Reef Health Monitoring to Inform Climate Change Policy in Jamaica

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Abstract: The Caribbean Planning for Adaptation to Climate Change (CPACC) project was a regional programme established in the Caribbean in 1998 by CARICOM countries in response to the growing concerns regarding the impacts of climate change. Component 5 of this project 'Coral Reef Monitoring for Climate Change Impacts" was implemented in three pilot countries, of which Jamaica was one, and was designed to establish a long term coral reef monitoring programme in the region. Despite challenges related to human and financial resources Jamaica was able to institutionalize the monitoring programme with field monitoring carried out by the National Environment and Planning Agency (NEPA) and data processing and analysis conducted by the Centre for Marine Sciences (CMS). Three Operational Areas were established (Eastern Portland, Discovery Bay and Port Royal) and monitored over the period 2000 to 2003 and 2007 to 2011 using the CPACC video monitoring protocol. This paper presents the results of this long term monitoring for climate change impacts for Discovery Bay on the north coast of Jamaica. Data analysis of the other two sites is ongoing. Over the monitoring period the benthic substrate was dominated by macroalgae and dead coral with algae. Hard coral cover ranged from 6.7% (2000) to 12.56% (2011) with a steady increase observed over the period 2007 to 2011. *Porites astreoides*, *Siderastrea siderea*, *Montastraea annularis* and *Agaricia agaricites* were the most commonly occurring species during the monitoring period. This study represents the only long term monitoring programme to result from the CPACC project.

Key words: Discovery Bay, Jamaica, video monitoring, coral reefs, long term monitoring, climate change

Introduction

In 1998 the Caribbean Community Secretariat (CARICOM) with the assistance of the Organization of American States (OAS), received funding from the Global Environment Facility (GEF) for the Caribbean Planning for Adaptation to Climate Change (CPACC) project. This project was developed in response to growing concerns regarding the impact of global climate change on the region. The goal of CPACC was to build capacity for adaption to climate change impacts in the Caribbean. The majority of CARICOM countries, including Jamaica, participated in the CPACC project through vulnerability assessment, adaptation planning and capacity building activities (Creary, 2001).

Component 5: *Coral Reef Monitoring for Climate Change Impact* represented one of the nine components of the CPACC project. This pilot–based component was aimed at establishing a long-term monitoring programme that could detect climate change impacts on coral reefs. Specialists from regional and international organizations collaborated to formalize the methodology. The pilot phase was implemented in the Bahamas, Belize and Jamaica in 2000 with the expectation that the programme would be expanded and institutionalized in all the CARICOM countries (Lawrence and Edwards, 2001). However, the CPACC project ended in 2001 with Jamaica being the only country able to institutionalize the Component 5 monitoring as originally envisaged.

Subsequent to this, funding was provided under the Mainstreaming Adaptation to Climate Change (MACC) project to conduct a second phase of monitoring in seven additional CARICOM countries (Antigua and Barbuda, Dominica, Grenada, St Kitts and Nevis, St Lucia, St Vincent and the Grenadines and Trinidad and Tobago). Under Component 1 of the MACC project support was provided to conduct monitoring over the period 2007-2009 (Creary, 2009).

This paper presents the results of the monitoring that was carried out at Discovery Bay on the north coast of Jamaica, during 2000-2003 and 2007 -2011.

Material and Methods

Site Selection

The selection of operational areas was based on the site selection protocol developed by Woodley (1999) for the CPACC project. This guide proposed that each country be responsible for selecting their own operational areas based on a gradient of least to most impacted, a mixture of remote and accessible sites and with consideration being given to their economic and ecological importance. In Jamaica three operational areas were selected, they were Monkey

Island in Portland (representing least impacted), Discovery Bay in St Ann (representing moderately impacted) and Port Royal Cays outside of Kingston Harbour (representing severely impacted) (Fig. 1). Within these operational areas the mixed zone, consisting primarily of spur and groove formations and dominated by the reef framework builder *Montastraea annularis*, was selected as the target habitat for monitoring. Monitoring was carried out within the depth range of 7-13 m.

