Caribbean: Planning for Adaptation to Global Climate Change

Component 5: Coral Reef Monitoring for Climate Change Impacts

Jamaica 2000

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List of Acronyms

AGRRA	Atlantic and Gulf Rapid Reef Assessment
ANOVA	Analysis of Variance
BOD	Biological Oxygen Demand
CARICOM	Caribbean Common Market
CARICOMP	Caribbean Coastal Marine Productivity Programme
CCDC	Caribbean Coastal Data Centre
CERMES	Centre for Resource Management and Environmental Studies
CMS	Centre for Marine Sciences
COD	Chemical Oxygen Demand
CPACC	Caribbean: Planning for Adaptation to Global Climate Change
CRIS	Coastal Resources Inventory System
DBML	Discovery Bay Marine Laboratory
DFA	Discriminant Function Analysis
GIS	Geographic Information System
GNP	Gross National Product
UWI	University of the West Indies
UNESCO	United Nations Educational, Scientific and Cultural Organization
NRCA	Natural Resources Conservation Authority
SE	Standard Error

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Executive Summary

Introduction

The Caribbean: Planning for Adaptation to Climate Change (CPACC) project was developed by CARICOM countries in response to their growing concerns about the impacts of global climate change on their members states. **Component 5 - Coral Reef Monitoring for Climate Change Impacts** (one of the nine components of the CPACC project) was designed to establish a long-term monitoring program, which over time would be expected to show the effects of global warming factors (temperature stress, sea level rise, and hurricanes) on coral reefs, starting with three pilot countries (The Bahamas, Belize and Jamaica). This first year of monitoring (2000) is considered critical as the information and experience gathered will be used to improve on the design and implementation of the programme. This report provides a summary of the results of the pilot monitoring exercise carried out in Jamaica.

Background

The coral reefs of the Caribbean are well developed primarily as fringing, patch and bank reefs. The over exploitation of the reef resources, excessive domestic and agricultural pollution and increased sediment from unregulated land use practices are some of the anthropogenic factors contributing to the decline of this ecosystem. Among natural factors hurricanes, coral diseases coral bleaching and the mass mortality of the sea urchin *Diadema*, have resulted in significant impacts on coral reefs throughout the Caribbean, which when combined with anthropogenic disturbances make recovery extremely difficult.

The island of Jamaica has well-developed fringing reefs on the north coast, which grow on a very narrow shelf and patchy reef formations on the south coast. Jamaican reefs were in excellent condition until they were severely impacted by Hurricane Allen in 1980 and Gilbert in 1988. Also occurring in the 1980's was white-band disease and the mass mortality of the normally abundant sea urchin *Diadema antillarum, w*hich caused excessive algal growth that smothered living corals, and prevented new corals settling. This algal growth was further exacerbated by nutrient pollution and the removal of grazing fish.

Methodology

The Natural Resources Conservation Authority (NRCA) and the Discovery Bay Marine laboratory (DBML) were responsible for conducting the field activities associated with Component 5 while the Caribbean Coastal Data Centre (CCDC) had overall coordinating responsibility for the monitoring, in addition to carrying out the data processing, entry, analysis and archiving.

Seven operational areas were initially proposed based on specified guidelines (Portland, Montego Bay, Negril, Portland Bight, Discovery Bay, Formigas Bank and/or Pedro Bank) of these only three were selected for monitoring based primarily on logistical constraints. These were Eastern Portland (least impacted), Discovery Bay in St Ann (mildly impacted) and Port Royal Cays in Kingston (severely impacted). The target habitat selected in each operational area was the mixed zone on the windward slopes, consisting mainly of spur and groove formations, dominated by *Montastrea annularis* within a depth range of 7-13 m. Twenty transects, each 20 m in length were located randomly within the target habitat and monitored using underwater videography. The resultant videotapes were catalogued. Using a computer and specialized software, adjacent non-overlapping images were captured, dotted and stored as photo files. The benthic components under the random dots were identified based on specified category codes and resultant data points summarized and stored in spreadsheets.

Results

Fleshy and calcareous algae, as well as dead coral with algae dominated the benthic substrate at all locations. Fleshly algae (52.3%) dominated the monitoring site at Monkey Island in Portland while dead coral and algae made up 17.0% and calcareous algae 14.3% of the bottom substrate. Hard coral accounted for only 7.1% while sand, pavement and rubble made up 6.6%. The remaining 2.7% was comprised mostly of soft corals, sponges and recently dead corals. At "Gorgo city', Discovery Bay the fleshy algae (49.5%) dominated the bottom along with dead coral and algae (15.6%) and calcareous algae 9.9%. Hard corals accounted for 6.8% of the bottom substrate while areas of sand, pavement and rubble accounted for 12.7%. The remaining 5.5% was comprised mostly of recently dead corals. Hard coral accounted for only 2.1% of the benthic cover at Southeast Cay, Port Royal. Even though fleshy algae also dominated this site (43.0%) there were a large proportion of calcareous algae (26.9%) and dead coral and algae (22.0%). The proportion of sand, pavement and rubble (4.6%) was much less than at the other two sites.

The proportion of bleached and diseased coral as a percentage of live coral was highest at Monkey Island, Portland where 1.9% and 2.2% percent of the corals were bleached and diseased respectively. Southeast Cay, Port Royal had the lowest incidence of bleaching (0.6%) while "Gorgo City', Discovery Bay had lowest percentage of diseased corals (0.5%).

A total of 13 coral species were identified for Jamaica. At Monkey Island, 12 species of hard corals were identified; the most abundant species was the opportunistic *Porites astreoides* with intermediate abundance shown by *Montastraea annularis*, *Montastraea cavernosa*, *Porites porites* and *Agaricia agaricites*. There were 11 species of hard corals recorded from "Gorgo City", the most abundant of which were *M. annularis*, *P. astreoides* and *Siderastrea siderea*. At Southeast Cay *P. astreoides* was the most abundant of the ten hard coral species identified.

Box and Whiskers plots and descriptive statistics showed that hard coral, fleshy algae, calcareous algae and dead coral and algae all exhibited normality an/or homogeneity of variance at all the monitoring sites. Analysis of variance (ANOVA) and discriminant function analysis (DFA) indicated that Southeast Cay, Port Royal exhibited significantly lower percentage cover for hard corals and significantly higher for calcareous algae. Dead coral and algae did not differ significantly among the sites. The Standard Error (SE) test was used to determine the minimum number of transects required for monitoring. These were determined to be 14 for Monkey Island, 11 for "Gorgo City" and 8 for Southeast Cay.

Discussion and Conclusions

The data collected in this study is intended to represent the baseline conditions, a starting point from which to document change over time and attempt to determine the reasons for these observed changes. For this study, coral reef health is being assessed by measuring coral cover, however it must be noted that coral reefs consists of an assemblage of organisms of which the corals are just one component. Other component of the coral reef ecosystems, such as fish species could also be used as indicator of reef health. The results from the operational areas along the north coast ("Gorgo City" and Monkey Island) are in keeping with those obtained from the AGRRA, CARICOMP and Cho & Woodley studies. The most significant difference in coral cover data was between that reported by Mendes *et al* (1999) at Lime Cay (18%) and Southeast Cay (2.1%) in the Port Royal Cays but this difference could possibly be attributed to the exposure to high wave energy existing at Southeast Cay.

Recommendations

The following recommendations are based on some of the findings of this study as well as recommendations proposed during the Technical Workshop for the Implementation of Component 5 held in Belize in March 1998 (Walling, 1998) and the Planning and Technical Review Meeting held in Jamaica in May 2001 (Lawrence & Edwards, 2001).

Site Selection

A review of other potential operational area should be conducted with a view to identifying a remote operational area that is unaffected by anthropogenic influences, in addition to or to replace the Portland area. Attempts should be made to include the assessment of the reef flats, deeper reefs and sheltered reef communities. The detailed sites descriptions, including an account of the adjacent land use patterns and the environmental history (e.g. storm events), along with appropriate maps should be prepared for inclusion in the next annual report. The monitoring sites should be geo-referenced to for inclusion in a GIS database such as the CRIS

Monitoring

Fixed transects should be established within the target habitats. In addition, permanent photo quadrats and the identification of monument corals should be included into the monitoring programme. Attempts should be made to incorporate fish data (fish counts and data from the Fisheries Division), *Diadema* abundance and other bio-indicator parameters to establish pollution gradients within the operational areas. Consideration should be given to adding coral growth (particularly as it relates to the increase in $CaCO_3$ in the water) and coral recruitment to the parameters to be monitored for climate change impacts. Physical parameters (temperature, salinity, dissolved oxygen, turbidity and pH) and hydrometeorological data (rainfall, cloud cover, hours of sunshine, wind speed and maximum & minimum temperatures) should be monitored to effectively assess the impacts attributable to climate change factors. It is also suggested that the roving team of experts be established to assist with monitoring in the countries with limited manpower capacity. Volunteers and dive shops should also be considered for assistance with assessing bleaching episodes.

Data Analysis and Processing

During the data analysis the preparation of an all-inclusive species list should be included as an additional exercise to ensure that the rare coral species and coral recruits are recorded. The CARICOMP species list, which includes all the Caribbean species of hard coral, soft coral and algae, should be adopted and incorporated into the final data entry spreadsheet. The present data entry sheet should be updated and standardized for distribution to CPACC member countries. The Benthic Features Manual should be upgraded and training in the identification of video images should be conducted especially in light of the difficulty of differentiating between turf algae and other algae as well as between boring sponges and non-boring sponges.

Statistical Analysis

The Standard Error Test (Bros & Cowell, 1987) should be carried out at a wider number of locations before the 20-transects/20m protocol can be modified. The figure for the number of transects and the length of transects should be standardized for all participating countries to facilitate spatial and temporal comparisons. Statistical analyses (such as Box and Whiskers graphs, ANOVA or any other appropriated analyses) should be incorporated into the monitoring and data analysis protocol. A statistician should be assigned to the project to ensure that the statistical analyses are homogeneous for all monitoring sites and countries.

