Caribbean: Planning for Adaptation to Global Climate Change (*CPACC*)

The Draft Proceedings

of the

Technical Workshop for the Implementation of Component 5: Coral Reef Monitoring for Climate Change

March 10-12, 1998

Belize City, Belize

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1.0 INTRODUCTION: CPACC PROJECT

The CPACC project was designed to support the participating Caribbean countries in preparing to cope with the adverse effects of global climate change, particularly sea level rise in coastal and marine areas. This is to be achieved through vulnerability assessment, adaptation planning and capacity building linked to adaptation planning. It is being executed through the cooperative effort of CARICOM member states and participating institutions over a period of four years (starting April 1997) by a combination of national pilot/demonstration components and regional components. The project is financed by a Global Environmental Facility (GEF) Trust Fund grant through the World Bank as one of its implementing agencies and executed by the Organization of American States (OAS). In addition a Regional Project Implementation Unit (RPIU) has been established at the University of the West Indies Center for Environment and Development (UWICED) in Barbados to ensure effective coordination and management of project activities at the regional level. CPACC participating countries include Antigua and Barbuda, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, Saint Lucia, Saint Kits and Nevis, Trinidad and Tobago and, and soon St. Vincent and the Grenadines.

Following a regional approach, the project will:

i. Strengthen the regional capability for monitoring and analyzing climate and sea level dynamics and trends, seeking to determine the immediate and potential impacts of GCC;

ii. Identify areas particularly vulnerable to the adverse effects of climate change and sea level rise;

iii. Develop an integrated planning and management framework for cost effective response and adaptation to the impacts of GCC on coastal and marine areas;

iv. Enhance regional and national capabilities for preparing for the advent of GCC through institutional strengthening and human resource development;

v. Identify and assess policy options and instruments that may help initiate the implementation of a long-term program of adaptation to GCC in vulnerable coastal areas.

1.1 CPACC PROJECT COMPONENT 5

The overall objective of Component 5 is to assist CPACC countries in establishing long-term coral reef monitoring programs, which over time show the effects of climate change factors such as temperature stress, sea level rise and hurricanes. These monitoring programs should continue beyond the life of

the project. The countries that have been selected for this activity are: The Bahamas, Belize and Jamaica, although the methodology will be transferred to the other countries in the project.

1.1.1 OBJECTIVES

The specific **objectives of Component 5** are as follows:

i. Determine the most appropriate methodology for recognizing impacts of climate change on coral reefs having regard to the need for long-term measurements,

ii. Establish and maintain monitoring sites in The Bahamas, Belize and Jamaica to determine the potential impacts of climate change on coral reefs, including biological and physical indicators.

iii. Establish mechanisms to ensure that coral reef monitoring continues beyond the life of the CPACC project.

iv. Strengthen existing institutions (public, private, and NGO) in coral reef monitoring.

v. Increase the level of awareness about the importance of coral reefs and the potential impacts of climate change.

vi. Since this is a pilot activity is initially confined to three countries, ensure that the benefits and lessons learnt are transferred to the other CPACC countries.

1.1.2 SUB-REGIONAL WORKSHOP

The original CPACC Project document envisaged a sub-regional forum of specialists comprising representatives from; government institutions, NGO's, and CARICOMP, as well as experts from the scientific community. The forum would be convened to identify methodologies to adjust and extend current monitoring methods, including the introduction of additional measurements aimed at monitoring the potential effects of GCC. This Workshop represents the substantial fulfillment of this expectation.

Planning for this workshop was initiated at a meeting at the OAS Headquarters, Washington, USA, on 08 10 97. Participating in the meeting were; Claudio Volonte (CPACC Technical Coordinator, GS/OAS), Eleanor Phillips (Fisheries Department, The Bahamas), Janet Gibson (Coastal Zone Management Project, Belize), Jeremy Woodley (Center for Marine Sciences, UWI, Jamaica). The purpose of the meeting was to begin planning the implementation of Component 5. A number of decisions were reached in the meeting (Appendix II) that guided the objectives and hence the agenda of the Sub-regional Workshop.

The Unit of Sustainable Development and Environment, GS/OAS, Washington posted notice of the Sub-regional Workshop on February 12, 1998, along with the objectives of the Workshop and the proposed agenda (Appendix III).

1.1.2.1 OBJECTIVES OF THE SUB-REGIONAL WORKSHOP

The stated objectives of the **Sub-regional Workshop** were:

i. To review the existing status of coral reef monitoring and research in the respective institutions in the three participating countries;

ii. To review the respective institutional capacities for coral reef monitoring;

iii. To design a monitoring program to determine the potential impacts of climate change on coral reefs, which can be established within the CPACC Project; and

iv. To determine the need for a monitoring program beyond CPACC.

The first Sub-regional Workshop for the Coral Reef Monitoring for Climate Change program, was held at the Fiesta Inn, Belize City, Belize over three days, from March 10 to 12, 1998. A total of 26 participants from five countries (Appendix I) attended the Workshop sessions.

2.0 SUMMARY PROCEEDINGS OF THE SUB-REGIONAL WORKSHOP

2.1 Day 1: March 10, 1998.

2.1.1 Opening Remarks

The Sub-regional Workshop opened with the welcome address, given by Mr. Noel Jacobs, Acting Fisheries Administrator, Fisheries Division (?), Belize. After welcoming the participants to Belize, Mr. Jacobs gave a report on the condition of Belize's coral reefs. He noted that in 1997, Belize had initiated a coral reef monitoring operation (?) to determine the parameters to be used for coral reef monitoring, and to standardize the coral reef monitoring methods being employed within the country. The entity responsible for these initiatives included NGO's and Government agencies. Mr. Jacobs gave the completion date for the NBSAP (?) as late 1998.

Mr. Kennrick (OAS Belize) gave a review of the CPACC project, emphasizing the importance of coral reefs in the region, and the natural and anthropogenic impacts to which they are subjected.

2.1.2 Overview of the CPACC Project and Component 5

Claudio Volonte (CPACC Technical Coordinator, GS/OAS) gave an overview of *Component 5: Coral Reef Monitoring for Climate Change*, emphasizing the linkages with, and support from other CPACC components. In this presentation, the participants were introduced to the project context in which decisions would be made.

2.1.3 The Effects of Climate Change on Coral Reefs

In the presentations that followed, Dr. Jeremy Woodley (CMS/UWI, Jamaica), Melanie McField (USF, Florida/Belize), and Dr. Judy Lang (UT/Austin, USA), discussed the likely scenario of climate change impacts on coral reefs and the subsequent changes that should be monitored (Appendix IV). Dr. Woodley's presentation suggested a range of potential climatic changes, their likely impacts to corals, and the coral reef attributes that would have to be monitored to detect and measure the effects of these changes. This information was summarized and reviewed by Dr. J. D. Woodley on Day Two of the workshop (Table 1). The likely changes in environmental conditions were listed, as were the corresponding parameters that would have to be monitored to detect and interpret the climate change effects on the coral reefs.

Table 1: Climate Change & Coral Reefs (prep. By Dr. J. D. Woodley)		
CHANGES IN …	**EFFECTS ON CORAL REEFS**	**PARAMETERS TO BE MONITORED**
CO^2	Carbonate Balance	Growth Calcification PH
Temperature	More coral bleaching and mortality	Temperature (θ) Bleaching events Coral Mortality Coral Abundance Community health
UV B (ozone loss)	More coral bleaching and mortality	Coral Abundance Community health
Sea Level	Landward shift of zones Upward growth of reef flats	Reef break waters *A. palmata* health
Storms	Physical damage especially to branching corals	Community character
Cloudiness	Reduced growth	Growth
Circulation Changes	Effects on growth if cooler/warmer	Growth, community
Terrestrial Run Off	More sedimentation & turbidity: coral decline	Turbidity Coral health, abundance

Melanie McField's discussed the relationship between CO_2 and coral reefs. She presented findings from the International Society for Reef Studies Symposium held in January 1998, entitled **Coral Reefs and Global Climate Change: Adaptation, acclimation, extinction**. The workshop was advised that although the effect on corals of increased CO2 in open natural systems was theoretical, expectations were that rates of coral reef calcification would be reduced. This was given as justification for the importance of measuring calcification (via coral growth) as part of this project. Since coral skeletons contained more aragonite than calcite, they would dissolve faster. This was explained in terms of the partial pressure of CO2 (p CO_2 = 3.68 atm x 10^{-4} at a pH of 8.32) relative to that of calcification (**3.67** atm x 10^{-4} H of 8.32) (?).

