The results of long term coral reef monitoring at three locations in Jamaica: Monkey Island, "Gorgo City" and Southeast Cay

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Abstract: The global and regional impacts of climate change are having devastating consequences on the coral reef ecosystems of the Caribbean. Long term monitoring are important tool for assessing reef health. Monitoring was established in 2000 in the Bahamas, Belize and Jamaica. Following the pilot project, the program was institutionalized in Jamaica and monitoring was conducted on eight occasions from 2000 to 2010. Monkey Island and "Gorgo City" near Discovery Bay (both on the north coast) and Southeast Cay at Port Royal on the south coast were selected. Macroalgae dominated the benthic substrate. Monkey Island and "Gorgo City" had the highest coral cover. *Porites astreoides*, *Montastraea* spp., *Porites porities, Siderastrea siderea*, and *Agaricia agaricites* were the most common species. Data from this programme have been used in local and regional coral reef assessment and management initiatives. Rev. Biol. Trop. 62 (Suppl. 3): 65-73. Epub 2014 September 01.

Key words: Discovery Bay, Portland, Port Royal, Jamaica, video monitoring, coral reefs, long term monitoring, climate change.

In 1992 the Intergovernmental Panel on Climate Change (IPCC) highlighted the vulnerability of low-lying island states to the impacts of climate change, particularly as it relates to sea level rise and increased sea surface temperatures (IPCC, 1992). This report pointed out that coastal ecosystems and populated low lying coastal plains would experience the most severe impacts and went on to recommend that the identification and assessment of the potential risks to coastal areas, islands and coastal resources be undertaken. This growing concern about the vulnerability of the small island developing states to the threats of climate change was highlighted in the United Nations Global Conference on Sustainable Development of Small Island Developing States held in Barbados in1994. Climate change, climate variability and sea level rise were identified as issues of grave concern and as such were judged to be priority areas in the Barbados Programme of Action (BPOA), which outlined specific actions to be taken to address these special challenges (UN, 1994). The Caribbean Planning for Adaptation to Climate Change (CPACC) project was subsequently implemented as a regional initiative coming out of the BPOA and was designed to address the issues related to climate change with a view to building capacity to adapt to climate change impacts. CPACC was implemented in the countries of the English speaking Caribbean during the period 1998-2001 with the Organization of America States (OAS) as the executing agency and funding provided by the Global Environmental Facility (GEF) through the World Bank (Deeb, 2002).

Component 5: The Coral Reef Monitoring for Climate Change Impact Programme was one of nine components of the CPACC project

established in 1998. A multidisciplinary forum comprising specialists from governments, Non-Governmental Organizations, CARICOM (Caribbean Community Secretariat) institutions and experts from the scientific community formulated this long term coral reef monitoring program for the assessment of reef health and to inform management decisions. Other expected outcomes included obtaining knowledge on the extent and sources of coral reef degradation within the region. The pilot project was implemented at the national level in The Bahamas, Belize and Jamaica, with the objective of having the monitoring programme eventually expanded and to all CARICOM countries (de Berdt Romilly, 2001; Creary, 2006). Recommendations coming out of the evaluation of the pilot project strongly supported the implementation of a regional coral reef monitoring program (Lawrence & Edwards, 2001) however, this did not materialize.

Jamaica is located in the northern Caribbean and is the largest English speaking country in this region. The island has a fringing reef developed on a narrow shelf on the north coast and patchy reef formations developed on a wide shallow shelf on the south coast (Gayle & Woodley, 1998). The Jamaican reefs were thought to be in excellent condition in the 1950's when much of the coral reef research was initiated (Goreau, 1959). Since that time the impacts of hurricanes (Woodley, 1991; Rogers, 1993), coral diseases (Bruckner, Bruckner & Williams, 1997; Knowlton, Lang,, Rooney & Clifford, 1981) and the loss of the herbivorous sea urchins (Hughes, Keller, Jackson and Boyle, 1985), as well as overfishing (Hughes, 1994) and nutrient loading (Lapointe, 1997) have resulted in a decline in the health of these reefs. Superimposed on these anthropogenic factors were the impacts resulting from climate change, particularly elevated sea surface temperatures which have resulted in mass bleaching events (Jones, et al., 2008; Crabbe 2010). These issues have, in large part, led to a change in the general structure of the benthic community, where macroalgae now cover the reefs that were once dominated by corals (Hughes, 1994).