Project Coordination and Management

A comprehensive Monitoring Manual needs to be produced which includes the site selection protocol, video monitoring protocol, benthic substrate identification manual, the quality control/quality assurance manual, the CARICOMP species list and category codes and the statistical analysis protocol. The manual should allow for modifications to be made to suit each country with information on the data entry mechanism, manpower and logistics requirements and communication procedures. A mechanism for ensuring the integrity of data (including off-site storage of duplicate data sets) and the sharing of experiences should also be included. The manual should be updated periodically, as decisions are taken or adjustments are made to the methodology. The monitoring programme requires more involvement of the interests groups and non-governmental organizations indicated in section 3.1, in the site selection and data collection processes. Analyzed data would then be sent back to them for use as a project management tool.

1. Introduction

The Caribbean: Planning for Adaptation to Climate Change (CPACC) project was developed by CARICOM countries in response to their growing concerns about the impacts of global climate change on their members states. **Component 5 - Coral Reef Monitoring for Climate Change Impacts** - represents one of the nine components of the CPACC project that was established in 1998 and is one of five pilot based components. The objective of Component 5 is to establish a long-term monitoring program, which over time will be expected to show the effects of global warming factors (temperature stress, sea level rise, and hurricanes) on coral reefs. Component 5 was also designed to document where possible the extent and sources of existing coral reef degradation in the region beginning with three pilot countries (the Bahamas, Belize, and Jamaica).

Specialist from a variety of governmental and non-governmental institutions collaborated to formulate the methodology for this programme. It was anticipated that this methodology would complement current monitoring efforts concerned with global warming impacts on coral reefs in the Caribbean. Essential to the monitoring programme is the review and enhancement of the methodology through regional meetings and consultations. Such meetings would also facilitate the training of country specialist from the other CPACC countries[1], presently not involved in the pilot phase, on the monitoring methodologies and the lessons learnt from the pilot studies.

This first year of monitoring (2000) is considered critical as the information and experience gathered from the pilot countries will be used to improve on the design and implementation of the programme. Data collected in 2000 represents the baseline, which will be used to make comparisons among monitoring operational areas within each country as well as comparisons over time, to document changes and attempt to discern those changes ttributable to climate factors. This report provides a summary of the results of the pilot monitoring exercise carried out in Jamaica.

2. Background

2.1 The Caribbean

The coral reefs of the Caribbean are well developed primarily as fringing reefs but also as patch and bank reefs especially on the broad shallow banks and island shelves. The over exploitation of the reef resources, excessive domestic and agricultural pollution and increased sediment from unregulated land use practices are some of the anthropogenic factors contributing to the decline of this ecosystem. Reefs are also an integral part of the livelihood and food supply of the human populations that live near them. The World Resources Institute (1998) has estimated that about one quarter of the potential fish harvests in developing countries come from coral reefs. Caribbean countries, which attract millions of visitors annually to their beaches and reefs, derive one half of their gross national product (GNP) from the tourism industry, valued at US$8.9 billion in

[1] The eight countries that will be involved in the second phase of the monitoring programme are, Antigua and Barbuda, Barbados, Dominica, Grenada, St. Kitts and Nevis, St. Lucia, St. Vincent, and Trinidad and Tobago.

1990. Reefs also provide essential services like coastal protection, buffering adjacent shorelines from erosive wave action and storm impacts. (World Resources Institute, 1998)

Among natural factors, hurricanes result in the most significant impact on coral reefs within the Caribbean, which when combined with anthropogenic disturbances make recovery difficult. Coral diseases (e.g. white band disease of *Acropora* species), coral bleaching and the mass mortality of the sea urchin *Diadema*, have facilitated massive increases in fleshy algae on many reefs. 1998 was the hottest year recorded and high seawater temperatures adversely affected many reefs throughout the Caribbean resulting in the mass bleaching of corals. The Caribbean now has the lowest average percentage of living coral cover in the world (22%) primarily attributed to these factors (World Bank, 2000).

2.2 Jamaica

The island of Jamaica (10,800 km^2) is situated in the northern Caribbean (18°N, 77°W). Cuba, 150 km to the north, moderates the effects of the northeast trade winds on the well-developed fringing reefs of the north coast, which have developed on a very narrow shelf. Patchy reef formations on the south coast grow on a shallow shelf up to 20 km wide, but are punctuated by rivers and sediment slopes. Coral reefs also grow on the neighbouring banks of the Pedro Cays, 70 km south, and the Morant Cays, 50 km southwest. The Jamaican population has doubled in the last 30 years to an estimated 2.5 million today. There are many coastal communities and industries concentrated on the southeast coast around the capital of Kingston, and there has been much recent tourism development on the north coast, which has placed, increased pressure on the coastal environment. (UNEP/IUCN, 1988; Wilkinson, 2000).

Jamaican reefs were in excellent condition when pioneering studies initiated Caribbean coral reef research (eg Goreau, 1959). They suffered little storm damage for more than 30 years, until they were severely impacted by Hurricane Allen in 1980 and Gilbert in 1988. Also occurring in the 1980's was white-band disease in *Acropora cervicornis* and the mass mortality of the normally abundant sea urchin *Diadema antillarum*. These combined natural impacts marked the beginning of a major deterioration of Jamaican coral reefs. The reefs did not recover because of the insidious and chronic human disturbance, notably over-fishing, and increased sediment and pollution runoff. Over-fishing, particularly of herbivorous fish, on the narrow north-coast shelf was obvious in the 1960s, but the unusually high abundance of *Diadema* grazed down the algae and allowed the corals to dominate. When the *Diadema* died, algae grew over the reefs, smothered living corals, and prevented new corals from settling. This algal growth was exacerbated by nutrient pollution and the removal of the grazing fish (Gayle & Woodley, 1998).

Soil erosion has been a major problem in Jamaica for over 50 years, and sedimentation has damaged the reefs near river mouths (Vierros, unpublished). Nutrient pollution of rivers and coastal waters has increased as human populations grew, particularly in Kingston Harbour and other near coastal communities, where nitrates percolate through porous limestone onto the reefs. Coral mortality has increased to the west of Kingston

Harbour, as a result of the impact of the highly eutrophic water flowing out of the harbour (Mendes, 1992).

In the late 1970s, the fringing reefs around the island had coral cover averaging 52% at 10 m depth, but this declined to 3% in the 1990s, in parallel with an increase in fleshy macroalgae from 4% to 92% (Hughes, 1994). Since then coral cover has shown slight increases. Cho & Woodley (in press) reports that at 27 sites along a 10 km coastline in the vicinity of Discovery Bay there has been recorded coral cover of 15% (algae – 35%) at 5m, 16% (algae – 56%) at 10m and 11% (algae - 63%) at 15m. The increase has been attributed to opportunistic species such as *Porites astreoides*, *P. porites* and *Agaricia agaricites.*

3. Methodology

The following organizations were involved in the collecting, processing and analysis of the data collected from Jamaica for Component 5. These were the Natural Resources Conservation Authority (NRCA), The Discovery Bay Marine Laboratory (DBML) and the Caribbean Coastal Data Centre (CCDC). The DMBL and the CCDC are both part of the Centre for Marine Sciences (CMS), of the University of the West Indies, Mona. The NRCA and DBML were responsible for conducting the field activities associated with Component 5 while the CCDC had overall coordinating responsibility for the monitoring, in addition to carrying out the data processing, entry, analysis and archiving. The Jamaica Report, prepared jointly by the NRCA and the CCDC was supplemented by statistical analysis of the data at the Centre for Resources Management and Environmental Studies (CERMES), UWI (Cave Hill).

3.1 Selection of Operational Areas

The guidelines for selection for the operational areas (Woodley, 1999) in each of the pilot countries was outlined in the Planning Workshop held in Belize in March 1998 (Walling, 1998). The operation areas should contain all reef types and be located, as far as possible, away from all point sources of human disturbances. The selection protocol called for the preparation of maps of the operational areas, which would include the distribution of the coral reefs, morphology (depth, slope, relief), wave energy, habitat zonation, fish and sea-urchin populations, signs of previous impacts and potential target habitats. This information is not yet available for Jamaica but will be progressively accumulated and presented in subsequent reports.

It was proposed that each country be responsible for selecting their own operational areas based on the following guidelines:

1. They represent a gradient from less to more impacted areas
2. They represent a mix of remote and accessible sties
3. That consideration be given to their economic and ecological importance.

For this monitoring programme “impact” is defined as land-based, anthropogenic stress, transported to reefs by fluvial inputs or actual physical impacts on reefs caused by activities within the marine environment. Jamaica initially proposed a number of coastal as well as remote operational areas, primarily because there were interest groups conducting or interested in conducting monitoring in these areas. The operational areas proposed and their corresponding interest groups were as follows:

- Portland (Portland Environmental Protection Agency)
- Montego Bay (Montego Bay Marine Park)
- Negril (Negril Coral Reef Preservation Society)
- Portland Bight (Caribbean Coastal Area Management Foundation)
- Discovery Bay (CARICOMP, Discovery Bay Marine Laboratory)
- Port Royal (University of the West Indies)
- Formigas Bank and/or Pedro Bank (remote areas)

Of the seven potential operational areas, only three were selected for monitoring based on a number of logistical constraints. These were Monkey Island in Portland (least impacted), Discovery Bay in St Ann (mildly impacted) and Port Royal Cays in Kingston (severely impacted) (Figure 1).