Dr. Lang placed the issue of climate change induced CO2 changes in context, with a presentation on the likely scale of CO2 changes, given historical changes in temperature and greenhouse gases emissions, and natural cycles.

Dr. Woodley and Ginger Garrison (USGS/USVI) then reviewed past and current long-term coral reef monitoring approaches and methodologies. In his review, Dr. Woodley emphasized the need to define

the reason for monitoring benthic communities and suggested that benthic communities be characterized by;

- the relative abundance of major visible space occupiers and foundation formations,
- variations in time to recruitment and mortality, noting that the latter might be caused by disease, sedimentation, floods, storms or climatic variation,
- increases in the relative abundance of free-living algae due to coral mortality.

A suite of monitoring methods was suggested, comprising; quadrats, and belt and line transects using a point count or continuous measure approach. Photographic/video monitoring methods were considered superior to other methods since they captured a range of information, including population health and colony history. A recommendation was made that the methodology should take into account the need for planning at the project area level as well as at the level of the monitoring profiles. The participants were advised to decide weather their particular situation required a random sampling approach or fixed or permanent monitoring stations. It was also noted that a description of the adjacent land use patterns should be provided for each monitoring station.

2.1.4 Reviews of Past and Current Long-term Coral Reef Monitoring Methodologies

Reviews of global and regional monitoring programs were given by;

- Dr. Woodley who described the CARICOMP Program and the Global Coral Reef Monitoring Network (Appendix IV.I);

- Dr. Lang, who described the Reef Check and Atlantic and Gulf Reef assessment (AGRA) programs (Appendix IV.II); and

- Melanie McField, who described the US EPA Coral Reef Monitoring Project in the Florida Keys National Sanctuary (Appendix IV.III).

2.1.5 Coral Reef Monitoring Activities in The Bahamas, Belize and Jamaica

A series of presentations were made on coral reef monitoring activities in the three Caribbean countries participating in the C^5 pilot project. Presentations were made by Simon Ciappara (PEPA, Jamaica), Janet Gibson (Coastal Zone Management Project, Belize), Peter Wilson-Kelly (NRCA, Jamaica), Peter Gayle (DBML, Jamaica), Eleanor Phillips (Fisheries Division, The Bahamas), and Malden Miller (Montego Bay Marine Park, Jamaica). The summaries of the submitted presentations are presented in Appendix V. Of particular significance to the implementation of Component 5 and its sustainability, were country reports of constraints to monitoring activities that resulted from; insufficient financial resources for fuel, salaries, equipment and training; the dependence on foreign researchers in the

absence of local institutional capacity, to conduct monitoring programs. This scenario was further born out by the reports for the Montego Bay Marine Park and the Portland Environmental Protection Association/Port Antonio Marine Park. No monitoring activities were currently being undertaken, although ecological assessments had been done by foreign researchers six and forty years ago, respectively.

Peter Wilson-Kelly reported that the NRCA had recently completed a digitized coastal resource map of Jamaica using satellite imagery and aerial photographs. Peter Gayle reported that most of the monitoring activities conducted from the Discovery Bay Marine Lab involved the previously discussed CARICOMP method.

Simon Ciappara emphasized the need for monitoring programs to be flexible, sustainable, with some commercial potential so that income could be generated for further monitoring. He suggested corporate sponsorship as one of many potential financial support options.

2.1.6 Priority Parameters for Coral Reef Monitoring at the National Level

In the final activity for Day 1, Floyd Homer asked representatives from Belize, Jamaica and the Bahamas to list the monitoring parameters that were of primary interest to the respective countries. This provided a summary of the coral reef monitoring parameters that were of national interests to the countries concerned. (Tables 2 to 4).

Table 2: Priority Parameters for Coral Reef Monitoring: Bahamas.

Life Form	Parameter	Comments
Coral	Health, Vitality, Species list	Substrate coverage in quadrats
Algae	Species list	
Sponges	Species list	
Octocoral	Species list	
Fish Populations	Density, Diversity, Biomass (herbivores/carnivores), Species list	
Site Usage	Dive visitors Level of commercial fishing	

Table 3: Priority Parameters for Coral Reef Monitoring: Belize		
Life Form	**Parameter**	**Comments**
Coral and Algae	Abundance Diversity Coral health Live coral/algal cover Disease Bleaching Urchin counts Species presence	Point intercept Weighted bar Video transects (Aronson + EPA protocols) being used at 17 fore reef sites.
Fish	Abundance Species	Commercial species. Belt transects
Physical Parameters	Salinity Water transparency Water temperature Rainfall Air temperature (min/max)	Refractometer Sechhi disc Data loggers Rain gage Thermometer

Table 4: Priority Parameters for Coral Reef Monitoring: Jamaica.		
Life Form	**Parameter**	**Comments**
Coral and Algae	% cover	main life forms
Fish counts	Number Size Diversity Population structure	Emphasis on herbivores (Parrotfish, Acanthurids). Utilize dive operators.
Physical Parameters	Temperature Salinity Dissolved oxygen Turbidity (Secchi) Rainfall BOD COD Nitrate Phosphate	

The lists of parameters were summarized and presented to the workshop on Day 2 for comment regarding the list's completeness.

2.2 Day 2: March 11, 1998.

The goals of the day's proceedings were to;

- discuss the range of methodologies available to monitor the likely impacts of climate change on coral reefs.
- determine the most appropriate coral reef monitoring methodology for C^5.

The likely effects of climate change on coral reefs discussed on the first day of the workshop were summarized and reviewed by Dr. J. D. Woodley (Table 1).

At the end of the first day of the workshop, representatives from Belize, Jamaica and the Bahamas had been asked to list the coral reef monitoring parameters that were of national interests to their respective countries. The lists of parameters were summarized in table form (Tables 2 to 4) and presented to the workshop for comment regarding their completeness. The summary of the discussions follows.

2.2.1 Discussions on the Parameters to be Monitored to Detect the Impacts of Climate Change on Coral Reef s.

It was recommended that coral growth be included in the list as it was considered to be a priority for climate change monitoring purposes, although it might not be rated highly as a national priority. Coral growth was subsequently added to the list of parameters.

Coral recruitment was suggested as an important parameter to be monitored. This was because planula larvae and young coral forms might be more susceptible than adults to UV B radiation might. It was also recommended that attention be given to the shallow reefs that function as break waters, and in particular to *A. palmata.* This raised the question of whether or not indicator species should be added to the list of parameters to be monitored. Butterfly fish were mentioned. Angle fish were mentioned as potential indicator species that might serve as the Caribbean equivalent to the Butterfly fish, although this had not yet been proven

Commercially important species, such as lobster and conch, were recommended as indicator species. The value of these species was acknowledged, and it was suggested that flexibility be employed in selecting a suite of indicator species.
Large corals were also suggested as important indicators. It was noted that their inclusion might require modification to the standard line transect approach to monitoring. Size frequency analysis was suggested as a method of monitoring both coral recruitment and older corals. More specifically the method was identified as "size frequency distribution measurement". Further discussion was differed to the session on appropriate methodology.

2.2.2 Physical and Chemical Parameters

The list of physical parameters that had been selected, comprised; salinity, pH, turbidity, dissolved oxygen, temperature (max/min). Additional parameters on the list were, nitrates, phosphates, biological oxygen demand and sedimentation.

A recommendation was made to have chlorophyll added to the list of physical parameters. This recommendation was agreed to.

2.2.3 Hydro Meteorological Data

This list comprised; rainfall, % cloud cover (the converse being hours of sunshine), air temperature (mean month max/min), and wind speed and direction. There were no recommendations for additions to this list.

With respect to monitoring frequency it was proposed that there would be a need for higher resolution to detect coral bleaching events. It was suggested that it might be necessary to generate hourly means rather than monthly means.

It was agreed to defer discussion of this matter to a later working session as it was felt that this kind of decision would have to be made at a national or site/station level.

It was also suggested that consideration be given to tracking, extreme events (e.g. hurricanes and floods), adjacent land use (e.g. settlement, agriculture) and water use (e.g. fishing and boating) in the vicinity of site. It was further suggested that the environmental history (e.g. storm events) and historical patterns of use should be investigated.

It was noted that the likelihood of increased rainfall due to climate change would make pollution indicators relevant to the development of appropriate *methodologies.*

In closing the discussion on the list of parameters to be monitored, Dr. Woodley noted that monitoring benthic community composition at one stroke would provide information on a number of community characteristics. These included the abundance of coral, algae and other species that occupy bottom space, as well as coral health and coral population dynamics (growth, species diversity, size frequency distribution and recruitment).