This paper presents the results of the coral reef monitoring programme implemented under the Component 5: Coral Reef Monitoring for Climate Change Impacts of the CPACC project that was carried out at three locations in Jamaica (Monkey Island, "Gorgo City" and Southeast Cay) during the period 2000-2003 and 2007-2010.

MATERIALS AND METHODS

Site selection and description: The protocol for the selection of the Operational Areas was developed by Woodley in 1999 (Creary, 2001; Creary, 2006; Creary, Jones Smith & Green, 2012; Deeb, 2002) for each of the pilot countries (The Bahamas, Belize and Jamaica). Three reef sites were established in Jamaica, according to this protocol, to represent a gradient of anthropogenic impacts. These sites were Monkey Island (also known as Pellew Island) in the Parish of Portland (18º10'56"N, 76º47'5"W), "Gorgo City" near Discovery Bay in the Parish of St Ann (18º28'40N, 77º25'46"W) and Southeast Cay, one of the Port Royal Cays in the Parish of Kingston (17º53'56"N, 76º23'27"W). Monkey Island, which was selected as a minimally impacted site, was located on the northeast coast of the island in an area of limited land-based stressors. There were no built up areas, industrial activity or agriculture production in close proximity to the reef site (NRCA, 1995). The major economic activity was eco-tourism with a few villas located along the coast. The fringing reef was made up of spurs and groves, developed on a narrow submarine shelf with a moderate sloping profile. The Discovery Bay reef site was located centrally along the north coast, just North West of the bay in an area called "Gorgo City" (approximately 1.4km North West of the Dancing Lady site). The main economic activities in and around the Discovery Bay area included artisanal fishing, bauxite loading, tourism and research (Gayle & Woodley, 1998). The reef formation was similar to that

of Monkey Island consisting of the gently sloping spur and grove formation developed on a narrow submarine shelf. Southeast Cay, which forms part of the Port Royal Cays, is located on the south coast of the island just offshore of the capital city of Kingston. The Cays are comprised of a series of small coral islets situated on the island shelf which forms a protective barrier for the Palisadoes tombola and the town of Port Royal. The reef formation at Southeast Cay exhibits a gentle to flat profile. Despite being located outside of the eutrophic Kingston Harbour (Morrison & Greenaway, 1989) this area is important for artisanal fishing, recreation, tourism and transshipment activities (Mendes, 1992).

Video monitoring: The location of the transects within the designated Operational Areas were randomly selected following the procedure outlined in the Draft Site Selection Protocol developed by Woodley in 1999 (Creary, 2001; Deeb, 2002). A total of 20 transects, each 20m in length, within the depth range of 7-13m, were established for each reef site. The benthic substrate was monitored using the video monitoring protocol developed for the CPACC project (Miller, 2000; Miller & Rogers, 2002). Coming out of the Technical Review Workshop held at the end of the pilot project in 2001, Woodley recommended the change from random to fixed transects which would eliminate variation and facilitate direct comparison over time (Lawrence & Edwards, 2001). However, because of resource constraints this change in methodology was not implemented until 2007. Monitoring was carried out at Monkey Island, "Gorgo City" and Southeast Cay annually for the period 2000-2003 and 2007-2010 between the months of September to November.