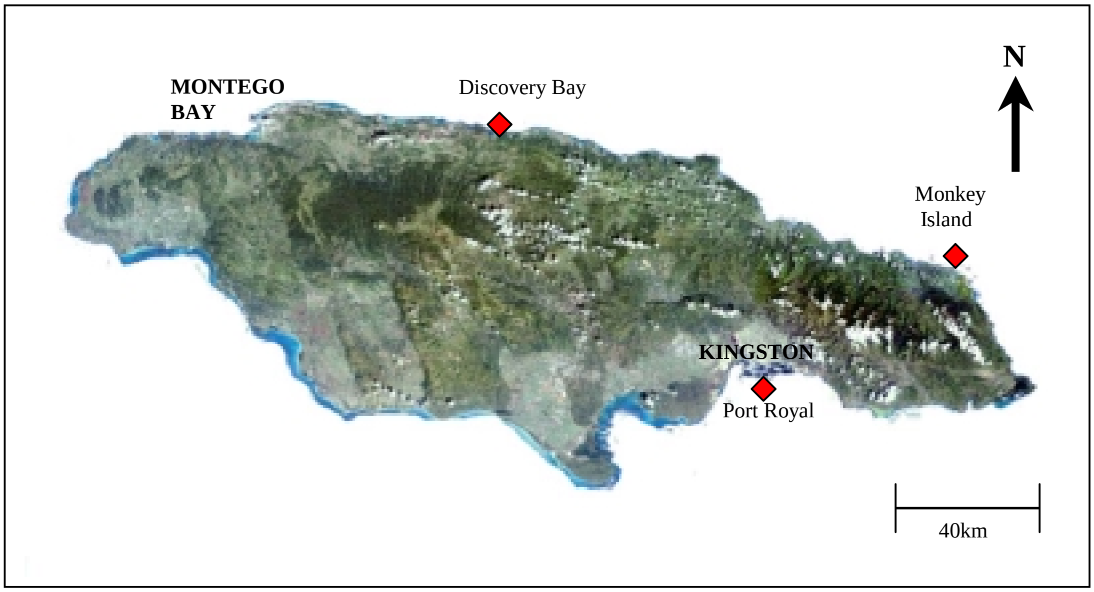

Figure 1 Map of Jamaica showing the location of the least impacted (Monkey Island, Portland) mildly impacted (Discovery Bay, St Ann) and severely impacted (Port Royal, Kingston) operational areas.

3.2 Description of the Operational Areas

Portland is located on the northeastern section of the island, which has the highest annual rainfall and is comprised predominantly of mountainous terrain, deciduous forests and numerous small to medium sized rivers. The parish is sparsely populated with agriculture, tourism and fishing being the main activities. Bananas and coconuts are produced for export while smaller areas are cultivated with sugar and mixed farming for local use. The parish capital, Port Antonio, has port facilities that serve cruise ships and banana exporting vessels. Low intensity tourism is practiced in this parish and there has been in recent times the increased popularity of ecotourism because of the undisturbed and natural nature of the landscape. There are no major industrial activities in this parish (NRCA, 1995). The extent of relatively undisturbed coastline and the numerous fringing coral reefs were factors that contributed to Portland being selected to locate the least impacted site.

Discovery Bay is located on the west central portion of the north coast and is bordered by a continuous fringing reef of *spur and groove* formation developed on a narrow submarine shelf. The bay itself has not no permanent rivers flowing into it but instead groundwater enters through deep crack in the basement limestone which causes there to be a stratification of temperature and salinity in the back reef. Discovery Bay has experience two severe hurricanes, Hurricane Allen in 1980 and Hurricane Gilbert in 1988. The waves generated by these storms resulted in a high level of destruction of corals, which in turn provided the new opportunities for algal growth. The impact of overfishing in this area is also pronounced because the selective fishing methods employed on the narrow submarine shelf has removed many of the large herbivores and predators. It has been proposed that the combination of anthropogenic and natural factors has cause a phase shift from a high diversity coral-dominated reef to a low diversity algae-dominated system (Hughes 1994). The town of Discovery Bay extends to the south and east of the Bay, while to the southwest is located the loading facility for the Kaiser Jamaica Bauxite Company from which bauxite excavated from the interior of St Ann is shipped. Kaiser is the principal employer in Discovery Bay with fishing, tourism, research and teaching being the other main activities (Gayle & Woodley, 1998

The Port Royal Cays is located off the southeastern coast of the island and represents moderately to heavily impacted conditions, being close to a major city (Kingston) and also down current of several major rivers and gullies. The quality of the water in the Harbour has been determined to be poor (as measured by coliform bacteria counts, nutrient levels and dissolved oxygen concentrations) with the benthic communities consisting primarily of polycheate worms. The major contributor to pollution in the Harbour and by extension the Cays is domestic sewage effluent from the city of Kingston (Mendes, 1992; Mendes *et al*, 1996). The area (Figure 4) consists of a collection of eight small coral islets (Gun Cay, Rackhams Cay, Lime Cay, Drunkenman's Cay, East Middle Ground, South Cay, Southeast Cay and Maiden Cay) situated on the island shelf of the south coast and covering and area of approximately 2500 hectares (Mendes, 1992) The barrier reef to the south is considered to be a drowned eroded landscape consisting of limestone and sand (Goreau & Burke, 1996). The cays serve as a protective barrier for the Palisodoes and the town of Port Royal. These Cays are very important to the nearshore artisanal fishing industry serving the nearby fishing communities of Port Royal, Rae Town, Port Henderson and Hellshire (Head & Hendry, 1985). The Cays are also an important recreational site for locals as well as tourist and serve as destinations for pleasure boats, sightseeing cruises and scuba diving (Mendes, 1992).

3.3 Selection of the Monitoring Sites

The target habitat in each operation area selected for monitoring was the Mixed Zone (Goreau, 1959; Woodley, 1999) on the windward slopes, consisting mainly of spur and grove formations dominated by the important frame-builder *Montastrea annularis*. The depth range for the target habits was between 7 and 13 m.

Other potential target habits include the breaker zone (0-5m), deeper for reef (25-40m), shallow reefs (2-10m), shelf-edge pinnacle reef (12-15m) which will be considered for addition to the monitoring programme in the future.

3.4 Description of the Monitoring Sites

3.4.1 Monkey Island, Portland

The monitoring site is located approximately 10km east of Port Antonio, away from any major land-based influences, and extends from due north of Monkey Island eastwards to the Blue Hole area following the 7 – 13 meter depth contour (Figure 2). Water visibility extended to approximately 50 meters and there was negligible water current.

Figure 2. Aerial photograph showing the location of the monitoring site at Monkey Island, Portland representing reef conditions considered to be least impacted.

3.4.2 "Gorgo City" Discovery Bay

The monitoring site, located to the west of Discovery Bay at "Gorgo City" (Figure 3), was regarded as the mildly impacted. The monitoring site has a gentle profile between the depths of 7-13 meters with strong bottom currents and visibility estimated at less than 15m.

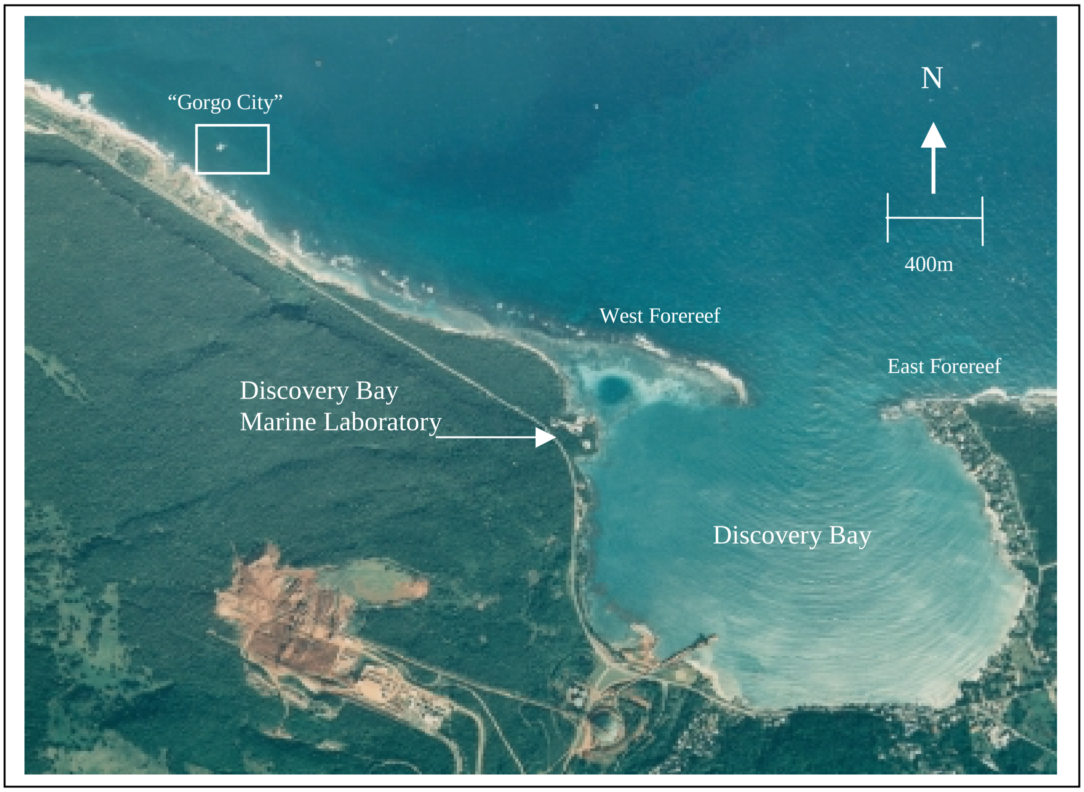

Figure 3 Aerial photographs showing the location of the monitoring site at "Gorgo City", Discovery Bay, representing mildly impacted reef conditions.