After discussion and comments, the amended list of priority parameters was divided between the two working groups (Appendix VI). Each working group was requested to decide on the appropriate methodology for monitoring each of the listed parameters. A representative from each working group presented the methodologies selected by their respective groups. This information was summarized and presented for revision and comment on the morning of Day 3 of the Workshop (Tables 5 and 6).

2.3. Day 3: March 12, 1998.

2.3.1 Working Group Summary Report: Group 2
Rapporteur: Peter Wilson-Kelly

Table 5: Appropriate Methodology for Monitoring Climate Change - Physical and Chemical Parameters - Group 2.

Parameter	Monitoring Method	Comments
salinity pH dissolved oxygen turbidity temperature (max/min)	Portable measuring equipment e.g. YSI Meter	Appropriate methodology will be site dependent. This aspect of methodology can be kept simple. Explore in country capacity to monitor these parameters.
water circulation.		
turbidity	Secchi Disk	
Rain % cloud cover hours of sunshine temp (max/min) wind speed direction.	Data should be accessible from national or institutional meteorological station. Country averages. Rain gage may be sufficient.	
nitrate phosphate BOD chlorophyll sedimentation		May not warrant monitoring if no CC induced run-off at remote site.
Adjacent land use	Info from physical planning units, land use maps, GIS surveys.	Implications for site selection.
On site water activities		An in country consideration

2.3.1.1 Discussion: Appropriate Methodologies for Monitoring Coral Reefs for the Effects of Climate Change- Physical and Chemical Parameters.

Peter Wilson-Kelly presented four points on the subject of data analysis, that Group 2 considered important. They were;

- The need for a national repository for information collected in monitoring exercise.
- The need to standardize data sheets to facilitate the comparison of data between countries
- The need for a regional repository e.g. CARICOMP.
- The need for an international repository for information collected in monitoring exercise.

Following the presentation by the Group 2 representative a number of questions were raised. They were:

◊ who will be responsible for analyzing date and how will the data be analyzed? It was suggested that two persons from each country be trained in data analysis and presentation.

◊ how frequently would the parameters be monitored? It was suggested that, where data sets existed for these parameters, they could be analyzed for trends. These trends could be used to determine the required the frequency of monitoring. Where there are no existing data sets for the parameters in question, they could be monitored on a monthly basis.

The Workshop was advised that the CARICOMP Project monitored physical parameters both on a daily and weekly basis using a mix of portable and deploys able instruments. The deployable instruments used by CARICOMP/DBML measured parameters at 48-minute intervals. In the absence of automatic monitoring equipment, turbidity, water temperature and salinity were monitored on a weekly basis.

◊ The validity of monthly mean data values was questioned as it was felt that one time monthly measurements of water transparency, for example, not good enough.

◊ Logistic considerations were raised. In the case of Inagua or southern sites in the Bahamas, just getting equipment to the sites would be costly, without considering high sampling frequencies. When it was suggested that automatic sampling equipment might address the problem of logistic costs, the problem of theft of such units, was posed.

2.3.2 Working Group Summary Report: Group 1
Rapporteur: Dr. Jeremy D Woodley

Table 6: Appropriate Methodology for Monitoring Climate Change – Biological Parameters - Group 1.

Parameter/Factor	Monitoring Method	Comments
Site selection		Each country selects its own sites. A gradient from less to more impacted sites. A mix of remote and accessible sites. Consider economic & ecological importance.
Depth (existing reef monitoring activities)		**Bahamas:** 2m -5 m. **CARICOMP:** 7 m. - 13 m. **Belize:** Seventeen fore reef sites at 15 m. Nine years Patch reef data for one site. Expand depth range to improve between country comparability by adding five patch reef sites.
Community composition	Video Point intercept line transect	Preferred method most logistically simple & practical space occupier record. Backup method 10 x 10 m transects/site/habitat Permanent (a la CARICOMP)
Coral health	Point intercept line transect random swims photo records aerial photography	Bleaching, disease, recently dead, long dead & size frequency by modifying transect. One time estimate of proportional occurrence of health. *A. palmata*. Ground truth.
Urchins Map corals	Expanded transect	
Coral growth	Schlero-chronology	*M. annularis*, (10 -20 heads)/ 5 to 20 yr.

2.3.2.1 Discussion: Appropriate Methodologies for Monitoring Coral Reefs for the Effects of Climate Change - Biological Parameters.

◊ On the subject of data analysis Dr. Woodley noted that, data analysis for video records of line transects is complex. Questions also arose about intermediate analysis, storage, and archiving. It was noted that **data analysis consumes as much as 80 % of the available budget.**

◊ On the subject of **fish catch monitoring data** to estimate the health of reef populations; it was recommended that catch data be obtained from the national Fisheries Division. This data was usually generated for large sampling areas and was not localized. It was felt that this represented a

source of data that might be available in all three countries.

◊ The **under water visual census technique** was not considered to be an effective monitoring technique as the number of replicates collected at one time or over time, was often insufficient. This was because the high level of variability in reef fish populations would require a large number of counts to detect change.

◊ It was suggested that the assessment of the **size frequency distribution of corals** could be achieved by widening the transects. It was noted that CARICOMP transects were 1 m wide. A minimum count of 50 individuals over ten transects was advised, noting that this count would be dependent on the width of the transects, and the nature of the site.

◊ A recommendation was made for **coral recruitment** to be monitored over smaller sample areas rather than the entire area covered by the line/belt transects. An area of 5 m^2 (representing 80, haphazardly placed, 25 cm. x 25 cm. quadrats) was suggested based on the methodology being used by AGRA. **A final decision on this matter was postponed until after the findings of the AGRA workshop in June**.

◊ It was recommended that ***A. palmata health*** be monitored, as well as the recruitment of new *A. palmata* colonies, which would contribute to the future breakwater function of the reef. The **method of monitoring was to be decided at a later date.**

After a review of the methodological approaches that had been selected the Workshop participants broke up into the three country groups. Floyd Homer directed the participants to consider:

- priority sites for monitoring in their respective countries
- the institutional, material and logistic requirements for conducting the priority monitoring activities in the respective countries.

He asked the participants to not that CPACC had a budget line item for equipment, to be shared among countries. The participants were advised that other funds were available for training, communications, etc. The participants were asked to try to finish their deliberations by 3:30 p.m. Regional scientists were asked to float from group to group to offer advice, rather than congregating in one group.

Before the participants broke up into country groups, it was suggested that the **minimum requirements for site selection be one major CPACC site per country** with the understanding that every country wanted a wider assessment of reef condition based on wider coverage. To this end it was suggested that the selected sites cover a range of human disturbances. The final number of sites in each country would be a national decision, possibly striking a balance between existing and new monitoring activities.

3.0 COUNTRY PRESENTATIONS

3.1 BELIZE

◊ **Site selection:**

Five patch reef locations were chosen since they were the most common coral reef habitat. The five sites were located at;

- Lighthouse Reef (atoll reef)
- Glovers Reef (undisturbed atoll reef, controls)
- Ambergris Caye (barrier reef near San Pedro the main area of tourist development)
- Dangriga (barrier reef, sediment output being measured by operation Raleigh)
- Turneffe Atoll patch reefs (MRC/UCB)

◊ **Personnel:**

- **Lighthouse: Belize Audubon/ Fisheries Division**
- **Glovers Reef: park staff** would soon be in place and would be able to handle the patch reef monitoring in that area.
- **Ambergris Caye:** Primarily **park staff** (Alberto and Dylan).
- **Dangriga:** would be monitored with the assistance of staff from the **Fisheries Division** and the **Coastal Zone Management Project**. A former member of the Fisheries Division staff, **Earl Young**, who had worked with Caroline Rogers, would be available to assist with monitoring and to provide guidance.
- **Turneffe Atoll: MRC/UCB**

◊ **Frequency:** Once per year for coral reef parameters. Data for the physical parameters could be obtained from the **Audubon station on Light House Reef**, where there is a weather station.

Physical parameters around Glovers Reef were being monitored by WCS and could be acquired.

Because of its relative location monitoring physical parameters around Dangriga would be more difficult.

◊ **Resource needs:**

Digital video camera, housing and capture board (total approx. US $7,000)
Hobo Temps
pH meter (4 x US $500)
Videotapes
Refractometer
Software (Coral Point Count, Image Pro Plus)

Trimble GPS (there is a Trimble base station in Belize)

◊ **Training:** Ginger Garrison suggested that it might be possible to arrange a training workshop in the USVI with Walt Japp. The country representatives could be trained while analyzing their country data. It was considered important that a copy of the software be brought to the workshop.