Data processing and analysis: The resultant video tapes were checked for clarity, then numbered, catalogued and the content of each tape logged. Non-overlapping images were captured from the video tapes using a Sony™ Mini DV player connected to a computer loaded with the Pinnacle Studio™ software. During the early stages of the monitoring programme (2000-2003), a specially-developed CPACC software format, involving the use of Adobe Photoshop in combination with Winbatch for Windows, was used to place the10 random dots on the captured images. The benthic component under each dot was identified and entered into a Microsoft Excel spreadsheet designed to tabulate and summarize the data (Miller, 2000; Miller & Rogers, 2002). With the development of the more user friendly Coral Point Count with Excel Extension (CPCe) tool for the determination of coral cover (Kohler & Gill, 2006) the CPACC protocol was modified and the analysis of the captured images for the period 2007-2010 was carried out using this new tool.

RESULTS

Hard coral cover: Coral cover was generally low, falling below 15% at all three monitoring sites (Table 1). Hard coral cover ranged from a low of 6.2% (SE±0.8) in 2002 to a high of 14.6% (SE±2.4) in 2010 at Monkey Island in Portland. Notwithstanding the gap in the monitoring between the years 2004-2006, hard coral cover showed a moderate increase from 12.2% (SE±2.4) in 2007 to 14.6% (SE±1.3) in 2010. For 'Gorgo City" near Discovery Bay hard coral cover ranged from 5.9% (SE±1.2) in 2003 to 11.7% (SE±1.2) in 2010. This site also exhibited a slight increase in coral cover during the second period of the monitoring programme (2007-2010) ranging from 9.4% (SE±0.8) in 2007 to 11.7% (SE±1.2) in 2010. In contrast, the Southeast Cay site at Port Royal exhibited very low levels of hard coral cover throughout the entire monitoring period. Values ranged from 0.9% (SE±0.3) in 2009 to a high of 2.2% (SE±0.4) recorded in 2003. The hard coral cover of 1.3% (SE±0.3) recorded in 2010 points to a gradual decline over the 10-year period (Fig. 1). *Porites astreoides, Montastraea spp, Porites porities, Siderastrea siderea,* and *Agaricia agaricites* were the most commonly occurring coral species at Monkey Island and "Gorgo City" while *P. astreoides*

TABLE 1
Summary of the mean percentage cover for hard coral at Monkey Island, Portland; "Gorgo City" Discovery Bay and Southeast Cay, Port Royal, Jamaica for the periods 2000-2003 and 2007-2010

Year	Monkey Island, Portland		"Gorgo City", Discovery Bay		Southeast Cay, Port Royal	
	Mean	SE	Mean	SE	Mean	SE
2000	7.1	0.9	6.7	0.7	2.1	0.3
2001	11.2	1.1	8.1	0.8	1.2	0.3
2002	6.2	0.8	11.1	1.2	2.1	0.6
2003	11.8	1.8	5.9	1.2	2.2	0.4
2007	12.2	2.4	9.4	0.8	1.3	0.4
2008	10.5	2.1	10.2	1.0	1.5	0.5
2009	14.6	2.4	10.9	0.9	0.9	0.3
2010	14.6	1.3	11.7	1.2	1.3	0.3