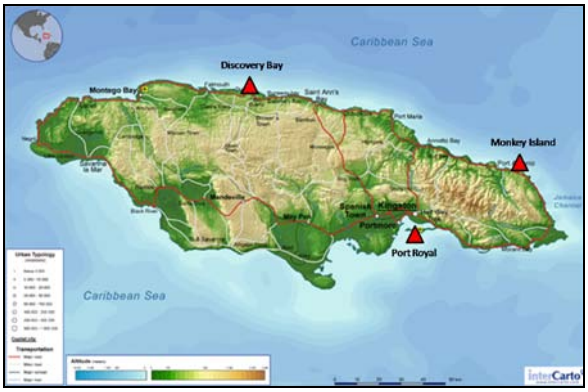

Figure 1: Map showing Jamaica and the location of the monitoring sites of Discovery Bay, Monkey Island and Port Royal.

Description of the Monitoring Site at Discovery Bay

The monitoring site of "Gorgo City" is located near the town of Discovery Bay, in the Parish of St Ann along the north coast of Jamaica (Fig. 2). The main activities taking place in this area includes bauxite export, fishing, tourism and research (Discovery Bay Marine Laboratory). The monitoring site, which is considered to be moderately impacted by human activities based on the criteria outlined in the site selection protocol (Woodley, 1999), has a gently sloping profile with a continuous fringing reef in a spur and groove formation developed on the narrow submarine shelf typical of the north coast of Jamaica (Gayle and Woodley, 1998).

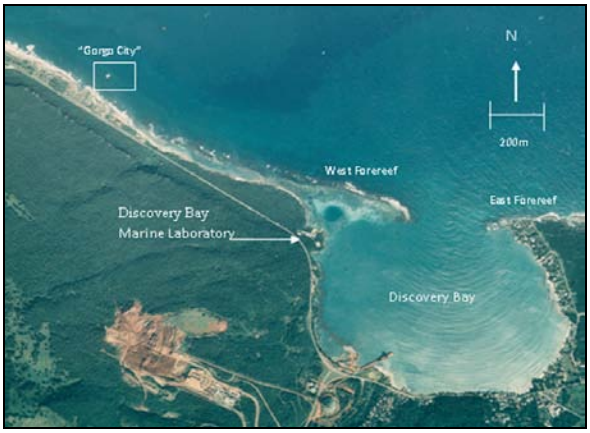

Figure 2: Aerial photograph showing the location of the monitoring site at "Gorgo City", Discovery Bay.

Over the past 30 years there have been dramatic changes on reefs along the north coast, which were once dominated by corals. According to Woodley *et al* (2000), AGRRA (Atlantic and Gulf Rapid Reef Assessment) surveys of 47 sites along the north coast in 2000 at an average depth of 9m indicated that the mean percentage coral cover was 12%. Previous assessments of the reefs close to Discovery Bay conducted in 1997 (Woodley *et al* 2000), produced mean percentage coral cover of 15% at 5m, 16% at 10m and 11% at 15m. During this assessment the most commonly encountered coral species were the opportunistic *Porites astreoides*, *P. porites* and *Agaricia agaricites.*

Monitoring Protocol

The benthic cover of the coral reefs was monitored using underwater videography following the CPACC Video Monitoring Protocol (Miller, 2000; Miller and Rogers, 2002). Twenty transects, each 20m in length, were located randomly (2003-2004) and fixed (2007-2011) within the target habitat parallel to the depth contour within a depth range of 7-13m. In 2007 permanent transects were installed and monitored annually. The divers used a high resolution digital video camera fitted with a wide angle lens and videotaped the transect while swimming slowly and holding the camera perpendicular to the substratum at a height of approximately 40cm. Prior to filming, a slate containing transect metadata (site name, date, depth, transect number and videographer) was recorded on the videotape. Field monitoring was carried out during the months of October to November by the staff of the National Environment and Planning Agency (NEPA, formally the Natural Resources Conservation Authority).