3.4.3 Southeast Cay, Port Royal

Southeast Cay is isolated (unlike Rackhams and Drunkenman's Cays) from the direct influence of the highly eutrophic water from Kingston Harbour (Morrison & Greenaway, 1989), which flows predominantly southwards. The monitoring site at Southeast Cay had a gentle profile between the depths of 7-13 meters with strong bottom currents and visibility estimated at less than 15m.

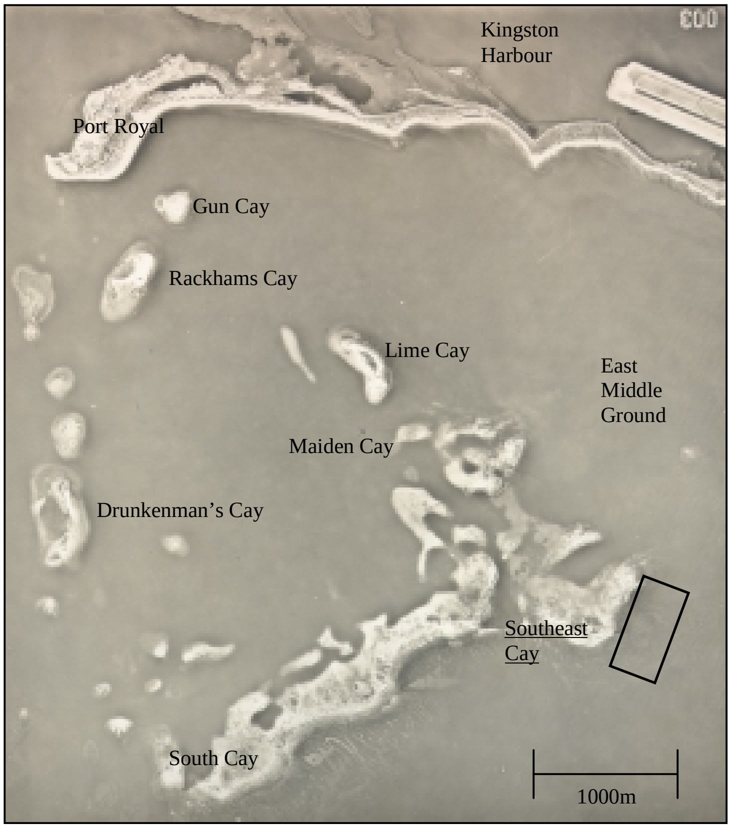

Figure 4 Aerial photographs of the Port Royal Cays showing the location of the monitoring site, Southeast Cay. This site is representative of moderately to severely impacted reef conditions.

3.5 Monitoring

3.5.1 Locating Transects

The locating of the transects followed the procedure outlined in the Draft Site Selection Protocol (Woodley, 1999) taking into consideration the constraints encountered in each monitoring area. A modified random selection process was employed by the NRCA field team to determine where transects would be laid at the three designated locations. The selection process is outlined below:

1. At the site, two three-way compass bearings or GPS references were used to pinpoint the start points, which were arbitrarily chosen based on boating approach, suitable anchorage etc.
2. The anchor line served as the start point and in the case of the Portland site where a chartered boat was used, the point directly under the location at which the dive was begun was used.
3. The first transect was laid at the start point, with the orientation of this transect being determined by the orientation of the target area (parallel to bottom contour 7-13 meters).

4. Once completed, a randomly chosen bearing (pre-selected before the dive using figures from a telephone directory) was then taken from the start point of the first transect and a distance from this point (also pre-selected before the dive from a directory) was then swum, using "calibrated" fin-stroke measuring techniques to estimate distances. The next transect was then established at the new start point, orientated to keep it within the target depth and habitat. Subsequent transects were then located in this manner until all transects allotted for the particular dive (three to five) were done or dive time was consumed.
5. In the event that the distance/bearing resulted in being the transect outside of the designated study area (i.e., 7-13 meters), the transect was run along the edge of the boundary in the general direction suggested by the bearing, then the next random bearing that steered the team back into the study zone was used.
6. A total of 20 transects each 20m in length were monitored at each monitoring site.

3.5.2 Underwater Videography

The benthic cover of the coral reefs was monitored using underwater videography. The divers used a high-resolution digital video camera fitted with a wide-angle lens and underwater housing. Prior to filming each transect a slate was containing information on the transect (site name, date depth, transect number and videographer) was recorded. The diver then videotaped while swimming slowing along the transect holding the camera perpendicular to the substratum at a height of 40 cm (guided by a 40cm wand attached to the camera housing) in order to provide a belt transect that was approximately 40 cm wide (Miller, 2000). At the end of filming each transect recording was continued in a more horizontal view, making a 360^{o} rotation of the transect area and then a "swim back" along the transect tape at about 1-2 m above the bottom. This exercise was to record a wider reef area in order to provide a qualitative view of the reef and to put the transect in context.

3.6 Data Processing and Analysis

The resultant videotapes were viewed to ensure that clarity and resolution were satisfactory, after which the tapes were numbered and catalogued (Appendix 1) and the content of each tape logged (Appendix 2) to ensure that the individual transects at each site could be located at a later date with relative ease. A computer was connected to a videotape player and the tape played to "capture" adjacent, non-overlapping images (photo quadrats) which where converted to photo files and saved in an image library. Ten random dots were placed on each image during a process that used Microsoft Excel and Adobe Photoshop and that was automated by WinBatch for Windows (a batch processing program). After the images were processed, the benthic components under the random dots were identified while viewing the images in Adobe Photoshop. Data points were identified to species (where possible) or to a higher functional taxonomic group. Other benthic components (substrate categories) included the hard substrate (sand, rubble, pavement etc), points falling on equipment (e.g. tape, wand etc) and areas that could not be identified (shadow and unknown) (Appendix 3). These data were entered into data sheets developed in Microsoft Excel, which automatically tabulated and grouped the substrate categories and calculated the percentage cover and standard deviation (Appendix 4) for each transect (Miller, 2000).

4 Results

4.1 Benthic Substrate Cover

The assessment of the bottom substrate for three operational areas in Jamaica (Monkey Island, Portland; "Gorgo City", Discovery Bay; Southeast Cay, Port Royal) was conducted during the period June – July 2000 using the video monitoring technique described above. Table 1 and Figure 5 provide a summary of the results of this monitoring exercise. Fleshy and calcareous algae, as well as dead coral and algae dominated the benthic substrate at the all locations.

Table 1 Summary of the mean percentage cover for the substrate categories found at Monkey Island, Portland; "Gorgo City", Discovery Bay; and Southeast Cay, Port Royal.

SUBSTRATE CATEGORY	Portland		Discovery Bay		Port Royal	
	Mean	Stdev	Mean	Stdev	Mean	Stdev
HARD CORAL	7.1	3.9	6.7	3.3	2.1	1.4
SOFT CORALS	0.3	0.4	0.1	0.3	0.1	0.3
SPONGES	0.1	0.2	0.6	0.9	0.6	1.1
RECENTLY DEAD CORAL	2.0	2.0	4.0	3.8	0.2	0.4
FLESHY ALGAE	52.3	11.6	49.5	9.4	43.0	8.6
OTHER, LIVE	0.0	0.1	0.3	0.5	0.0	0.0
DEAD CORAL WITH ALGAE	17.0	11.3	15.6	9.5	22.0	11.0
CALCAREOUS ALGAE	14.3	10.3	9.9	5.8	26.9	11.2
SAND, PAV, RUB	6.6	4.9	12.7	6.8	4.6	7.8
UNKNOWN	0.3	0.3	0.5	0.5	0.4	0.8

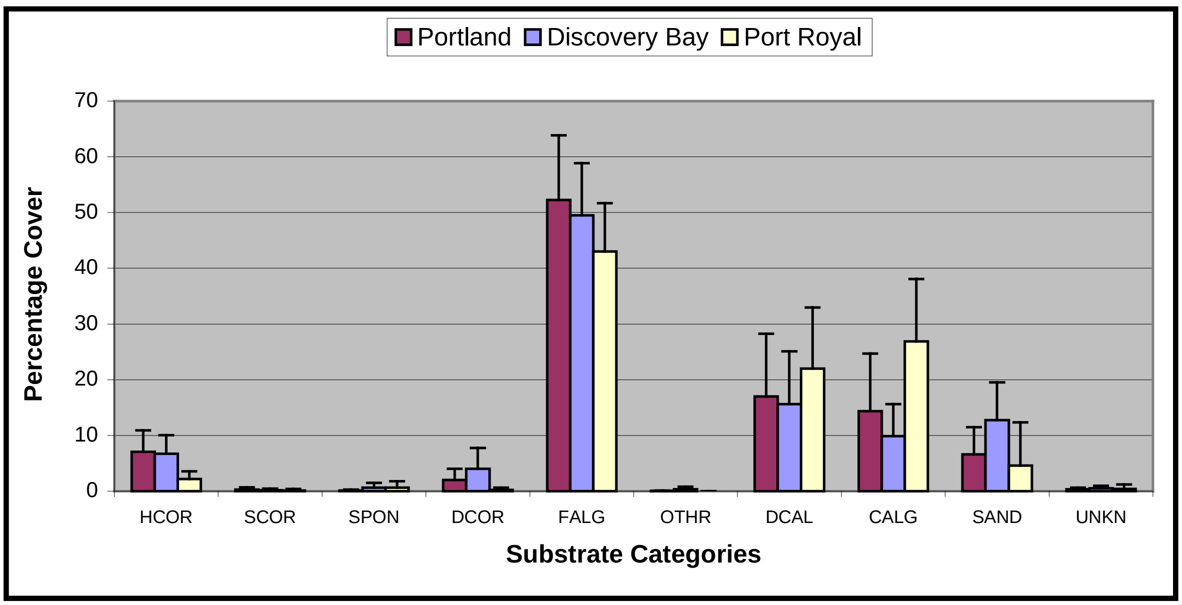

Figure 5 Graph illustrating the mean percentage cover of the different substrate categories found at Portland, Discovery Bay and Port Royal. Error bars represent Standard Deviation (SD). (Substrate

categories: HCOR - Hard coral; SCOR - Soft coral; SPON – Sponge; DCOR - Recently dead coral; FALG – Fleshy algae; OTHR – Other; DCAL - Dead coral with algae; CALG – Calcareous algae; SAND – Sand, rubble etc; UNKN – Unknown.)

