annularis, M. annularis* f. *faveolata* & *M. annularis* f. *franksi*) (OR *Montastraea annularis* complex) *
Montastraea cavernosa
Porites astreoides
Porites furcata
Porites porites (OR *Porites porites* f. *furcata, Porites porites* f. *porites*)
Siderastrea siderea (OR *Siderastrea radians* f. *siderea*)
Solenastrea bournoni
Solenastrea hyades
Stephanocoenia intersepta
Millepora complanata

Participants are encouraged to try to discriminate among the morphs of the *M. annularis* complex, since their mortality rates are morph-dependent.

APPENDIX 2

Raw data from benthic surveys collected by CCC field science staff.

Coral species: Acer = *Acropora cervicornis;* Aaga = *Agaricia agaricites;* Aten = *Agaricia tenuifolia;* Cnat = *Colpophyllia natans;* Dlab = *Diploria labyrinthiformis;* Mann = *Montastraea annularis;* Mcav = *Montastraea cavernosa;* Past = *Porites astreoides;* Ppor = *Porites porites;* Ssid = *Siderastrea siderea.*

*** = disease present. Diseases: BBD = black band; WT = white band; YBD = yellow band; RBD = red band; UK = unknown.**

Transect 1.

Transect #	1	% Live Coral Cover		11	Depth	Start m	12
Diadema #						End m	12
Head Number	1	2	3	4	5		
Species	Mann	Ssid	Ppor	Aaga	Ssid		
Width cm	215	25	40	35	70		
Height cm	180	20	20	25	25		
% Old	60		50	60	20		
% New			5				
% BBD							
% WT							
% YBD							
% RBD							
% UK			*				
% Bleached	30	100	30	40	80		
Quadrat No.	1	2	3	4	5		
Substrate	Rubble	Dead Coral	Dead Coral	Dead Coral	Sand		
Macro	10	30	40	50	40		
Turf	50	30	50	30	60		
Coralline	10	20	20	10	10		
Other	40	20	10	10			
Height mm	10	20	30	30	50		

Transect 2.

Transect #	2	% Live Coral Cover		27.9	Depth	Start m	13					
Diadema #						End m	13					
Head Number	1	2	3	4	5	6	7	8	9	10	11	12
Species	Mann	Man n	Aaga	Cnat	Mann	Mann	Mann	Mann	Ppor	Ssid	Mann	Mann
Width cm	110	100	40	70	40	45	70	40	45	30	50	130
Height cm	135	40	30	30	30	30	50	40	25	20	55	150
% Old	90	70	10	10	10	10	40	30	40	20	70	40
% New							5		20	5		10
% BBD												
% WT												
% YBD												
% RBD												
% UK							*		*	*		*
% Bleached	10	25	50		90	20	55	10			30	50
Quadrat No.	1	2	3	4	5							
Substrate	Rubble	Dead Coral	Dead Coral	Rubble	Sand							
Macro	30	10	30	20	20							
Turf	60	80	40	10	20							
Coralline	10			10	15							
Other	10	10	30	60	45							
Height mm	30	10	10	10	10							

Transect 3.

Transect #	3	% Live Coral Cover		24	Depth	Start m	15			
Diadema #						End m	14			
Head Number	1	2	3	4	10	5	6	7	8	9
Species	Mann	Dlab	Mann	Mcav	Mann	Mann	Mann	Acer	Mann	Mann
Width cm	60	40	50	35	25	30	70	40	50	50
Height cm	60	25	40	40	35	40	45	35	50	30
% Old	50		30	10	10	20	40	50	25	10
% New							10	5		
% BBD										
% WT								*		
% YBD							*			
% RBD										
% UK										
% Bleached	50	50	60		10	10	40		60	80
Quadrat No.	1	2	3	4	5					
Substrate	Dead Coral	Dead Coral	Dead Coral	Rubble	Rubble					
Macro	30	10	30	30	50					
Turf	40	60	10	20	50					
Coralline		10	10	20						
Other	30	20	50	30						
Height mm	30	40	30	50	20					

Transect 4.

Transect #	4	% Live Coral Cover		47.5	Depth	Start m							
Diadema #						End m							
Head Number	1	2	3	5	6	7	8	9	10	11	12	1	2
Species	Mann	Mann	Mann	Acer	Mann	Aaga	Mann	Mann	Mann	Mann	Mann	Mann	Ppor
Width cm	30	160	60	70	80	30	50	30	80	60	50	50	50
Height cm	25	150	25	30	55	30	45	35	60	80	35	25	30
% Old	20	30	30	60	20	10	20	20	40	10	20	40	60
% New	20	10		20			10						10
% BBD													
% WT				*			*						
% YBD	*												
% RBD													
% UK													
% Bleached	40	55	70		60	10	50	70	40	40	20	30	30
Quadrat No.	1	2	3	4	5								
Substrate	Rubble	Dead Coral	Sand	Dead Coral	Dead Coral								
Macro	60	10	10	10	10								
Turf	20	40	50	80	50								
Coralline	10	20		10									
Other	10	40	40	10	40								
Height mm	40	10	10	10	30								

Transect 5.