The resultant video tapes were catalogued and the content of each tape logged. With a Sony™ Mini DV Player connected to the computer and utilizing specialized software (Pinnacle Studio 9™) adjacent non-overlapping images were captured, dotted and stored as image files. Images were initially analyzed using Microsoft Excel and Adobe Photoshop in combination with Winbatch for Windows for monitoring carried out over the period 2000-2003. Subsequent analysis was conducted using the more user-friendly Coral Point Count with Excel Extension (CPCe) software (Kohler and Gill, 2006). Prior to the change comparative analyses were conducted on the same datasets which indicated that the CPCe results were comparable to those obtained using the previous CPACC software set up. The data processing and analysis was conducted by the Caribbean Coastal Data Centre (CCDC) of the Centre for Marine Sciences (CMS) at the University of the West Indies. (UWI).

Results

Benthic Substrate

The results of the monitoring conducted during the periods 2000 to 2003 and 2007 to 2011 are presented in Table 1. Hard coral cover ranged from 5.91% (2003) to 12.56% (2011) (Fig. 3). There is a gap in the dataset between 2004 and 2006 because monitoring was not conducted during the period. Mean coral cover showed a steady increase from 9.37% in 2007 to 12.56% in 2011.

The results showed that the area was dominated by macroalgae, making up between 30.37% (2001) and 54.74% (2010) of the benthic substrate (Fig. 4) and to a lesser extent by dead coral with algae (0.16 – 26.76%). The algal species commonly found were *Dictyota*, *Lobophora* and *Sargassum*. The gorgonians accounted for less than 1% of the benthic cover, except in 2002 (5.03%) and 2011 (1.20%). Sponges were not very abundant at this site as they accounted for only 0.61% (2000) to 2.04% (2002) of the benthic cover. Zoanthids were rarely observed and were only seen to occur in five of the nine years (2001, 2007, 2009, 2010, and 2011) and accounted for less than 1% of benthic cover. Coralline algae cover was highest in the earlier years (2000 to 2003) where they accounted for between 6.72% (2001) and 13.52% (2003) of the benthic cover. For the period 2007 to 2011 the maximum cover of 6.36% was obtained in 2010.

The category comprising sand, pavement and rubble made up between 11.95% (2009) and 30.26 % (2011) of the benthic substrate. In the data entry sheets developed under CPACC project (Miller, 2000; Miller and Rogers, 2002) there was included a separate category for "recently dead corals", described as "recently dead corals, devoid of algal growth with indentation of polyps still visible". This category was included in the "dead coral with algae" in the CPCe program. However, even though this category was assessed separately for the period 2000 to 2003 it did not account for more than 4% of the benthic substrate.

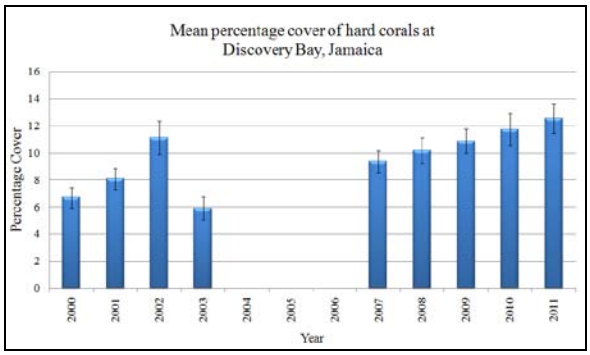

Figure 3: Graph showing the mean percentage coral cover found at "Gorgo City, near Discovery Bay, Jamaica over the period 2000-2003 and 2007-2011. (The standard error bars are shown).

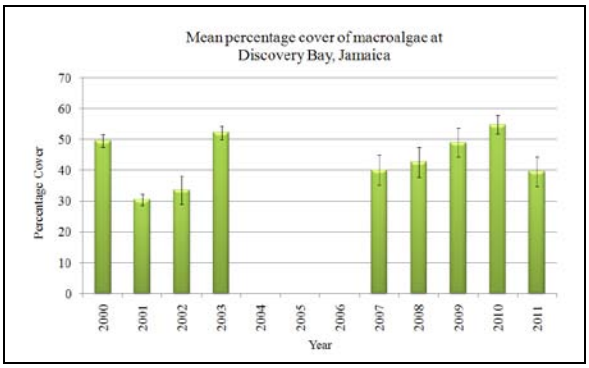

Figure 4: Graph showing the mean percentage cover for macroalgae found at "Gorgo City" near Discovery Bay, Jamaica over the period 2000-2003 and 2007-2011. (The standard error bars are shown).