Figures 6-8 below illustrates the proportion of the benthic substrate occupied by the more abundant substrate categories, with the percentage cover represented by hard coral highlighted for comparison.

Figure 6 illustrates the overall composition of the benthic substrate at Monkey Island in Portland. This site was dominated by fleshly algae, which accounted for 52.3% of the bottom. The main species identified were *Dictyota*, *Lobophora* and *Sargassum*. Dead coral and algae made up 17.0% of the benthic cover and calcareous algae 14.3%. Hard coral accounted for only 7.1% while sand, pavement and rubble made up 6.6%. The remaining 2.7% was comprised mostly of soft corals, sponges and recently dead corals.

At "Gorgo City", Discovery Bay the fleshy algae (49.5%) also dominated the bottom along with dead coral and algae (15.6%) and calcareous algae (9.9%), which also contributed significantly to the bottom cover. Hard corals accounted for 6.7% of the bottom substrate while areas of sand, pavement and rubble accounted for 12.7%. The remaining 5.5% was comprised mostly of recently dead corals (Figure 7).

Hard coral accounted for only 2.1% of the benthic cover at Southeast Cay, Port Royal. Even though fleshy algae (primarily *Dictyota*) also dominated this site (43.0%) there were a large proportion of calcareous algae (26.9%) comprised mainly of *Halimeda*, and dead coral and algae (22.0%). The proportion of sand, pavement and rubble (4.6%) was much less than at the other two sites (Figure 8).

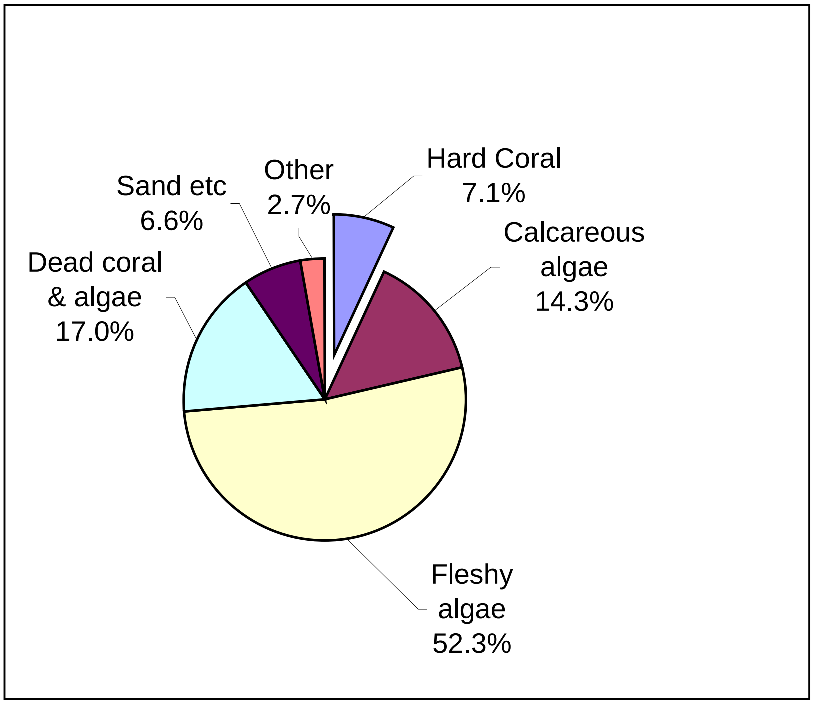

Figure 6. *Monkey Island, Portland* – Pie Chart illustrating the composition of the benthic substrate as represented by mean percentage cover, highlighting the proportion that is hard coral.

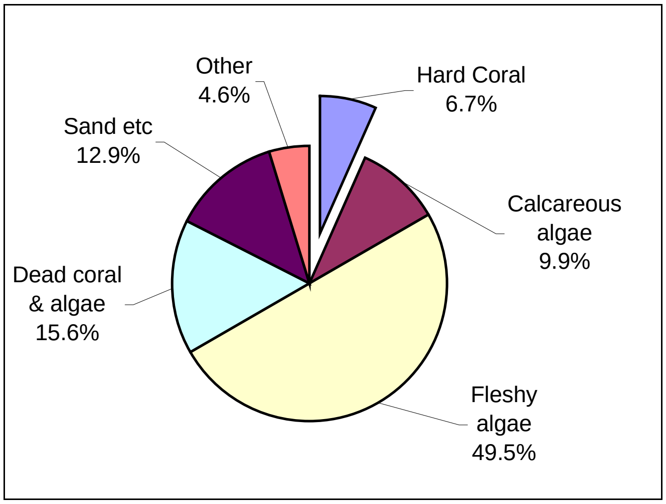

Figure 7 *"Gorgo City", Discovery Bay* – Pie Chart illustrating the composition of the benthic substrate as represented by mean percentage cover, highlighting the proportion that is hard coral.

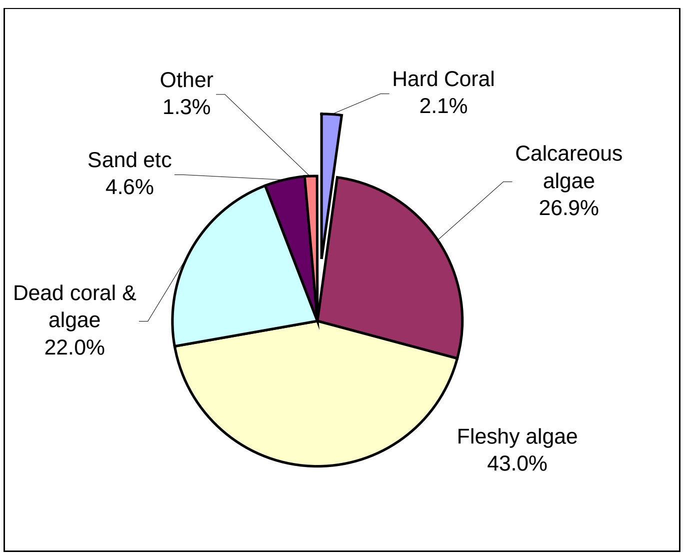

Figure 9 *Southeast Cay, Port Royal* – Pie Chart illustrating the composition of the benthic substrate as represented by mean percentage cover, highlighting the proportion that is hard coral.

4.2 Coral Diseases

The proportion of bleached and diseased coral as a percentage of live coral was highest at Monkey Island, Portland where 1.9% and 2.2% percent of the corals were bleached and diseased respectively (Table 2). Southeast Cay, Port Royal had the lowest incidence of bleaching (0.6%) while "Gorgo City", Discovery Bay had lowest percentage of diseased corals (0.5%).

Table 2. Summary of coral health from the three monitoring sites Portland, Discovery Bay and Port Royal, Jamaica.

Coral Health	Portland	Discovery Bay	Port Royal
Bleached as % of Corals	1.9	1.1	0.6
Diseased as % of Corals	2.2	0.5	1.1

4.3 Coral Species

A total of 13 coral species were identified for Jamaica under the random dots generated on the video images of the substrate. Table 3 provides the summary of the percentage cover for each coral species found at the three monitoring locations. Those species that could not be readily identified were recorded as "coral sp".

Table 3. Coral species identified at Portland, Discovery Bay and Port Royal, Jamaica.

CORAL SPECIES	Portland	Discovery Bay	Port Royal
Acropora cervicornis	0	0.08	0.23
Agaricia agaricites	0.57	0.19	0.07
Diploria labyrinthiformis	0.15	0.07	0.01
Diploria strigosa	0.37	0.15	0.10
Madracis mirabilis	0.01	0	0
Millipora complanata	0.04	0.02	0.08
Montastrea annularis	0.78	1.18	0.28
Montastrea cavernosa	0.77	0.45	0.01
Montastrea faveolata	0.23	0.05	0
Porites astreoides	2.35	1.89	1.12
Porites porites	0.65	0.42	0.06
Siderastrea radians	0.03	0	0
Siderastrea siderea	0.27	1.76	0.04
Coral sp.	0.85	0.45	0.15
Total % coral cover	**7.06**	**6.70**	**2.15**
Number of Species (S)	12	11	10
Shannon Diversity (H')	1.92	1.76	1.47

At Monkey Island, 12 species of hard corals were identified during the monitoring exercise. The most abundant species was the opportunistic *Porites astreoides* with intermediate abundance shown by *Montastrea annularis*, *M. cavernosa*, *Porites porites* and *Agaricia agaricites*. Two species, *Madracis mirabilis* and *Siderastrea radians* were identified only at this location. There were 11 species of hard corals recorded from "Gorgo City", the most abundant of which were *M. annularis*, *P. astreoides* and *Siderastrea siderea*. At Southeast Cay *P. astreoides* was the most abundant of the ten hard coral species identified.

4.4 Statistical Analyses

Box and Whiskers plots and descriptive statistics summary tables were produced to assess the distribution of the habitat variables at each monitoring site and to identify outliers. The more important substrate categories under consideration exhibited normality and/or homogeneity of variance for all the sites. These were Hard Coral, Fleshy Algae, Calcareous Algae, and Dead Coral and Algae. Soft Coral, Sponges, Other, Recently Dead Coral, Unknown and Sand, Rubble and Pavement showed considerable departure from normality (Valles, 2001). The summary of the descriptive statistics used to assess the distribution of the variables at each site can be found in Appendix 5.1.