◊ **Estimated total cost of new equipment :** US $14,000.00

3.2 BAHAMAS

◊ **Site selection:**

Three sites were selected;

- New Providence, southern end of island,
- Exuma Cays' and Sea Park, or
- Lee Stocking Island, (ten years of physical data, but shallow water flow patterns are so complex that one cant extrapolate data even to reefs within 1 km of a thermographic site)
- Inagua

Aerial photographs from the Lands and Surveys Dept. will be analyzed to identify specific sites for monitoring.

In terms of levels of human impact, New Providence will be a high human impact site, Exuma medium and Inagua low impact.

◊ **Personnel:**

No capacity in Fisheries Dept. Options that could be considered to overcome this constraint are to enroll the assistance of;

- students from the Collage of Bahamas and trained fisheries officers.
- dive operators on New Providence, and on the south west side of the island. This arrangement would also ensure that equipment and water transport were available.

◊ **Frequency and analysis:**

Twice per year for coral parameters because of marked seasonal differences in climatic conditions. Two weeks per site would be spent at the more remote field sites, using at least two people.

Assistance would be requested from TNC, in making Mark Chiappone available to training and coordinate the initial monitoring efforts.

◊ **Equipment:**

Computer w/ battery packs and software (process data on two week field trips e.g. to Inagua .

Six (6) Hobo Temp mentors (one for each of the three sites, one on rotation and two spares).

Four (4) sets of dive equipment
Digital video:
Tapes
GPS
No need for purchasing equipment to measure physical parameters

◊ **Travel expenses:**

High for the two remote sites. Access to the Inagua monitoring site would involve air fairs at US $200/person. Access to the Lee Stocking Island, Exuma site would involve both air and taxi fairs.

3.3 JAMAICA

◊ **Site selection:**

Six sites to begin with, corresponding to six groups that are already conducting or interested in initiating monitoring programs.
- Portland
- Montego Bay (MBMP,)
-Negril (NCRPS)
-Portland Bight
-Formigas Bank (remote off shore banks)
- Discovery Bay (CARICOMP/DBML)
In addition two sites of interest Site 6 and Pedro Banks are under consideration.

◊ **Equipment and resource needs:**

Monitoring effort will be partitioned between different groups monitoring at the present time. An option is to form a core group that would travel between locations to conduct the monitoring activities. The decision on the site locations for those areas that are not currently managed would be made collectively. Individuals trained in video survey methodology will conduct the monitoring activities in remote areas. They would not have to have species identification ability. The specifics of data collection at the managed sites would be left to the on site personnel. All sites would be monitored using CARICOMP methodology e.g. for selection and randomization of sites. Data would be analyzed and archived at CMS/CARICOMP. There is an immediate need for a digital video camera.

◊ **Frequency:** Once per year. Once per month for water quality.

◊ **Training:** Core group would develop protocol and teach monitoring technicians.

♦ **Time Lines For The Implementation Of The Coral Reef Monitoring For Climate Change Activities**

5.0 C5 IMPLEMENTATION TIME LINES

4.1 BAHAMAS (Table 7)

The Coral Reef Working Group (CRWG) planned to begin its implementation process by initiating dialogue and eventually entering into negotiations with a number of groups. The groups would include;

- the Department of Fisheries : technical assistance, personnel and logistic support,
- the College of the Bahamas: personnel,
- dive operators: personnel and logistic support,
- the Lands and Surveys Department :aerial photographs to assist in the selection of reefs monitoring sites.
- The Nature Conservancy (TNC): training for six to eight people.

Table 7: TIME LINE FOR C5 IMPLEMENTATION - BAHAMAS		**MONTH**										
		M	A	M	J	J	A	S	O	N	D	J
1.	Negotiate collaborative arrangements	■	■	■	■	■	■	■				
2.	Monitoring site reconnaissance: Inagua				■							
3.	Monitoring site reconnaissance: New Providence					■						
4.	Monitoring site reconnaissance: Exuma (LSI)						■					
5.	Training: Benthic sampling (TNC), 6-8 persons.	■										
6.	CPACC visit & institutional assessment.							■				
7.	Training: USVI video data management and analysis								■	■	■	■

4.2 BELIZE (Table 8)

The Belize working group decided to take use the existing Coral Reef Working Group (CRWG), to conduct a general assessment of the country capacity to undertake the responsibilities of implement the C5 project. This CRWG was reported to have been meeting for a number of months prior to the Sub-regional Workshop. It was also recommended that the CRWG be given the responsibility of working out the planning and implementation details for the Belize C5 project. This would include activity coordination and an assessment of equipment needs. All of these activities would be completed by the end of April, 1998.

The existence of a good aerial photograph series would speed up the site selection process, by enabling the CRWG to select potential patch reef monitoring sites quickly. After the precise sites are selected , work could proceed using the existing analog video camera on a trial basis at each of the five proposed monitoring sites. Sites would be monitored at a rate of 1 per month between June and September. Analysis could proceed without sophisticated computer software using the Aronson method, overlaying acetates of random points on the TV screen.

It was anticipated that the first monitoring run could be conducted in early 1999, with all site being monitored at the same time, for comparability, between May and June, 1999.

It was felt that the possibility existed for a fifth monitoring site to be established at the CARICOMP site at Turneffe, if the assistance of students could be arranged. It was noted that monitoring of the reef crest (coral reef breakwater function) was not on Belize time line as there had not been much discussion on the subject at the Workshop. Potential monitoring sites were said to exist, at Bacalar Chico, and Tobacco Reef, where personnel were in place to provide assistance with the monitoring. Some uncertainty surrounded Gallows Point as a potential monitoring site. The working group committed to choosing and ground truthing reef crest as soon as possible.

Table 8a: TIME LINE FOR C5 IMPLEMENTATION - BELIZE		**MONTH -1998**										
		M	A	M	J	J	A	S	O	N	D	
1.	General assessment by CRWG		■									
2.	CPACC visit & institutional assessment			■								
3.	Site selection and initial data collection at 4 –5 sites				■	■	■	■				
4.	Training: USVI video data management and analysis								■			

Table 8b: TIME LINE FOR C5 IMPLEMENTATION – BELIZE		MONTH -1999										
		J	F	M	A	M	J	J	A	S	O	N
5.	C5 monitoring activities	■	■	■	■	■	■	■	■	■	■	■

4.3 JAMAICA (Table 9)

Because of the familiarity of the members of the working group with the reefs in their respective locations around Jamaica's coast, and their proximity to potential sites, they were confident that they could initiate and complete the preparations for implementation in a comparatively short period of time. There was also the possibility that the existence of data from previous surveys might make preliminary assessment unnecessary in some cases.

The working group expected to be able to use data from the C5 monitoring activities in the proposed training workshop on video data management, interpretation and analysis, in the USVI.

Table 9: TIME LINE FOR C5 IMPLEMENTATION - JAMAICA		MONTH 1998											
		M	A	M	J	J	A	S	O	N	D	J	
1.	General assessment by CPACC	■	■										
2.	Purchase equipment		■	■	■								
3.	Site selection			■	■								
4.	Set up permanent monitoring stations						■	■					
5.	Training							■	■				
6.	First data sets from monitoring								■	■			
7.	Training: USVI video data management and analysis									■	■		

5.0 EVALUATION

The participants were asked to evaluate the C5 Sub-regional workshop using a standard evaluation format. The results of the evaluation are presented in Appendix IV.

APPENDIX I

A list of the participants in the Sub-regional Workshop
Component 5: Coral Reef Monitoring for Climate Change.

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Ciappara, Simon	Executive Director	PEPA, 6 Allan Ave., Port Antonio, Portland, Jamaica	(876) 993-9632		
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Garrison, Ginger	Marine Biologist	USGS, P.O. Box710, St. John, US Virgin Islands	(340) 693-8950	(340) 693-9500	ginger-garrison@usgs.gov
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Name	Title	Address	Phone	Fax	*e-mail*
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APPENDIX II

Caribbean Planning for the Adaptation to Global Climate Change
Summary Report: the Meeting on the Implementation of Component 5
OAS Headquarters
Washington, USA, October 8, 1997.