Coral Species

Approximately 40 coral species were identified during the monitoring period. The most abundant species were *Porites astreoides*, *Montastraea annularis*, *Siderastrea siderea* and *Agaricia agaricites*. Other commonly occurring coral species

Substrate Category	2000	2001	2002	2003	2007	2008	2009	2010	2011
Hard Coral	**6.70**	**8.08**	**11.13**	**5.91**	**9.37**	**10.17**	**10.88**	**11.74**	**12.56**
Gorgonians	**0.14**	**0.37**	**5.03**	**0.28**	**0.64**	**0.21**	**0.74**	**0.97**	**1.20**
Sponges	**0.61**	**0.25**	**2.04**	**1.12**	**1.91**	**0.78**	**0.89**	**0.99**	**1.61**
Zoanthids	**0.00**	**0.03**	**0.00**	**0.00**	**0.42**	**0.00**	**0.21**	**0.35**	**0.56**
Macroalgae	**49.49**	**30.37**	**33.59**	**52.08**	**40.06**	**42.49**	**48.98**	**54.74**	**39.56**
Other Live	**0.30**	**0.17**	**0.61**	**0.44**	**0.63**	**0.73**	**0.31**	**0.27**	**0.89**
Dead Coral With Algae	**15.63**	**24.60**	**12.21**	**7.77**	**26.76**	**19.53**	**25.73**	**0.16**	**9.85**
Coralline Algae	**9.86**	**6.72**	**12.21**	**13.52**	**0.04**	**0.05**	**0.03**	**6.36**	**3.14**
Diseased Corals	**0.00**	**0.00**	**0.11**	**0.05**	**0.01**	**4.94**	**0.02**	**0.00**	**0.00**
Recently Dead Corals	**3.98**	**0.28**	**0.81**	**2.01**					
Sand, Pavement, Rubble	**12.74**	**28.88**	**22.25**	**16.82**	**19.74**	**20.74**	**11.95**	**23.61**	**30.26**
Unknowns	**0.53**	**0.26**	**0.02**	**0.00**	**0.40**	**0.35**	**0.27**	**0.82**	**0.36**
Sum	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Table 1: Summary of the mean percentage cover for the benthic substrate categories found at "Gorgo City" near Discovery Bay, Jamaica over the period 2000-2003 and 2007-2011.

which were observed on at least seven of the nine sampling occasions were *Diploria labyrinthiformis*, D. *strigosa*, *Millepora alcicornis*, M. *complanata*, *Montastraea cavernosa*, M. *faveolata*, and P. *porites*. The number of coral species observed during the 2000-2001 period ranged from 8-17 while for the period 2007-2011 the number of species varied between 21 and 26. These results would tend to indicate an increase in species diversity over time.

Temperature and Rainfall

The mean monthly temperature and total monthly rainfall data for Discovery Bay was obtained from the Meteorological Service, Jamaica, for the period 2000-2011 (Fig. 5). During this period the highest temperatures were observed during the months of August and September (31.5°C) with maximum means of 32.0°C recorded in September 2001 and September 2002. The mean monthly minimum temperatures were generally seven degrees lower than the maximum for the corresponding month. The lowest mean was recorded for February with a value of 21.0°C.

Monthly rainfall totals exhibited the bimodal pattern typical for Jamaica. The highest periods of rainfall were experienced in the wet seasons of May (167mm) and October (166mm). The dry seasons occurred over the period February-March-April and June-July-August where the monthly total rainfall ranged from 57-91mm.

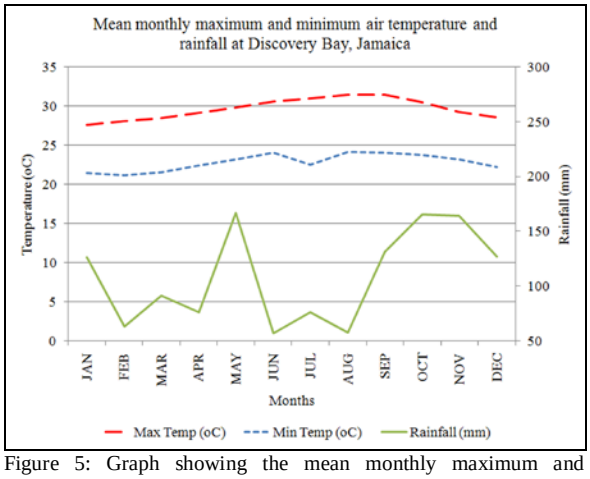

Figure 5: Graph showing the mean monthly maximum and minimum air temperature.