ANOVA (Analysis of Variance) was used to examine the relationship between within-sample variance and among-sample variance. Significant differences among sites were found for Hard Coral in which Port Royal exhibited significantly lower percentage cover than the other two sites. Port Royal also showed a higher percentage cover than the two sites for Calcareous Algae while the percentage cover for Other Algae was significantly lower than that of Portland. Dead Coral and Algae did not differ significantly among the sites. With respect to the number of species, Port Royal exhibited a significantly lower number of species and categories than Portland and Discovery Bay (See Appendix 5.2).

A discriminant function analysis (DFA) was performed on the four major substrate benthic (Hard Coral, Fleshy Algae, Calcareous Algae, and Dead Coral and Algae) variables that exhibited normality and homogeneity of variance. The sites appeared to differ only along one significant function that separated Discovery Bay and Portland from Port Royal according to the amount of Hard Coral, Calcareous Algae and to a lesser extent Dead Coral with Algae (Valles, 2001). This relationship is demonstrated in Appendix 5.3.

4.5 Comparison with Other Studies

Table 4 below presents a summary of the benthic substrate composition obtained from two other regional studies, namely AGRRA (2001), CARICOMP (CCDC, unpublished) and two other studies (Cho & Woodley, in press; Mendes *et al*, 1999) carried out in Jamaica. AGRRA, CARICOMP and Cho & Woodley have data from the reefs in the Discovery Bay area. AGRAA also monitored reef sites located in eastern Portland and Mendes *et al* monitored the reefs at Port Royal. The results from these studies have been included in this report to give an indication of the range of values obtained for hard coral, calcareous algae and fleshy algae cover within the operational areas monitored by CPACC.

CARICOMP recorded 12.2% hard coral cover for reefs in the Discovery Bay area while AGRRA reported 9% and Cho & Woodley reported 15.9%, which compares with 6.7% obtained from this study. In Portland three of the sites monitored by AGRRA (Long Bay - East Coast, Booby North Point and Boston Beach) recorded coral cover ranging from 6 to 12 %, which compares to the 7.1% obtained from this study. For the Port Royal Cays Mendes *et al* (1999) recorded coral cover of 18% at Lime Cay, this compares to Southeast Cay at which 2.1% coral cover was recorded. The differences in coral cover between Mendes *et al* and CPACC could possible be explained by the fact that the Southeast Cay site was more exposed to high wave energy than the reefs at Lime Cay.

Data for algal cover (calcareous and fleshy) was not available for all studies. In Portland (Long Bay - E. Coast, Booby North Point and Boston Beach) the AGRRA study recorded mean percentage calcareous algae cover between 5 and 30%, which compares to 9.9% obtained during this monitoring exercise. For the Discovery Bay area 16% calcareous algae cover was obtained from the AGRRA study and 29.5% from CARICOMP while 14.3% was recorded by CPACC. For the Port Royal cays no corresponding records were available to compare with the 26.9% calcareous algal cover obtained in this study.

The levels of fleshy algae were high from all studies. AGRRA recorded algal cover between 49 and 59% at the Portland locations while CPACC recorded 52.3% at Monkey Island. With the Discovery Bay area CARICOMP recorded 36.4%, AGRRA 67% and Cho & Woodley 56.5% fleshy algae cover which compares to 49.5% obtained from CPACC. For Port Royal fleshy algal cover was recorded as 43%.

Table 4 Summary of percentage cover data from other coral reef studies conducted in Jamaica.

Location	Study	Year	Depth (m)	Hard Coral	SD	Calcareous Algae	SD	Fleshy Algae	SD
Long Bay, E. Coast	AGRRA	2000	6	6	n/a	30	n/a	59	n/a
Booby North Point	AGRRA	2000	12	12	n/a	25	n/a	55	n/a
Boston Beach	AGRRA	2000	9	9	n/a	5	n/a	49	n/a
Monkey Island	CPACC	2000	7-13	7.1	3.9	9.9	5.8	52.3	11.6
Discovery Bay	CARICOMP	1999	6-8	12.1	5.2	29.5	10.0	36.4	n/a
Discovery Bay	AGRRA	2000	9	9	n/a	16	n/a	67	n/a
Discovery Bay	Cho &Woodley	1977	10	15.9	9.5	n/a	n/a	56.5	n/a
Discovery Bay	CPACC	2000	7-13	6.7	3.3	14.3	10.3	49.5	9.4
Port Royal (Lime Cay)	Mendes *et al*	1999	8	18	n/a	n/a	n/a	n/a	n/a
Port Royal (SE Cay)	CPACC	2000	7-13	2.1	1.4	26.9	11.2	43.0	8.6

4.6 Minimum Transect Number

The method outline in Bros and Cowell (1987) was used to calculate the Standard Error (SE) for 20 transects from each of the three coral reef monitoring locations (Portland, Discovery Bay and Port Royal). Coral species number was used as the measured or dependent variable and the graphs generated (Appendix 6) indicate that the minimum sample size for each monitoring sites was 14 for Portland, 11 for Discovery Bay and 8 for Port Royal (Table 5). The maximum number of transects would be determined by superposing a measure of sampling effort (such as cost and/or time) on the results obtained in the graphs.

Table 5. Minimum sample size calculated for Portland, Discovery Bay and Port Royal using the method outline in Bros and Cowell (1987).

	Portland	Discovery Bay	Port Royal
Minimum Sample Size	14	11	8

5. Discussion and Conclusions

The data collected in this study is intended to represent the baseline conditions, a starting point from which to document change over time and attempt to determine the reasons for these observed changes. For this study, coral reef health is being assessed by measuring coral cover, however it must be noted that coral reefs consists of an assemblage of organisms of which the corals are just one component. Other component of the coral reef ecosystems, such as fish species distribution and abundance could also be used as indicator of reef health.

The results of the monitoring exercise using the video monitoring techniques outlined by Miller (2000) reflected the generally reported conditions of the coral reefs in Jamaica (Wilkinson, 2000; AGRRA, 2001; CCDC, unpublished; Cho & Woodley, in press; Mendes *et al*, 1999). The areas selected for monitoring were dominated by fleshy algae (Portland - 52.3%; Discovery Bay – 49.5%; Port Royal - 43.0%) and to a lesser extent dead coral and algae (Portland – 17.0%; Discovery Bay – 15.6%; Port Royal – 22.0%) and calcareous algae (Portland – 14.3%; Discovery Bay – 9.9%; Port Royal – 26.9%). Hard coral cover was generally low (Portland – 7.1%; Discovery Bay – 6.7%; Port Royal – 2.1%) and very few sponges and soft corals were encountered, accounting for less than 1% cover at all locations. Less than 2% of the corals were bleached and less than 3% identified as being diseased.

A total of 13 coral species were identified using the random dot technique. This technique, however, may have overlooked the more rare species and coral recruits that might have been present. A separate review of the images would probably provide this information. The more abundant species were the important frame builder *Montastrea annularis* along with *Montastrea cavernosa, Porites porites* and Siderastrea *siderea.* The main algal species encountered were *Lobophora, Dictyota* and *Sargassum* at Monkey

Island, and *Dictyota* and *Halimeda* at Southeast Cay and mainly *Lobophora* was "Gorgo City".

The three operational areas selected were intended to represent least impacted, mildly impacted and moderately to severely impacted conditions and were chosen based on knowledge of the area and accessibility for monitoring. Statistical analyses performed on the data for 2000 showed that for the hard coral cover there was no significant difference between "Gorgo City" and Monkey Island, while these two locations were considered significantly different from Southeast Cay (Valles, 2001). Consideration should be given to locating an alternate area that has experienced minimal impacts such as Pedro Cays, which is located 70 km to the south of the island or the Formigas Bank (50 km to the east northeast). These operational areas were originally considered but discarded because of the logistical problems associated with reaching these locations.

The results from the operational areas along the north coast ("Gorgo City" and Monkey Island) are in keeping with those obtained from the AGRRA, CARICOMP and Cho & Woodley studies. The most significant difference in coral cover data was between that reported by Mendes *et al* (1999) at Lime Cay (18%) and Southeast Cay (2.1%) in the Port Royal Cays but as indicated above this difference in results could possibly be attributed to the exposure to high wave energy existing at Southeast Cay.

The number of transects was set initially at 20 with each being 20m long (i.e. 20/20) to ensure that sufficient data was collected. Evaluation of the preliminary data set was required to determine if the number of transects could be decreased in order to reduce the sampling effort. The use of the Bros and Cowell (1987) Standard Error (SE) Test has indicated that the minimum number of transects for Monkey Island (Portland) would be 14, 11for "Gorgo City" (Discovery Bay) and 8 for Southeast Cay (Port Royal). In order to compare monitoring sites (spatially and temporally) the number of transects should be standardized. Given the proposed expansion of Component 5 to the other CPACC countries and the potential variability of reef structure that exists between monitoring sites it would be premature to reduce the number of transects at this time. The SE test would have to be performed on a significant number of monitoring sites from the region before consideration can be given to adjusting the number of transects.

6. Recommendations

The following recommendations are based on some of the findings of this study as well as recommendations proposed during the Component 5 Technical Workshop for the Implementation held in Belize in March 1998 (Walling, 1998) and the Planning and Technical Review Meeting held in Jamaica in May 2001 (Lawrence & Edwards, 2001).

6.1 Site Selection

- A review of other potential operational area should be conducted with a view to identifying a remote operational area that is unaffected by anthropogenic influences, in addition to or to replace the Portland area. This should involve re-evaluating the issues associated with the establishment on a site offshore at Pedro Cays (70 km to the south) or the Formigas Bank (50 km to the east northeast).