Planning for this workshop was initiated at a meeting at the OAS Headquarters, Washington, USA, on 08 10 97. Participating in the meeting were; Claudio Volonte (CPACC Technical Coordinator, OAS), Eleanor Phillips (Fisheries Department, The Bahamas), Janet Gibson (Coastal Zone Management Project, Belize), Jeremy Woodley (Center for Marine Sciences, UWI, Jamaica). The purpose of the meeting was to begin planning the implementation of Component 5. A number of decisions were reached in the meeting that guided the agenda of the Sub-regional Workshop (Appendix I). The decisions that were made by the meeting's participants were as follows:

It would be advantageous to use the CARICOMP sites within each country as part of the CPACC network of sites to help ensure some long-term continuity in the program.

A three day, Sub-regional Workshop would be held in mid-February, with three to four representatives form each country attending.

A document summarizing the current status of coral reef monitoring would be prepared in time for the workshop.

Topics for the workshop would include;
- a review of the monitoring methods used locally and regionally,
- a review of institutional capacity in the governmental and non-governmental sectors,
- agreement to be reached on monitoring methods and material, institutional and logistic needs,
- the long-term sustainability of the program after the CPACC project ends.

The Sub-Regional Workshop would be followed by In-country Workshops that would provide training in the chosen methodologies for participating Governmental and Non-governmental agencies, user groups and marine protected area staff.

Public awareness activities in support of Component 5 would primarily be carried out by NGO's in each country.

The three country representatives participating in the workshop would maintain contact via e-mail to continue discussion on appropriate monitoring methodologies in preparation for the sub-regional workshop.

Each country representative would investigate possible venues for the Sub-regional Workshop.

It was suggested that an output of Component 5 could be a manual clarifying possible methodologies applicable under different situations.

APPENDIX III

Draft Agenda
CPACC
Component 5: Coral Reef Monitoring for Climate Change
Sub-regional Workshop
Fiesta Inn, Belize City, Belize,
March 10 -12, 1998.

Tuesday, March 10th, 1998

8:00	Welcome by representatives of the Government of Belize and the OAS	
8:30	Presentation 1: CPACC, Component 5 and linkages with and support from other CPACC components. Leslie Walling (CPACC/RPIU) and Claudio Volonte (CPACC/OAS)	
9:00	Presentation 2:	What are the effects of climate change on coral reefs and what should we be looking for? Dr. Jeremy Woodley (UWI/Mona), Melanie McField (U of Fl.) and Dr. Judy Lang (U of Tx, Austin)
10:00	Coffee Break	
10:15	Presentation 3:	Review of past and current long-term coral reef monitoring approaches and methodologies. Drs. Woodley and Ginger Garrison (USGS/USVI)
10:45	Presentation 4:	Global and regional monitoring programs. Drs. Woodley, Lang and McField.
11:30	Discussion	
12:00	Lunch	
2:00	Presentation 5:	Coral Reef monitoring activities in the Caribbean, specifically in the 3 participating countries. Janet Gibson (Coastal Zone Mgt. Unit, Belize), Eleanor Phillips (Fisheries Division, The Bahamas) and Dr. Woodley (Jamaica).
3:30	Coffee Break	
3:45	Presentation 5 (cont.) and Discussion	
5:30	Closing	

Wednesday, March 11th, 1998

8:30 Working Session: Discussion on Component 5.
Dr. Floyd Homer (CPACC/RPIU)
Questions/hypothesis to be addressed regarding predicted impacts of climate change on coral reefs;
Methods, pros and cons;
Site selection;

10:00 Coffee Break

10:15 Working Session (cont.)

12:00 Lunch

2:00 Working Session (cont.)
Plan of action for component implementation

3:30 Coffee Break

5:00 Closing

Thursday, March 12th, 1998

8:30 Summary: Preliminary design of the Coral Reef Monitoring for Climate Change program.
Leslie Walling

10:00 Coffee Break

10:15 Conclusion

12:00 Lunch

1:00 Optional Field Trip: Diving in the Belize coral reefs.

APPENDIX IV.I

Presentation by: Dr. J. D. Woodley, Director, Center for Marine Sciences, UWI, Mona, Jamaica.

Introduction

Coral reefs are carbonate structures at or near sea level, which supports viable populations of corals. They are constructed by carbonate producing animals called coral polyps, which live in a symbiosis with algae that process the coral's waste before it is excreted.

These structures grow in warm sea (minimum 20 degrees Celsius) and are important for many islands. Reefs provide many valuable functions. Some of these functions are (1) shoreline protection (2) sand sediment for beaches (3) support fisheries (4) support tourism.

Coral reefs are the marine equivalent to tropical forest and are taxonomically diverse and highly productive (primary productivity are 300-50009g cm^{-2}/y) (Ogden et al, 1982). That make up 0.1% of the earth surface; Caribbean coral reefs make up approximately 12% of all coral reefs.

Globally coral reefs are on the decline due to many destructive forces at work on the resource. This is occurring at a very rapid rate (Clarke, 1992). There are two groups of stressors affecting coral reefs: natural and anthropogenic stressors. Natural stress may be caused by:

(1) an outbreak of animals like the crown-of-thorn starfish

(2) whiteband and blackband disease

(3) hurricanes causing physical damage

(4) bleaching and

(5) die off of key species like the parrotfish and sea urchin that keep the reef clear of algae. (Clarke, 1992)

The increased use of the coastal zone increases direct and indirect impacts on coral reefs. Man's activities are superimposed over natural stressors. Damaging activities include: (1) siltation and sedimentation due to dredging, filling, other constructive activities and soil erosion.

(2) pollutants including oil spills, industrial wastewater and domestic sewage

(3) large amounts of fresh water run-off, due to diversions and storm-water outfalls.

(4) destructive fishing practices e.g. dynamite

(5) sale of young fish in aquarium trade

(6) tourist visits to reefs which result in breakage from boats and anchors (UNESCO, 1994)

Many stressors lead to sedimentation and eutrophication, which smother coral polyps limiting photosynthesis. Despite an increase awareness of the beauty and value of coral reefs and a greater amount of scientific information available, there is still a general decline in the integrity of coral reefs.

Caribbean Coastal Marine Productivity (CARICOMP) network collects and compiles information regarding the status of reefs for the long-term regional comparative study on biodiversity and Caribbean coastal ecosystem productivity. Since 1992, CARICOMP has examined seasonal and episodic changes. This monitoring exercise will allow one to 'discriminate between variability and human impact and assist in sustained regional coral reef management'.(UNESCO, 1994).

APPENDIX IV.II

Presentation by: Emily Schmitt, Ph.D., The Nature Conservancy

In the following presentation, I will discuss a coral reef monitoring program that The Nature Conservancy is conducting in the Bahamas through the Marine Conservation Science Center and with funding from the United States Environmental protection Agency and the Jeniam Foundation. The Marine Conservation Science Center is part of The Nature Conservancy located at the University of Miami, Department of Biology, under the direction of Dr. Kathleen Sullivan.

I will describe what we are trying to do, what we measure and how we conduct measurements. I will specifically discuss the need to be able to monitor for the detection of human-induced (anthropogenic) changes to coral reef systems in the context of global climate change. In order to know the effects of Global Climate Change, it will be important to know the effects of natural and human-induced changes, in addition to what may be global climate changes. This teasing apart of factors affecting change in coral reef communities is the major challenge we all face in doing marine research and ecological monitoring.

This particular research program has been initiated as a two-year project examining:

Ecological and economic sustainability of tropical reef systems by conducting an assessment of land-based sources of pollution and potential ecological threats in the Exuma Cays, Central Bahamas

The Project examines long-term impacts of coastal populations on near shore patch reefs in two areas of the Bahamas; the populated Nassau Harbor and the relatively unpopulated Exuma Cays Land and Sea Park. We are conducting ecological sampling in these two areas during both the summer and winter. We are able to examine both temporal changes over a 50-year history of development on the island of New Providence (particularly Nassau Harbor) as well as spatial comparisons of similar reef environments between inhabited and uninhabited islands. Patch reef sites were selected in a transect from near shore to offshore islands with varying population densities. The hypothesis is that there is some population density at which non-point sources of pollution begin to alter coral growth and the overall reef community.

This project has four specific research tasks that provide information for regional marine resource conservation and sustainable use planning (See handout).

1) Comparison of water quality parameters for patch reefs near populated Nassau Harbor and unpopulated Exuma Cays Land and Sea Park Islands.

2) Investigations of the ecology of large groupers including habitat and prey requirements

that may determine grouper home range as an indicator of harvesting intensity.