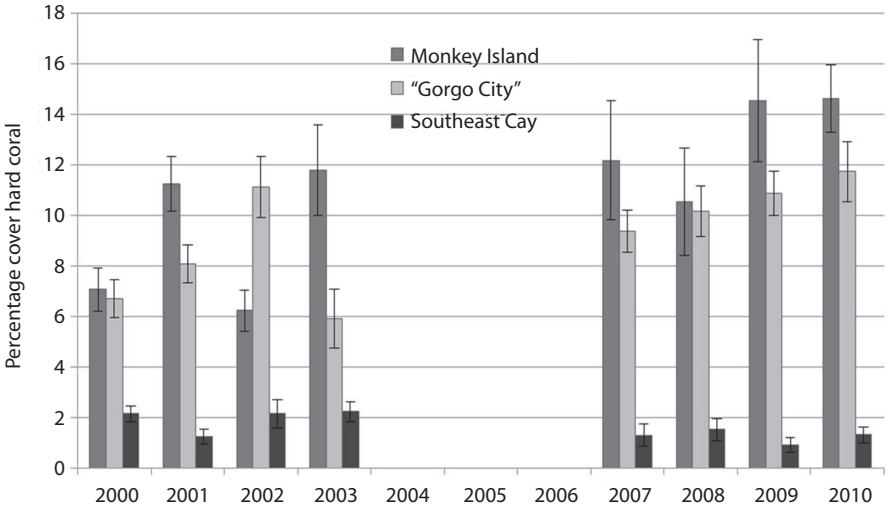

Fig. 1. Mean (with S.E.) percentage cover of hard coral at Monkey Island, Portland, "Gorgo City" Discovery Bay, St Ann and Southeast Cay, Port Royal, Kingston, Jamaica during the period 2000- 2003 and 2007 to 2010.

and *Montastraea spp* were the common species at Southeast Cay.

Macroalgae: The benthic substrate was dominated by macroalgae at all three monitoring sites (Table 2). At Monkey Island the macroalgal cover ranged from a low of 26.9% (SE±4.1) in 2001 to a high of 55.9% (SE±4.0) in 2003. However, macroalgal cover did not exceed 50% during the 2007-2010 period with a value of 40.5% (SE±5.8) recorded in 2010. For "Gorgo City" near Discovery Bay macroalgal cover ranged from 30.4% (SE±1.8) in 2001 to 54.7% (SE±2.9) in 2010. For this site macroalgal cover was showing an increasing trend. The macroalgal cover recorded at Southeast Cay, Port Royal, ranged from a low of 43.0% (SE±1.9) in 2000 to a high of 95.7% (SE±0.4) in 2007. Of note is the dramatic increase in macroalgal cover for the 2007-2010 monitoring period, with values exceeding 90% for all four years (Fig. 2). *Dictyota, Lobophora* and *Sargassum* were the macroalgal species commonly found at all three sites.

TABLE 2
Summary of the mean percentage cover for macroalgae at Monkey Island, Portland; "Gorgo City" Discovery Bay and Southeast Cay, Port Royal, Jamaica for the periods 2000-2003 and 2007-2010

Year	Monkey Island, Portland		"Gorgo City", Discovery Bay		Southeast Cay, Port Royal	
	Mean	SE	Mean	SE	Mean	SE
2000	52.3	2.6	49.5	2.1	43.0	1.9
2001	26.9	4.1	30.4	1.8	55.7	3.8
2002	55.0	2.3	33.6	4.5	58.5	3.1
2003	55.9	4.0	52.1	3.1	53.6	2.3
2007	36.3	5.7	40.1	4.9	95.7	0.4
2008	43.9	6.2	42.5	5.0	94.6	1.0
2009	49.1	6.7	49.0	4.7	94.8	1.1
2010	40.5	5.8	54.7	2.9	94.9	1.0