Transect #	5	% Live Coral Cover		28	Depth	Start m								
Diadema #						End m								
Head Number	1	2	3	4	5	7	8	9	10	11	12	3	4	4
Species	Cnat	Ppor	Mann	Mann	Aaga	Mann	Mann	Acer	Mann	Acer	Ppor	Aten	Mann	Ppor
Width cm	70	25	75	90	30	30	30	35	50	40	25	30	95	40
Height cm	40	10	30	40	10	20	30	20	50	20	20	25	45	10
% Old	50	60	80	60	10	10	50	5	40	90	60	20	20	10
% New							10						10	
% BBD														
% WT														
% YBD														
% RBD														
% UK							*							
% Bleached		40	20	40	4	90	10		60		10	20	70	90
Quadrat No.	1	2	3	4	5									
Substrate	Rubble	DC	Rubble	Rubble	DC									
Macro	70	10	30	50	40									
Turf	30	80	40	50	60									
Coralline	0	0	10	10	15									
Other	0	10	10	0	0									
Height mm	40	10	40	50	20									

Transect 6.

Transect #	6	% Live Coral Cover		25	Depth	Start m			
Diadema #						End m			
Head Number	1	2	3	4	5	6	7	8	9
Species	Cnat	Mann	Cnat	Mann	Ssid	Ssid	Mann	Ssid	Mann
Width cm	40	70	65	100	30	30	25	30	45
Height cm	35	40	30	60	20	25	35	15	25
% Old	10	10	100	30	50	90	40	10	60
% New						5			
% BBD									
% WT									
% YBD									
% RBD									
% UK						*			
% Bleached	90	70		60	50	5	50	80	35
Quadrat No.	1	2	3	4	5				
Substrate	Rubble	Rubble	Rubble	Dead Coral	Dead Coral				
Macro	30	80	10	10	20				
Turf	50	10	80	60	70				
Coralline	10		20	20	30				
Other		10		10					
Height mm	30	50	20	10	20				

Transect 7.

Transect #	7	% Live Coral Cover		31.5	Depth	Start m	15		
Diadema #						End m	14.5		
Head Number	1	2	4	5	6	7	8	9	10
Species	Mann	Mann	Mann	Mann	Mann	Past	Mann	Mann	Aaga
Width cm	35	35	30	35	55	25	60	60	30
Height cm	30	30	20	10	45	20	90	50	15
% Old	10	10	5	40	30	20	15	20	10
% New	5	25		10	10	10	5		
% BBD									
% WT		*			*				
% YBD	*								
% RBD									
% UK				10		10			
% Bleached	60	65	20	50	60	20	80	80	90
Quadrat No.	1	2	3	4	5				
Substrate	DC	Rubble		Rubble	DC				
Macro	35	25		10	25				
Turf	60	40		80	50				
Coralline	15	30		10	0				
Other	5	20		10	25				
Height mm	30	10		10	30				

Transect 8.

Transect #	8	% Live Coral Cover		26.5	Depth	Start m	14.1				
Diadema #						End m	14.6				
Head Number	1	2	4	5	6	7	8	9	10	11	12
Species	Cnat	Mann	Acer	Ppor	Mann	Mann	Mcav	Mann	Mann	Aaga	Mann
Width cm	80	50	30	30	120	80	25	50	60	30	40
Height cm	20	80	15	15	180	45	35	35	20	40	20
% Old	50	90	20	30	90	40	5	50	30	20	10
% New		2	5					30			
% BBD											
% WT			*								
% YBD								*			
% RBD											
% UK											
% Bleached		8		40	10	60	10	15	60	40	90
Quadrat No.	1	2	3	4	5						
Substrate	Rubble	Rubble	Rubble	Rubble	Dead Coral						
Macro	50	30	50	25	30						
Turf	50	60	30	40	50						
Coralline		10	10	40	40						
Other		10	20	20							
Height mm	40	30	10	10	10						

Transect 9.

Transect #	9	% Live Coral Cover		26	Depth	Start m	
Diadema #						End m	
Head Number	1	2	4	5	7	8	9
Species	Mann	Mann	Ppor	Mann	Ppor	Mann	Mann
Width cm	80	70	30	160	80	40	35
Height cm	65	80	20	80	20	20	60
% Old	50	60	80	40	80	40	10
% New		5		10			
% BBD							
% WT							
% YBD				*			
% RBD							
% UK							
% Bleached	50	35	10	50	5	60	10
Quadrat No.	1	2	3	4	5		
Substrate	DC	DC	R	DC	R		
Macro	80	20	30	45	50		
Turf	20	70	65	40	40		
Coralline	20	10	20	20	10		
Other		10	5	5	5		
Height mm	20	5	30	15	20		

Transect 10.