- Attempts should be made to include the assessment of the reef flats which are the active breaker zones and reef builders. Erosion of these barriers will be important with respect to sea level rise associated with global climate change. There should be the assessment of the deeper reefs, which are thought to still be in good conditions as well as the sheltered reef communities.
- The detailed sites descriptions, including an account of the adjacent land use patterns and the environmental history (e.g. storm events), along with appropriate maps should be prepared for inclusion in subsequent reports.
- The monitoring sites should be geo-referenced for inclusion in a GIS database such as the CRIS.

6.2 **Monitoring**

- Fixed transects should be randomly and independently established within the target habitats which will be located at specified depths to ensure that the same community is being sampled by all transects, a reduction in introduced variation and to allow for direct comparison over time. In addition, permanent photo quadrats and the identification of monument corals should be incorporated into the monitoring programme.
- The video monitoring exercise should include the filming of additional footage on the reefs and other relevant subject matter of importance and interest to be used to illustrate the reports and document required for the monitoring programme.
- Attempts should be made to incorporate fish counts (species, number and size) into the monitoring exercise. Additional fish data could also be obtained from the Fisheries Division to give an indication of the species caught and their distribution.
- Bio-indicator parameters such as turf algae, sponges, *Diadema*, and Chlorophyll 'a' could be used to establish pollution gradients within the operational areas.
- Consideration should be given to adding coral growth (particularly as it related to the increase in $CaCO_3$ in the water) and coral recruitment to the parameters to be monitored for climate change impacts.
- Physical parameters such as temperature, salinity, dissolved oxygen, turbidity and pH should be monitored to effectively assess the impacts attributable to climate change factors. Additional parameters such as chlorophyll, BOD, COD, nitrate, phosphates and sedimentation should also be considered.
- Hydrometeorological data (rainfall, cloud cover, hours of sunshine, wind speed and maximum & minimum temperatures) should be obtained from the National Meteorological Services to complement the physical data collected.
- It is suggested that a roving team of experts be established to assist with monitoring in the countries with limited manpower capacity. Volunteers and dive shops should also be considered for assistance with assessing bleaching episodes.

6.3 Data Analysis and Processing

- During the data analysis the preparation of an all-inclusive species list should be carried out as an additional exercise to ensure that the rare coral species and coral recruits are recorded.

- The CARICOMP species list, which includes all the Caribbean species of hard coral, soft coral and algae, should be adopted and incorporated into the final data entry spreadsheet.
- The present data entry sheet should be updated and standardized for distribution to CPACC member countries.
- The Benthic Features Manual should be upgraded and training in the identification of video images should be conducted especially in light of the difficulty of differentiating between turf algae and other algae as well as between boring sponges and non-boring sponges.

6.4 Statistical Analysis

- The Standard Error Test (Bros & Cowell, 1987) should be carried out at a wider number of locations before the 20-transects/20m protocol can be modified. The figure for the number of transects and the length of transects would have to be standardized for all participating countries to facilitate spatial and temporal comparisons.
- Statistical analyses (such as Box and Whiskers graphs, ANOVA or any other appropriated analyses) should be incorporated into the monitoring and data analysis protocol.
- A statistician should be assigned to the project to ensure that the statistical analyses are homogeneous for all monitoring sites and countries.

6.5 Project Coordination and Management

- A comprehensive Monitoring Manual needs to be produced which includes the site selection protocol, video monitoring protocol, benthic substrate identification manual, the quality control/quality assurance manual, CARICOMP species list and category codes and the statistical analysis protocol. The manual should allow for modifications to be made to suit each country with information on the data entry mechanism, manpower and logistics requirements and communication procedures. A mechanism for ensuring the integrity of data (including off-site storage of duplicate data sets) and the sharing of experience from personnel should also be included. The manual should be updated periodically when decisions are taken or adjustments are made to the methodology.
- The monitoring programme requires more involvement of the interests groups and non-governmental organizations indicated in section 3.1 in the site selection and data collection processes. Analyzed data would then be conveyed to these organizations for use as a project management tools.

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8. Appendices

Appendix 1

Catalogue of videotapes for Jamaica for the years 1999 and 2000 for the CPACC Component 5 – coral reef monitoring programme.

Tape #	Date	Specific Site	Location	Filmed by	Camera	Exposure	Lens	Focus	Shutter Speed	Light
JM01	13/10/99	Discovery Bay - West Fore Reef	Transect 1, 3, 5	D. Street	Sony DVX1000	Auto	Wide	Auto	Automatic	No filter
JM02	13/10/99	Discovery Bay - West Fore Reef	Transect 2, 4, 6	P.Wilson-Kelly	Sony DVX1000	Auto	Wide	Auto	Automatic	No filter
JM03	14/10/99	Discovery Bay - West Fore Reef	Transect 8, 10, 12, 14, 16, 18		Sony DVX1000	Auto	Wide	Auto	Automatic	No filter
JM04	14/10/99	Discovery Bay - West Fore Reef	Transect 7, 9, 11, 13, 15		Sony DVX1000	Auto	Wide	Auto	Automatic	No filter
JM05	14/10/99	Discovery Bay - West Fore Reef	Transect 20, 22, 24		Sony DVX1000	Auto	Wide	Auto	Automatic	No filter
JM06	08/06/00	Port Royal - Southeast Cay	Transects 1- 5	P.Wilson-Kelly, J. Smith	Sony DVX1000	Auto	Wide	Auto	Automatic	No filter
JM06	09/06/00	Port Royal - Southeast Cay	Transect 6 - 9	P.Wilson-Kelly, J. Smith	Sony DVX1000	Auto	Wide	Auto	Automatic	No filter
JM07	10/06/00	Port Royal - Southeast Cay	Transects 10 - 20	P.Wilson-Kelly, J. Smith	Sony DVX1000	Auto	Wide	Auto	Automatic	No filter
JM08	15/06/00	Portland, Monkey Island	Transects 1 - 8	P.Wilson-Kelly, J. Smith	Sony DVX1000	Auto	Wide	Auto	Automatic	No filter
JM09	16/06/00	Portland, Monkey Island	Transects 9 - 13	P.Wilson-Kelly, J. Smith	Sony DVX1000	Auto	Wide	Auto	Automatic	No filter
JM09	18/06/00	Portland, Monkey Island	Transects 14 - 18	P.Wilson-Kelly, J. Smith	Sony DVX1000	Auto	Wide	Auto	Automatic	No filter
JM10	18/06/00	Portland, Monkey Island	Transects 19 - 20	P.Wilson-Kelly, J. Smith	Sony DVX1000	Auto	Wide	Auto	Automatic	No filter
JM10	22/06/00	Discovery Bay - West Fore Reef	Transects 1 - 6	P.Wilson-Kelly, J. Smith	Sony DVX1000	Auto	Wide	Auto	Automatic	No filter
JM11	22/06/00	Discovery Bay - West Fore Reef	Transects 7-10	P.Wilson-Kelly, J. Smith	Sony DVX1000	Auto	Wide	Auto	Automatic	No filter
JM12	23/06/00	Discovery Bay - West Fore Reef	Transects 11 - 20	P.Wilson-Kelly, J. Smith	Sony DVX1000	Auto	Wide	Auto	Automatic	No filter

Appendix 2

Example of a tape log using Tape #JM10, Discovery Bay, Jamaica 2000 Transect 1-6.

Location	Tape counter	Depth (ft)	Comments
Transect 1, Intro	13:52 - 14:12	35	Start of tape has
Transect 1	14:13 - 19:12		transects 19 and 20
Transect 1 Swim back	19:13 - 19:30		from Portland
Transect 2 Intro	19:40 - 20:00	27	
Transect 2	20:01 - 25:56		
Transect 2 Swim back	25:57 - 26:26		
Transect 3 Intro	26:27 - 26:51	38	
Transect 3	26:52 - 31:37		
Transect 3 Swim back	31:38 - 32:13		
Transect 4 Intro	32:14 - 32:45	38	
Transect 4	32:46 - 38:38		
Transect 4 Swim back	38:39 - 39:05		
Transect 5 Intro	39:06 - 39:34	36	
Transect 5	39:35 - 44:43		
Transect 5 Swim back	44:44 - 45:20		
Transect 6 Intro	45:21 - 46:01	41	
Transect 6	46:02 - 51:14		
Transect 6 Swim back	51:15 - 52:23		

Appendix 3

List of category codes used for substrate types and species.

Substrate Types

Hard Coral	Branching corals	BRAN
	Massive corals	MASS
	Encrusting corals	ENCO
	Foliaceous corals	FOLI
	Milleporines	MILL
	Coral juvenile	CORJ
Soft Coral	Gorgonians	GORG
	Encrusting gorgonians	ENGR
	Anemones	ANEM
	Corallimorpharians	CMOR
	Zoanthids	ZAON
Sponges	Erect sponges	ERSP
	Encrusting sponge	ENSP
	Encrusting calcareous algae	EALG
Algae	Turf algae	TALG
	Fleshy algae	FALG
	Calcareous algae	CALG
Non-Living	Bare Boulders	BOUL
	Bare Rock	ROCK
	Rubble	RUBB
	Sand	SAND
	Recently dead coral	DCOR
	Dead coral with algae	DCAL
Misc.	Unknown	UNKN
	Other	OTHR
	Tape	TAPE
	Wand	WAND

Species

Acropora cervicornis	ACER
Acropora palmata	APEL
Agaricia agaricites	AAGA
Agaricia grahamae	AGRA
Agaricia humilis	AHUM
Agaricia lamarcki	ALAM
Diploria labyrinthiformis	DLAB
Diploria strigosa	DSTR
Madracis mirabilis	MMIR
Millipora alcicornis	MALC
Millipora complanata	MCOM
Montastrea annularis	MANN
Montastrea cavernosa	MCAV
Montastrea faveolata	MFAV
Montastrea franksi	MFRA
Porites astreoides	PAST
Porites furcata	PFUR
Porites porites	PPOR
Solenastrea bournoni	SBOU
Scolymia sp	SCOL
Stephanocoenia michelinii	SMIC
Siderastrea radians	SRAD
Siderastrea siderea	SSID
Dictyota sp	DCIT
Lobophora sp	LOBO
Schizothrix sp	SCHI
Halimeda sp	HALI
Sargassum sp	SARG

Appendix 4

Example of data sheet developed in Microsoft Excel in which the data has been tabulated and grouped showing the calculated mean and standard deviation. The data sheet also summarizes the proportion of corals that are bleached and diseased.