3) Construction of a regional economic model of the long-term economic impact of the Exumas Park as a natural area and marine fisheries reserve in the Central Bahamas. This includes a tourism/visitor survey, an evaluation of park management and financial planning, and an assessment of local businesses influenced by the Park.

4) Establishing a regional data management strategy and data center to make information more accessible for regional planning.

When conducting marine ecological monitoring work, it is important to keep the goals of marine conservation in mind.

Several of these goals are:

Minimize coastal impacts, land-based sources of pollution

Preserve linkages from hydrological cycles
Rain, tides, rivers

Sustainable harvesting

In order to meet these goals, we have to recognize the existence of various anthropogenic threats (as well as effects of global climate change) to coastal systems such as:

Water-quality degradation
Point and non-point sources
Pollutants, contaminants
Physical impacts
Recreational,
Groundings, anchors
Harvesting impacts
First order effects (changes in populations of predators, i.e. target species)

Second order effects (changes in populations of herbivores, i.e. non-target species)

These threats often go hand-in-hand with economic development.

For example, the cruise ship industry (cruise ship slide) can bring tourism money and economic interest to an area while at the same time increasing the potential for pollution and serious anchor damage.

There are several different characteristics related to coral reef ecological status that we are measuring in Nassau Harbor and the Exuma Cays (see handout). These are:

Sediment nutrients
Water column characteristics
Coral health
Benthic coverage
Fish populations

These parameters are being measured at 6 sites in Nassau Harbor and six sites in the Exuma Cays Land and Sea Park. Additionally, we hope to be working in Georgetown Harbor in the near future. This work involves a team of 7-10 people working 2-3 weeks in the summer and 2-3 weeks in the winter.

I will now briefly explain how these characteristics are measured:

Sediment nutrients:

N and P are measured in the sediments around patch reefs in Nassau vs. the Exuma Cays Land and Sea Park.

Water Column characteristics:

N, P, salinity, temp., DO, and chlorophyll content are measured at sites in Nassau Harbor and the Exuma Cays land and Sea Park at dawn, dusk and high and low tide (slide)

The establishment of permanent reef monitoring sites Nassau Harbor (populated) and Exuma Cays (un-populated) required three steps:

1-- the reconnaissance of the area and mapping of reef communities

2-- installation of pins for the marking of permanent plots (5m x 5m with 5 permanent transects within these plots)

3-- collection of information on reef benthic fauna (including corals, algae, and sponges) as well as fishes.

Coral Health:

We are quantifying coral vitality (coral health and incidence of disease, species lists, sediment deposition rate, and coral recruitment and growth within permanent 1 m^2 quadrats within the permanent 5m x 5m monitoring plots at each site.(slides)

Benthic Coverage:

Point intercept coverage (slide) based on a 1 m^2 quadrat with 100 points. Twenty of these quadrats are conducted at each site.

Algae species list

Sponge species list

This includes the use of a chain transect for measuring topographic complexity and a depth and temperature profile for the sites.

Fish populations

Density, diversity, biomass of herbivores

Density, diversity, estimated biomass of predators

Total fish species list

This was done by counting the fish present within 5 m^2 quadrats during 10-minute time intervals. These quadrats were repeated 20 times at a site.

We examine the herbivores (slides of blue tang and redband parrotfish), which are eaten by the predators (grouper slide), and in turn we have done some studies in the Florida Keys to examine the algae, which grow starting from a bare substrate when herbivores are missing. Show slides of exclusion cages, what grew inside how the benthos in the cage was measured, and how fast the algae was consumed once the cages were opened.

Predominately *Spyridia sp.* grew in these cages over 6 months during the summer. Once these cages were opened, fishes consumed all the algae within 2 hours.

In the Bahamas on the patch reef study sites, we have put down plain tiles to see how much algae grows on these plain tile substrates in the different areas which are subjected to different nutrient levels and other water conditions. From data that have been analyzed so far, it appears that herbivorous fish communities are very similar among all the sites, so any differences in algal coverage would be expected to be due to differences in available nutrients, not grazing, at least grazing by fishes.

We are also recording the species composition and relative abundance in the $\log_{10}$ categories of Single (1), Few (2-10), Many (11-100), and Abundant (>100) for the entire fish assemblage at the patch reef sites. To do this, we are using methodology developed by the Reef Environmental Education Foundation (REEF)..mention handouts… as part of the REEF Fish Survey Project. REEF is an NGO founded by marine life photographers and authors Paul Humann and Ned DeLoach to educate volunteers in fish identification and conduct fish surveys. The survey method used is called the roving diver technique. This survey method involves a diver swimming around a site and recording the species of fish that are seen and their abundance categories. Standardized data-sheets are used and data are scanned into a special database where reports can be generated via the web site http://www.reef.org/. This is the type of program that volunteers get excited about doing, especially when it can be part of their regular recreational dives. More and more SCUBA divers are being trained in fish identification and survey techniques and can be a valuable (almost free) resource for surveying fish populations, especially when done in conjunction with local dive shops or tour groups.

I have given an overview of the reef monitoring work The Nature Conservancy is conducting in Nassau and the Exumas. Elements of this work could be adapted for any reef-monitoring program to examine process related phenomenon such as changes in water quality, herbivory recruitment, and predation.

APPENDIX IV.III
Presentation by: Dr. Judith Lang

Changes at the Earth's surface occur all of the time. During the last 600 million years, atmospheric CO_2 has been ten times or more greater than it is today, and global temperatures have been 10 degrees Celsius or more higher than they are today.

Between 18,000 year ago (end of last glacial low stand) and the late eighteenth century, atmospheric CO_2 has increased from 180 to 280 ppm, atmospheric CH_4has increased from 350 to 750 ppb, sea level has been raised by 150m and global temperature by five degrees Celsius. In the late 18^{th} century, the oceans were a source of CO_2 for the atmosphere.

In the last 200 years, atmospheric CO_2 has increased to almost 360 ppm, atmospheric CH_4 to 1,700 ppb, atmospheric N_2O from 285 to 310 ppb, and CFC concentrations from zero to several hundred trillion. All of these are greenhouse gases which, by absorbing reradiated long wave IR radiation, can lead to an enhanced greenhouse and so potentially modify global climate.

In the last 100 years, there has been an ~0.5 degree Celsius increase in mean global temperatures. Between ~1870 and 1940 an average annual temperature increase of ~ 0.14 degrees Celsius per year was recorded. At lease some of this may have been due to the "recovery" of Earth's climate system from the end of the Little Ice Age (which has lasted from the 15^{th} century through the mid-19^{th} century).

Between 1940 and the mid-1970s Earth's temperature underwent a slight, erratic cooling. The cause of the cooling is debatable and may have included the effects of anthropogenic SO_2 emissions. Since the mid-1970s, global mean temperature has risen by about 0.02 degrees Celsius/year i.e., faster than earlier in the century . Is this a global warming signal?

Global Carbon Budget:

In the 1980s, fossil fuel combustion and land use practices released 7.0 ± 1.2 Gt C/year to atmosphere. Approximately 3.2 Gt C/year remained in the atmosphere; ~ 2.0 ± 0.8 G plus C year was taken up by the oceans. There is a "missing sink" of about 1.8 Gt C/year . It is generally thought that some or much of this is taken up by terrestrial ecosystems, by plants, and soils, especially at mid-latitudes in the Northern Hemisphere.

Note: As temperature warms, the capacity of the ocean to store carbon is likely to be decreased as the CO_3^{2-} (carbonate ion) is titrated by increased anthropogenic CO_2 and warmer water can hold less CO_2 (i.e. CO_2 is less soluble in warmer water). However, ultimately the storage capacity of the ocean will be increased by the dissolution of the carbonic minerals calcite and aragonite in the deep ocean. - After F. T. Mackenzie (300 %)

Re Coral Calcification: Aragonite is oversaturated (300%) in present warm tropical seawater.

If atmospheric CO2 doubles, the PH of the seawater will decrease by about 0.3 PH units – aragonite would still be oversaturated, but quite as much (..240%). - After L. S. Land

APPENDIX V.I
Coral Reef Monitoring Activities in the Caribbean - BAHAMAS
Presented by: Eleanor A. Phillips

The Commonwealth off the Bahamas is an independent nation within the British Commonwealth. It comprises the only example of a large open island system lying within the Atlantic Ocean tropics and consists of a 260,000 square kilometer archipelago that extends over 800 kilometers between southeast Florida and Hispaniola.