Transect #	10	% Live Coral Cover		36.5	Depth	Start m	14					
Diadema #						End m	14					
Head Number	1	1	2	3	4	5	6	7	8	9	10	11
Species	Mann	Mann	Past	Aten	Mann	Mann	Mann	Mann	Mann	Ppor	Ppor	Mann
Width cm	50	50	25	50	110	70	50	45	60	70	35	80
Height cm	30	40	30	40	40	60	30	25	45	40	30	80
% Old	40	60	30	60	30	20	60	10	60	10	80	50
% New	5		5							5		5
% BBD												
% WT	*											
% YBD												
% RBD												
% UK			*							*		*
% Bleached	50	10		20	70	40	40	80	40	40	20	40
Quadrat No.	1	2	3	4	5							
Substrate	Dead Coral	Rubble	Dead Coral	Bed Rock	Dead Coral							
Macro	20	30	70	50	60							
Turf	60	70	10	30	15							
Coralline	20	20		5	10							
Other	20		20	20	20							
Height mm	10	30	20	20	10							

APPENDIX 3

Common names of reef fish

Species	Common name	Family
Acanthurus bahianus	Ocean Surgeonfish	Acanthuridae
A. chirurgus	Doctorfish	Acanthuridae
A. coerulus	Blue Tang	Acanthuridae
Aulostomus maculatus	Trumpetfish	Aulostomidae
Balistes vetula	Queen Triggerfish	Balistidae
Melichthys niger	Black Durgon	Balistidae
Ablennes hians	Flat Needlefish	Belonidae
Caranx bartholomaei	Yellow Jack	Carangidae
C. latus	Horse-eye Jack	Carangidae
C. ruber	Bar Jack	Carangidae
Decapterus macarellus	Mackerel Scad	Carangidae
Chaetodon capistratus	Foureye Butterflyfish	Chaetodontidae
C. ocellatus	Spotfin Butterflyfish	Chaetodontidae
C. striatus	Banded Butterflyfish	Chaetodontidae
Gobiosoma horsti	Yellowline Goby	Gobiidae
Gramma loreto	Fairy Basslet	Grammatidae
Anisotremus surinamensis	Black Margate	Haemulidae
A. virginicus	Porkfish	Haemulidae
Haemulon carbonarium	Caesar Grunt	Haemulidae
H. flavolineatum	French Grunt	Haemulidae
H. parra	Sailors Choice	Haemulidae
H. plumieri	White Grunt	Haemulidae
H. sciurus	Bluestriped Grunt	Haemulidae
Holocentrus adscensionis	Squirrelfish	Holocentridae
H. rufus	Longspine Squirrelfish	Holocentridae
Bodianus rufus	Spanish Hogfish	Labridae
Clepticus parrae	Creole Wrasse	Labridae
Halichoeres garnoti	Yellowhead Wrasse	Labridae
Lachnolaimus maximus	Hogfish	Labridae
Thalassoma bifasciatum	Bluehead	Labridae
Lutjanus apodus	Schoolmaster	Lutjanidae
L. mahogoni	Mahogany Snapper	Lutjanidae
Ocyurus chrysurus	Yellowtail Snapper	Lutjanidae
Pseudupeneus maculatus	Spotted Goatfish	Mullidae
Opistognathus aurifrons	Yellowhead Jawfish	Opistognathidae
Lactophrys polygonia	Honeycomb Cowfish	Ostraciidae
Holacanthus ciliaris	Queen Angelfish	Pomacanthidae
H. tricolor	Rock Beauty	Pomacanthidae
Pomacanthus arcuatus	Grey Angelfish	Pomacanthidae
P. paru	French Angelfish	Pomacanthidae
Chromis cyanea	Blue Chromis	Pomacentridae
Microspathodon chrysurus	Yellowtail Damselfish	Pomacentridae
Stegastes diencaeus	Longfin Damselfish	Pomacentridae

S. fuscus	Dusky Damselfish	Pomacentridae
S. leucostictus	Beaugregory	Pomacentridae
S. partitus	Bicolor Damselfish	Pomacentridae
S. planifrons	Threespot Damselfish	Pomacentridae
Scarus coelestinus	Midnight Parrotfish	Scaridae
S. coeruleus	Blue Parrotfish	Scaridae
S. croicensis	Striped Parrotfish	Scaridae
S. guacamaia	Rainbow Parrotfish	Scaridae
S. taeniopterus	Princess Parrotfish	Scaridae
S. vetula	Queen Parrotfish	Scaridae
Sparisoma aurofrenatum	Redband Parrotfish	Scaridae
S. chrysopterum	Redtail Parrotfish	Scaridae
S. rubripinne	Yellowtail Parrotfish	Scaridae
S. viride	Stoplight Parrotfish	Scaridae
Equetus punctatus	Spotted Drum	Sciaenidae
Scomberomorus regalis	Cero	Scombridae
Epinephelus adscensionis	Rock Hind	Serranidae
E. cruentatus	Graysby	Serranidae
E. fulvus	Coney	Serranidae
E. striatus	Nassau Grouper	Serranidae
Mycteroperca bonaci	Black Grouper	Serranidae
M. tigris	Tiger Grouper	Serranidae
Hypoplectrus chlorurus	Yellowtail Hamlet	Serranidae
H. guttavarius	Shy Hamlet	Serranidae
H. indigo	Indigo Hamlet	Serranidae
Diodon hystrix	Porcupinefish	Tetraodontidae