Hurricanes and Bleaching

The combined effect of hurricanes and bleaching has had varying impacts on the reefs of the north coast of Jamaica. These impacts have been dependent on the intensity, duration and path travelled by the storm. During the period 2000 to 2008, a total of 13 storm systems ranging from tropical depressions to category 4 hurricanes passed within a radius of 100 nautical miles of the island. Five of these systems passed along the north coast; Debby and Helene between 24 August and 19 September 2000, Lili (September 2002), Dennis (July 2005) and Olga (December 2007). Tropical Storm Lili which was later upgraded to a hurricane passed within 50 nautical miles of the monitoring site and may account for the reduction in coral cover recorded in the 2003 assessment.

Mass bleaching was recorded for several sites on the north coast of Jamaica (Jones *et al*, 2008) in 2005 when sea surface temperatures were above average for approximately 5-6 weeks. Observations of up to 80% bleaching were reported but unfortunately for this monitoring programme no assessments were carried out during the 2004 -2006 period.

Discussion

The data showed that after more than ten years of monitoring at Discovery Bay the site is still dominated by macroalgae which remained at around 40-50% of the benthic cover. Coralline algae appeared to be making a comeback over the 2010 to 2011 period and dead coral with algae appear to be on the decline. Coral cover for the period 2007 to 2011 showed a gradual increase in coral cover (9.37% to 12.56%). The observed increase in coral cover and coral diversity (as suggested by the higher number of coral species) may indicate a gradual recovery in Discovery Bay. However, changes in the monitoring protocol such as the introduction of fixed transects, the improvement in video camera and tape playing equipment and the adoption of the CPCe software may have resulted in an improvement in data processing and analysis. Notwithstanding, the coral cover values were in keeping with those results reported in the *Status of the Environment Reports* (NEPA, 2011) for Jamaica, which stated that coral coverage has remained stable at around 13% over the past three years.

These results represent the only ongoing institutional scientific coral monitoring programme being conducted in Jamaica at this time. The previous long term coral monitoring studies was conducted through the regional Caribbean Coastal Marine Productivity (CARICOMP) programme which came to an end for Jamaica in 2003.

In most countries of the region the establishment of long term coral reef monitoring programmes comes with challenges, these invariably include the lack of adequate human and financial resources. Often programmes are initiated as projects but once the funding period has ended the responsible institutions are not able to continue without additional support. The CPACC coral reef monitoring programme was implemented to initially establish baseline conditions and then to document the change in coral reef health,

represented by percentage coral cover, over the long term. At the time of the implementation of the programme the new and emerging video monitoring technique was selected because it had the advantage of reducing the time required under water and also that the video tapes could be re-evaluated if required. The use of the video monitoring protocol has aided in the continuation of this programme and the monitoring for each site can be completed in a maximum of two days. The results obtained using this protocol were similar to the generally reported conditions observed in the AGRRA and CARICOMP assessments of the coral reefs in Jamaica (Creary, 2001; Creary *et al* 2006).

Recommendations to include additional assessments such as fish counts, coral growth, bio-erosion indicators and physiochemical parameters were not initially implemented due to capacity constraints. However, recent efforts have been made to include roving diver fish assessments as well as fish biomass and rugosity measurements. Despite the challenges, Jamaica has been able to successfully institutionalize the coral reef monitoring programme in the work plans of both NEPA and CMS. This has been formalized through the signing of a Memorandum of Understanding between NEPA and CMS/UWI to conduct research and provide technical support.

Coming out of the CPACC programme the CMS/UWI has been able to provide technical support to other countries of the region and has facilitated the long term monitoring in the island of Tobago by conducting the analysis of the video tapes for the past 5 years (2007-2011)(Creary, 2009; Creary, 2011).

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