There are many areas with fine extensive and virtually untouched coral reefs. A shallow-water Fisheries Resources survey found that reefs covered 1832 sq. km (2.2%) of the Great Bahamas Bank and 324 sq. km (2.2%) of the Little Bahama Bank. (Higgs in lit., 21.9.84). Living coral reefs fringe most of the windward northern and eastern coasts and the bank edges (Storr, 1964 and 1959) and hermatypic corals are widely distributed around the leeward edges and in areas sheltered from bank waters. Reef corals are generally absent from the shelf lagoon of the Great Bahama Bank on account of turbidity, but the banks do support small patch reefs whenever a rocky substrate shows through the constantly forming oolitic sediments.

Reefs in the Bahamas are relatively healthy and scientists have used the Bahamas reefs as a control for reef studies for many years. There are however, areas that are heavily impacted especially around the population centers, for example, Nassau Harbour, New Providence.

The CPACC project will be coordinated through the BEST (Bahamas Environment Science and Technology) Commission's Climate Change Committee. The Department of Fisheries will serve as the executing agency for the Coral Reef Monitoring Component. This department is responsible for the management and development of fisheries in the Bahamas. In addition, the Department of Fisheries is responsible for issuing annually an average of 400 scientific research permits to foreign researchers, about half of which are directly related to research on coral reefs. Once permits are issued, researchers are responsible for submitting reports and/or publications resulting from their work.

The Department of Fisheries has 8 officers who could be utilized once trained, to impart monitoring methodology to persons selected to do the actual monitoring work. There is a need within the Department for capacity building and a great need to impart monitoring techniques and training to fisheries officers.

There are a number of groups within the Bahamas who could be utilized to assist with component 5 of the CPACC Project. The College of the Bahamas has just established a Research Division and it is hoped that we would be able to involve students interested in Marine Biology in this project. There are also a number of Field Stations in the Bahamas: BERC (Bahamas Education Research Center) and Forfar Field Station in Andros; Caribbean Marine Research Center, Lee Stocking Island, Exuma; Bimini Biological Field Station, Bimini; The Bahamian Field Station, San Salvador.

NGO's that could offer logistical or public awareness support are;

- the Bahamas National Trust; a quasi government organization established by an Act of Parliament in 1959, responsible for the management of the Bahamas National Park system;
- Oceanwatch, a commercial dive operators organization;
- BREEF the Bahamas Reef Environment Education Foundation and the Andros Ad-Hoc Committee on Conservation.

The Nature Conservancy (TNC), Marine Conservation Science Center, located at the University of Miami is continuing a multi-disciplinary project concerning ecological sustainability of tropical reef systems in the Central Bahamas. TNC seeks in this project to solicit scientists to get involved with marine parks and protected areas. We would expect TNC to be of great assistance in implementing this climate change component as they are already involved in monitoring a reef system in the Exuma Cays' Land and Sea Park.

The Bahamas has also just completed a Biodiversity Data Management (BDM) Plan, a UNEP funded project. This project was implemented to facilitate communication within government agencies in areas of environmental concern and to disseminate Biodiversity information to help with decision-making and to assist in identifying ecological hot spots. The BDM Plan has identified the BEST commission as the agency to hold Biodiversity data sets and information from the monitoring of sites for Component 5 of the CPACC project could be deposited in this system.

Initially, it was decided that the Bahamas would monitor ten sites that would encompass a variety of user levels. The following were suggested: Walker's Kay ; Central Abaco;
Freeport, Grand Bahama; Central Andros Barrier Reef; New Providence; Exuma Cays Land and Sea Park; Southern Exumas; Rum Kay; San Salvador and Inagua.

APPENDIX V.II

Coral Reef Monitoring Activities in the Caribbean – BELIZE

Coral Reef Monitoring in Belize - An Overview

Presented by: Janet Gibson.

Introduction

Coral reef monitoring in Belize started for the most part within the framework of the CZM programme which began in early 1990 with the establishment of the CZM Unit in the Fisheries Dept. One of the main activities recognized was the need to monitor any changes on our reefs due to anthropogenic stresses and climate change. The results of such monitoring would help to guide management measures to be implemented. There was at the time concern regarding a possible increase in algal growth on the reefs; this was, however, just anecdotal information and there was no quantitative data available. The importance of collecting data as soon as possible to serve as a baseline against which changes could be measured was also recognized, as well as the need to link this to the water quality monitoring programme that was being initiated at the same time.

Initial Monitoring Efforts

Recognizing this need, the newly-established CZM Unit requested assistance from CEHI which was based in St. Lucia to help set up a monitoring system. Dr. David Shim then came to Belize to work with the Unit's biologist, Earl Young, and he introduced the straight-line chain transect method. Earl had also received training in monitoring techniques during an earlier attachment to the Park in USVI, under Dr. Caroline Rogers. As a result of the CEHI consultancy, transect data was collected and a database set up in 1992. In 1994 a report was completed by Earl and included the data collected for 4 permanent sites along the barrier reef:

- Tackle Box off San Pedro,
- 2 sites on Gallow's Pt. reef, and
- one on Tobacco Reef.

These preliminary results showed a hard coral cover ranging from 16% to 29%. Data was subsequently collected from an additional 3 sites:

- at Glover's Reef and
- one at Half Moon Cay.

Although comparisons cannot be made between these initial surveys, they can serve as baseline data for future monitoring efforts. During the time, the Unit also formed a Reef Monitoring Committee to discuss the merits of various methods, the equipment and personnel needs, site selection, etc. Sites were selected to represent different reef types, extent of use, degree of terrestrial influence, proximity to coastal development and taking into account ease of access and

available manpower.

At a meeting of this group in 1995, monitoring at different levels or scales was recommended e.g. detailed monitoring by CARICOMP sites, at a medium-scale either using video or transect methods, and at a large scale using satellite imagery or aerial photography. During this meeting, a list was compiled of the equipment that was available, the data analysis that would be required, and a list of the sites and organizations that would be responsible for the monitoring of each site. Over the years, there had been much discussion as to what would be the most suitable method to use. Due to the constraints of the chain transect method i.e.

- highly trained personnel and significant field time required,
- the small area surveyed, and
- the risk of damage to the reef through this method,

the Working Group agreed that the video transect method, as described by Richard Aronson, was the preferred technique. This technique is less time consuming in the field, can be used by a wider range of people, a wider area can be covered, and the data can be archived for future use.

Other Activities

During this period, 2 areas were established as CARICOMP monitoring sites:

- Carrie Bow Cay (by the Smithsonian) and
- Hol Chan Marine Reserve.

it was felt that other sites could be established where there were permanent staff such as at other marine research stations and marine reserves. The Hal Chan Marine Reserve has also conducted reef monitoring and monitoring of lobster and conch populations since the reserve was established (and perhaps James or Alberto can explain this more during the discussion). Over the years, Kathleen Sullivan from TNC has been carrying out reef fish surveys using visiting volunteers through their REEF (Reef Environmental Education Foundation) programme. This data can help in detecting differences of fish populations due to different management regimes such as inside and outside marine reserves, or areas of different levels of use, and can look at select species such as predators and herbivores, reflecting the general health of a reef. Raleigh International has also been monitoring sediments on the reefs near Coco Plum and Cary Cays for the past couple of years. Using sediment traps in mid-1995, the Fisheries Dept. and WCS hosted a regional workshop on coral reef monitoring, with participants from all the Central American countries and Mexico. The recommendations included comments on mapping, data management, the parameters to be monitored, information exchange, and training and funding.

More Recent Efforts

As a result of the Working Group decision, the CZM Project, a GEF/UNDP Project that began in early 1993, decided to invest in the equipment required for the video monitoring method. The CZM Project had also included reef monitoring as one of its major activities and pointed out the need to identify indicator species e.g. specific corals such as elkhorn, large predators such as groupers, and sea urchins, etc. Due to constraints with personnel, however, the programme has been sporadic and has acquired data primarily through collaboration with Melanie's work (Melanie will be explaining more about the actual methodology and also her specific project in a moment). Nevertheless, during the bleaching event of 1995, data was collected using a specially adapted video technique, and additional data was collected at the sites later in 1996. At some sites, individual coral colonies were tagged and their recovery monitored using still photography. This exercise has been

documented and also fed into the regional report compiled by CARICOMP.
during the bleaching data collection and the routine monitoring process, the private sector has assisted to a limited extent; however, there are NGOs based in San Pedro (Green Reef), Cay Caulker (Siwa Ban) and Punta Gorda (TIDE) who would be interested in assisting with the programme. The ESTAP project in P.G. is already collaborating with the CZM Project in the water quality monitoring programme.
CARICOMP sites have been extended to Calabash Cay, Turneffe Islands, managed by UCB's MRC based there; TNC also has a CARICOMP site in Port Honduras, but this is looking at seagrass and mangroves; there are plans to establish a site at Glover's Reef and possibly at Bacalar Chico.
through the efforts of the biologist at Bacalar Chico Marine Reserve, Dylan, the Monitoring Working Group has recently been re-vitalized with an updated set of objectives and terms of reference established
Dylan has also been carrying out basic monitoring using the transect method at this reserve and again he can probably expand on this during the discussion time
I would also like to mention that Reef Check which was held in connection with the IYOR, had one of its sites off Ambergris Cay in Belize but we have not yet received the results of this survey
finally, Belize is planning to take part in the AGRA (Atlantic and Gulf Reef Assessment) protocol which is a rapid reef assessment method; this process can possibly help in the selection of sites that need to be monitored in the future.