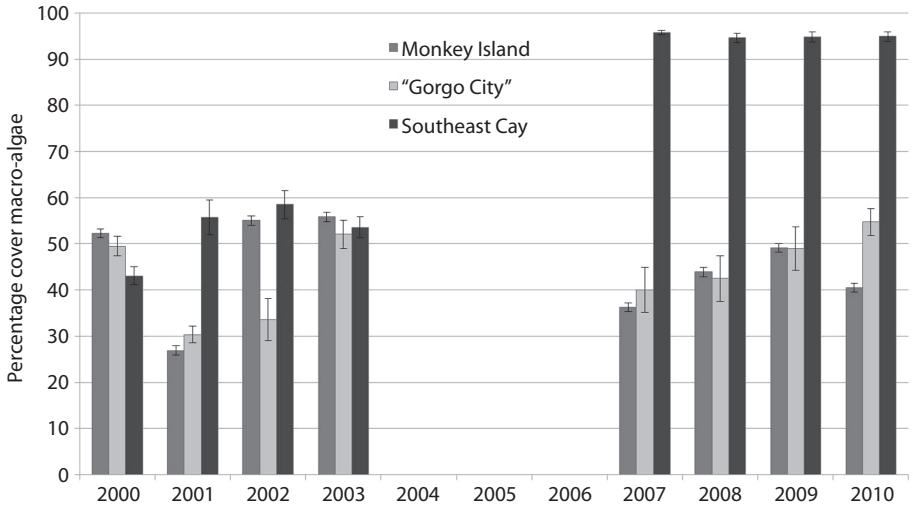

Fig. 2. Mean (with S.E.) percentage cover of macroalgae at Monkey Island, Portland, "Gorgo City" Discovery Bay, St Ann and Southeast Cay, Port Royal, Kingston, Jamaica during the period 2000- 2003 and 2007 to 2010.

DISCUSSION

There is a vast body of literature that has documented the decline of coral cover and the resultant increase in other taxa, particularly macroalgae (Gardner, et al., 2003; Cote, Gill, Gardner & Watkinson, 2005; Mumby et al., 2007; Creary et al., 2008) and in most cases human activity has been implicated (Hughes, Baird, Bellwood, Card & Connolly, 2003). Schutte, Selig and Bruno (2010) in their analysis of 875 sites over a 35 year period showed that region-wide hard coral and macroalgae cover have changed very little since 1980, however, they suggest that there were local spatial-temporal variations in the benthic structure underlying this broad pattern.

The results presented here are of importance because they document the long term dynamics of three Jamaican reef ecosystems. For this monitoring programme coral reef health was assessed by looking at the relationship between hard coral and macroalgae. Coral cover at the two north coast sites (Monkey Island and "Gorgo City") showed a small but gradual increase particularly for the period

2007-2010. In contrast, for the Southeast Cay site on the south coast, coral cover was low and declining. All three sites were dominated by macroalgae; however, the north coast sites maintained cover at around 50% while on the south coast macroalgae cover increased dramatically to over 90% by 2010.

Indications are that for the north coast sites coral cover is making a comeback and that macroalgae cover in remaining relatively stable. Crabbe (2011, 2012) in his studies carried out between 2000 and 2008 concluded that the corals around Discovery Bay exhibited good resilience, particularly with regards to coral recruits. Cho and Woodley (2000) indicated that prior to the start of this study, the reefs at Discovery Bay were recovering and they attributed this to the recruitment and growth of opportunistic coral species such as *P. asteroides, P. porites and A. agaricites,* aided by the increasing abundance of *Diadema antillarum.* These coral species are still an important component of the coral community on the sites monitored during this study. Cho and Woodley's (2000) study also showed that coral cover was variable with a mean of 15.9% at 10m while mean macroalgae was 56.5% at the same depth. Similar results were reported for the CARICOMP (Caribbean Marine Productivity Program) site on the west forereef of Discovery Bay where coral cover remained relatively constant at around 11% during the period 1994 to 2007 (Gayle, Charpentier, Spence & Levre, 2010). A more recent study by NEPA (2011) has also reported that coral cover on a number of sites around the island has stabilized at around 13% over the period 2007 to 2010. This is also in keeping with trends in some other sites throughout the Caribbean where stability as well as gradual recovery on the local scale has been detected (Cote et al., 2005). A review of regional assessment of coral communities by Schutte et al. (2010) suggests that regional coral cover is stable at about 16% with coral cover in the northern Caribbean at about 20%.

In 2005 widespread sea surface temperature anomalies were recorded throughout the Caribbean resulting in extensive coral bleaching (Eakin, 2010). However, reports on the status of the coral reefs in Discovery Bay indicated that bleaching did take place but with little resultant mortality (Jones et al., 2008; Creary et al., 2008), which suggested that the coral reefs in this area were showing some amount of resilience to temperature stress (Crabbe, 2012). So, although no monitoring was carried out during the period 2004-2006 the data collected in 2007 and onwards does not suggest a substantial decline in coral cover prior to this.