APPENDIX V.III

Coral Reef Monitoring Activities in the Caribbean -JAMAICA
Presented by: Malden Miller.

Mailer (1982) collected qualitative data in the vicinity of the Montego Bay Marine Park. This was the first known documentation of the reefs in the area. Percent coral cover was greater than 70%.

In 1992 The Nature Conservancy (TNC) conducted a Rapid Ecological Assessment (REA) of the Montego Bay Marine Park. This has formed the basis for additional research in the Marine Park. The REA utilized belt quadrats as the main data-collecting instrument along with presence/absence surveys and substrata and life form characterization. The target life forms were coral, algae, soft coral and sponges. The main substrate categories were sand-mud, sand, rubble and hard reef. The sites were selected using GPS and a community base map was produced.

The Park does not have a coral reef monitoring in the pure sense although several plans have been drafted. We rely on special projects to answer specific questions related to our needs.

In 1995 a student from Harvard conducted a joint benthic and water quality survey in the Marine Park entitled: Eutrophication: the death angel of coral reefs in the Montego Bay Marine Park.

In 1997, the British Overseas Development Agency funded a project to conduct benthic surveys in several Caribbean countries. The Montego Bay Marine Park was one of the chosen sites in Jamaica. Photo-quadrats were used at the selected sites. The sites will be revisited in 1998.

Monthly fish counts were conducted at select sites using the Bohnsack & Bannerot (1986? Or is it 1987) technique in 1993. This will form the basis for comparative studies once these sites are revisited.

A comprehensive environmental monitoring program was conducted in the Park as part of a Montego Bay Sewerage Improvement Sub-project, one component of the Northern Jamaica Development Project. Areas looked at were Biological Monitoring, Water Quality monitoring, Oceanographic Survey, Study of Pollution Load, Literature Survey, Simulation Study of Water Quality, Environmental Impact Analysis, Study of Alternatives and Countermeasures and a Training Program consisting of a series of Workshops. Institutions that received training included the Montego Bay Marine Park, Natural Resources Conservation Authority (NRCA), Water Resources Authority and the National Water Commission (NWC). Monitoring was conducted from January 1992 to June 1996. Having done the in depth study water quality monitoring is done quarterly by staff from the Montego Bay Marine Park and the National Water

Commission. The NWC analyzed the water samples and the Park staff provide the boat and field assistance.

In addition to monitoring for biological and physical parameters, a number of socioeconomic surveys have been done in the Park funded by the CIDA through the Caribbean Conservation Association (CCA) and the World Bank. The World Bank is also conducting an economic valuation of the coral reefs in the Montego Bay Marine Park.

APPENDIX VI

EVALUATION: Technical Workshop for the Implementation of Component 5
Coral Reef Monitoring for Climate Change (CPACC)
March 10-12, 1998
Belize City, Belize

1. **How much did you know before the workshop about:**
(1 not much; 4 very much) (percent of actual responses)

	1	2	3	4
CPACC	40	20	30	10
Monitoring of coral reef techniques	20	10	30	40
Monitoring programs in the region	20	45	30	5
Impacts of climate change on coral reef	20	20	40	20

2. Did you find the workshop useful in improving your knowledge about these topics:
(1 not useful: 4 very useful)

	1	2	3	4
CPACC	0	10	10	80
Monitoring of coral reef techniques	5	20	30	45
Monitoring programs in the region	5	0	65	30
Impacts of climate change on coral reef	5	15	40	40

3. Do you like to receive more materials/documentation about these topics?

CPACC	Yes	11	No	2
Monitoring of coral reef techniques	Yes	14	No	2
Monitoring programs in the region	Yes	14	No	2
Impacts of climate change on coral reef	Yes	13	No	2

4. In your opinion, what were the workshop's strong points?

- Its informality, the information provided, its flexibility, and focus towards having consensus on decisions.
- Ability and willingness to share information on other monitoring projects in the regional.
- Time management to achieve goals.
- Excellent leadership of workshop and different sessions
- Many knowledgeable committed participants. Expertise of facilitators & presenters/lecturers
- Interaction of participants: opportunity to meet people and agencies involved in monitoring.
- Bringing together in-country managers, officers, project organizers, scientists and field specialist to outline work that will be done to begin reef monitoring
- Introduction to CPACC
- Reef Monitoring Techniques.
- Expert technical assistance.
- Stimulating monitoring effort within the countries.
- It was well organized and the participants were motivated to participate/comment on all topics discussed.

5. What were the weak points?

- Starting a bit late at times.
- Having a bit more time for country presentations to be able to understand what is happening with respect to results/data in different countries.
- Perhaps could (maybe not) have used more "structure" in country presentations to ensure participation by all participants.
- There seemed to be some confusion over the budget and moneys that would be available.
- More information on how the budget would be divided between the countries.
- More specific documentation in relation to climate change.
- It would have been good if the scope of the objective had allowed for monitoring sites other than those associated with climate change.
- We could have gone to the meat of the topic at a sooner time by preparing country presentations for circulation before arriving at the workshop.
- Effective group leaders were needed to reduce/eliminate going off on a tangent and keeping the group focused on what was required.
- Not being able to get copies of information discussed/issues agreed on at the end of the day/workshop.
- OAS true ($) commitment s to project.
- Conclusions not as firmly decided as I had hoped/anticipated.
- To much repetition on facts and decisions that one always being fought over. Stop wasting time and put it to a vote. Use the voting system.

6. What topic(s) would you like to have added or receive more emphasis?

- More time needed on defining actual methodologies to ensure uniformity of approach.
- More information on data capture/analysis methods.
- More time needed for discussing strengths & weaknesses of methods and effects of climate change.
- More details of the actual methodology that will be used in the Project – but this will be presented and discussed in the workshop summary document, and will be variable at the different sites in the region.
- To come to a firmer conclusion as to what parameters would be measured.
- Specific impacts on reefs due to climate change.
- Small presentation on public education that the project can serve as a springboard for.
- Have someone (form Australia maybe) who has monitored reefs for climate change share their experience. What do we do it there are catastrophic impacts.
- More time was needed to develop detailed monitoring methods.
- The true justification of all the organizations like the UNEP, OAS etc. involvement in the project.
- Primary site selection & the ability to draw inference across the region with high confidence.
- Funding and focal points for this project (pilot)

7. What actions/initiatives will you take in your country based on what you learned in this workshop?

- To help coordinate the monitoring activities agreed on and to provide support for the data management and analysis components.
- Re-evaluation of present methodology especially with respect to. sample size.
- Some modifications of methods and will try methods which are new to me (haven't field tested)
- Initiate training workshops
- Communicate among different potential collaborators and other people within my organization.
- Try to get budget support for reef assessment and monitoring activities in the country because we are very weak in this area.
- Implementation of monitoring project in The Bahamas.
- Assist Department of Fisheries, Bahamas, with raising Public Awareness of the Project.

- Education for the layperson.
- Help implement the programs in this pilot program.
- Implementation of monitoring of reefs for climate change.
- Coordinating the group that will be assisting with setting up and conducting the monitoring.
- Promote programs/projects that promote coral reef conservation/monitoring.
- There has been no coordinated effort at coral reef monitoring in country. The CPACC Program may prove to be the catalyst that will bring this to life.
- Assess our (Marine Parks) capability of doing monitoring and initiate the process regardless of CPACC.
- Try to involve myself in other monitoring projects as well as try to get support of students at the University to become involved in monitoring programs.
- Start the monitoring program geared for data collection for CPACC.
- Try to improve communications among certain academicians and professionals to further support regional efforts.
- Start to set my sites and get preliminary data.