When the monitoring programme was established to measure coral reef health it was expected that data obtained in 2000 would represent a baseline against which annual changes would be compared. For the period 2000-2010 monitoring was actually carried out in two four-year blocks (2000-2003 and 2007-2010) with a gap of three years (2004-2006). The sites selected were based on a gradient of anthropogenic impacts. Monkey Island was identified as being minimally impacted, "Gorgo City" moderately impacted and Southeast Cay severely impacted. The results for the period 2000-2010 showed little difference between coral and macroalgae cover for the minimally (Monkey Island) and the moderately ("Gorgo City") impacted sites on the north coast. With regards to the Monkey Island, despite not being located in an area of significant economic activity or coastal development pressure, this site still exhibited relatively low coral cover (i.e. less than 15%). This become more apparent when compared with "Gorgo City" near Discovery Bay where bauxite loading, tourism activities (such as villas and public beaches), artisanal fishing and the presence of a population center was expected to have exerted more anthropogenic pressure on the adjacent reefs. However, studies have shown that the abundance of coral and macroalgae can also vary as a result of other factors such as reef morphology, wave energy and biological factors (Cho & Woodley, 2000).

Although the objective of establishing a long term monitoring programme was to show the effects of global warming factors

on coral reefs, this was not entirely achieved due the failure of Component 1of the CPACC project (the establishment of the sea level/ climate monitoring system) which would have provided the climate related data. In addition, with the focus of the programme on coral reef monitoring, this precluded the possibility of collecting additional physical, chemical and meteorological data under Component 5. With the exception of Jamaica, the expectation that CARICOM countries would institutionalize the coral reef monitoring programme after the pilot project was not realized. Wide scale monitoring programmes are expensive and with limited human and financial resources, monitoring institutions can find it difficult to implement and support such programmes over the long term, Financial resources represented the greatest challenge faced in Jamaica and this resulted in data not being collected for the period 2004 to 2006. As with many data collection programmes of this nature (e.g. CARICOMP) their long term success require stronger support if they are to perform at the level that is expected to achieve sustainability. Despite the many challenges, the need for monitoring has been strongly recognized (Rogers & Miller 2006) and the resultant data has provided valuable information to local and regional agencies requiring inputs to their decision making process.

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RESUMEN

Resultados del monitoreo a largo plazo en los arrecifes de coral en tres lugares de Jamaica: **Isla Monkey, "Ciudad Gorgo" y Cayo Sureste.** Los impactos regionales y globales del cambio climático están teniendo consecuencias devastadoras en los ecosistemas de arrecifes de coral en el Caribe. Se establecieron monitoreos en el 2000 en Las Bahamas, Belice y Jamaica. Siguiendo el proyecto piloto, el programa se institucionalizó en Jamaica y el monitoreo se llevó a cabo en ocho ocasiones del 2000 al 2010. Se seleccionaron los sitios: Isla Monkey, "Ciudad Gorgo " cerca de la Bahía Discovery (ambos en la costa norte) y el Cayo Sureste en el Puerto Royal en el sur de la costa. Las macroalgas dominaban el sustrato bentónico. Isla Monkey y "Ciudad Gorgo" tuvieron la mayor cobertura de coral. *Porites astreoides*, *Montastraea spp, Porites porities, Siderastrea siderea*, y *Agaricia agaricites* representan las especies de corales más frecuentes. Los datos de este programa se han utilizado en las iniciativas de evaluación y manejo de arrecifes de coral locales y regionales.

Palabras clave: Bahía Discovery, Portland, Puerto Royal, Jamaica, videovigilancia, arrecifes de coral, monitoreo a largo plazo, cambio climático

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