SUBSTRATE CATEGORY	01TRAN	02TRAN	19TRAN	20TRAN	MEAN	STDEV
CORAL	6.2	4.6	5.2	7.0	6.70	3.35
SOFT CORALS	0.2	0.2	0.3	0.0	0.14	0.32
SPONGES	0.3	0.0	0.0	0.0	0.61	0.86
RECENTLY DEAD CORAL	0.0	1.0	2.5	1.3	3.98	3.76
OTHER ALGAE	24.0	36.3	55.4	54.8	49.49	9.36
OTHER, LIVE	0.0	0.0	0.5	0.0	0.30	0.51
DEAD CORAL WITH ALGAE	39.9	30.1	19.2	25.4	15.63	9.47
CALCAREOUS ALGAE	8.9	21.0	0.8	3.9	9.86	5.76
SAND, PAV, RUB	20.5	5.3	15.3	7.5	12.74	6.76
UNKNOWNS	0.0	1.6	0.7	0.0	0.53	0.46
TOTALS	100.0	100.0	100.0	100.0		
BLEACHED CORAL, % OF CORAL	0.0	0.0	0.0	0.0	1.12	2.42
DISEASED CORALS, % OF CORALS	0.0	0.0	0.0	0.0	0.47	1.33

Appendix 5

Draft CPACC Coral Reef monitoring report for Jamaica and Belize for the year 2000. CERMES, UWI Cave Hill Barbados. Valles, H. (2001). Prepared for CPACC. – *Selected excerpts*.

Appendix 5.1 Box and Whiskers plot and Descriptive Statistics.

The Box and Whiskers plots visually showed moderate or/and extreme outliers (identified by transect number on each plot) for most variables at each site (Figure 5.1). Outliers may be the result of incorrect recording or collecting of data and they may cause a sample to seriously deviate form normality and homogeneity of variance (Underwood, 1997; Zar, 1999). However, Zar (1999) also adds that "outliers might be valid data, and their presence may indicate one should not employ statistical analysis that require population normality and variance equality". Non-parametric testing would be more appropriate in cases where outliers contribute to serious deviations from normality and homogeneity of variance of the samples (Zar, 1999). In all instances, outliers should be tracked back to the raw data (and period of collection) to be re-examined in order to make sure that they are valid data.

The Box and Whisker plots also visually showed five variables very likely to seriously deviate from normality and/or homogeneity of variance for all three sites (i.e. absence of symmetry across median and very different distributions of data points among samples) (Figure 5. 1). These are Bleaching coral % cover, Disease coral % cover, Soft living coral % cover, Other % cover, Sponge % cover.

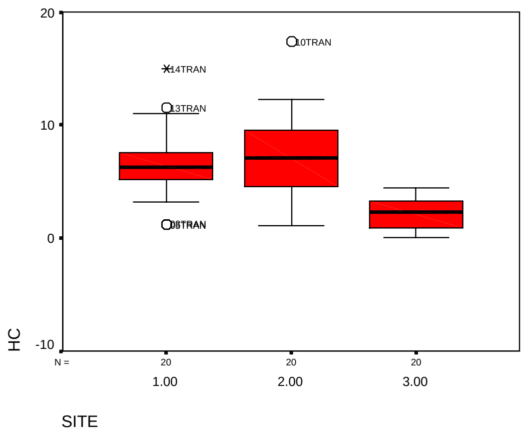
Three other variables showed considerable departures from normality (e.g. absence of symmetry across the median) for one or two sites (i.e. Recently dead coral % cover, Unknown % cover and Sand, Pave, Rubble % cover).

The rest of the variables appeared comparable using parametric testing (i.e. Hard living coral % cover, Fleshy algae % cover, Calcareous algae % cover, Dead coral with algae cover).

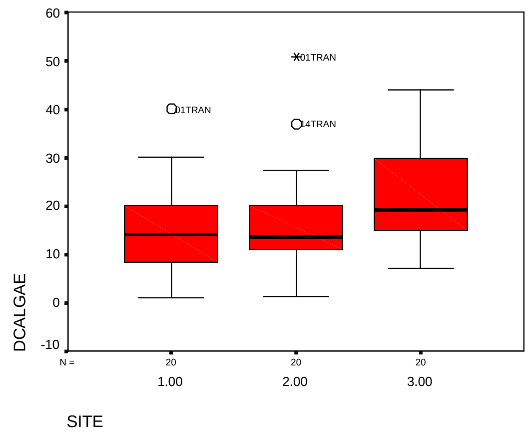
The descriptive statistics summary table (Table 5.1) provided numerical information useful to assess the distribution of the variables at each site and the relationship of their statistics. The mean, median (and mode) being close to each other is consistent with the existence of normality (although does not necessarily imply normality).

Figure 5.1 Box and Whiskers graphs showing among-site comparison for each habitat variable for Jamaica.

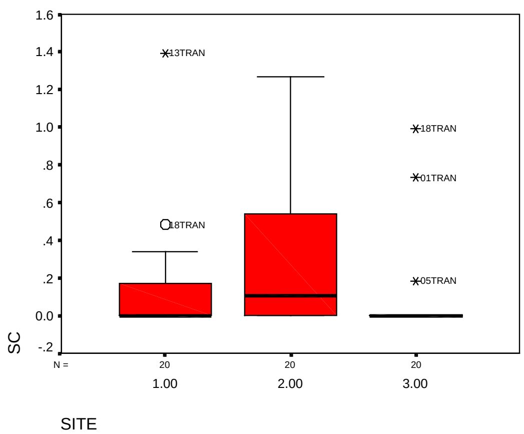
a) Hard living coral % cover (1-Discovery Bay; 2- Portland; 3- Port Royal)



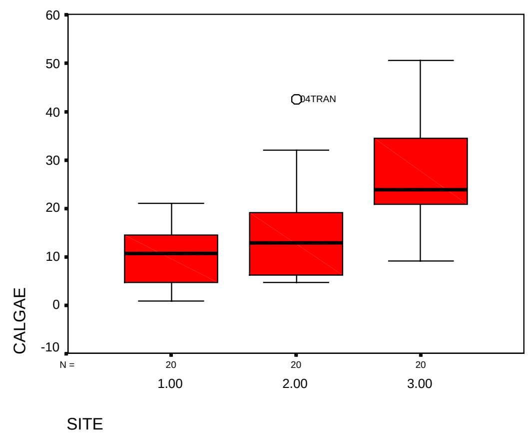
d) Dead coral with algae % cover (1-Discovery Bay; 2- Portland; 3- Port Royal)



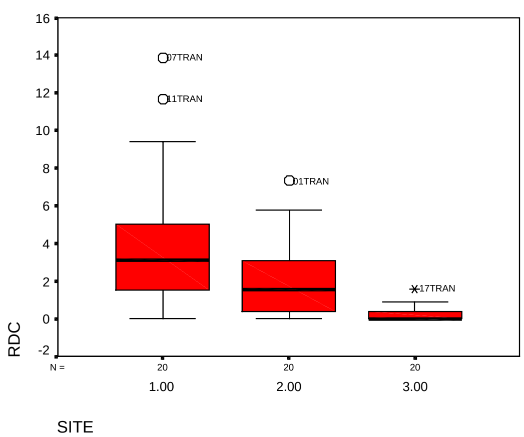
b) Soft living coral % cover (1-Discovery Bay; 2- Portland; 3- Port Royal)



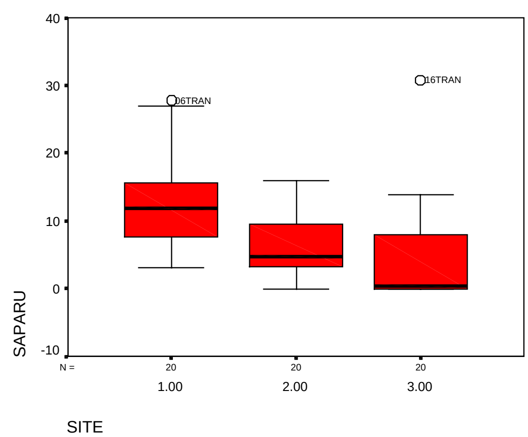
e) Calcareous algae % cover (1-Discovery Bay; 2- Portland; 3- Port Royal)



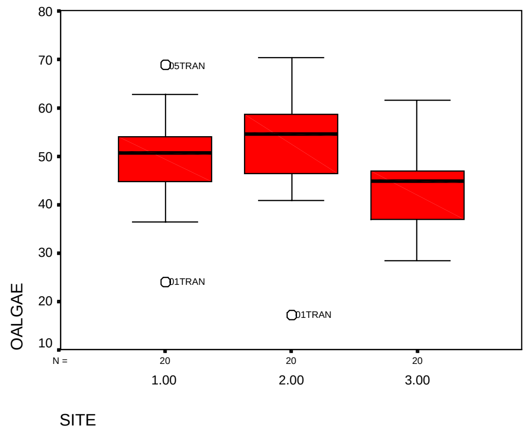
c) Recently dead coral % cover (1-Discovery Bay; 2- Portland; 3- Port Royal)



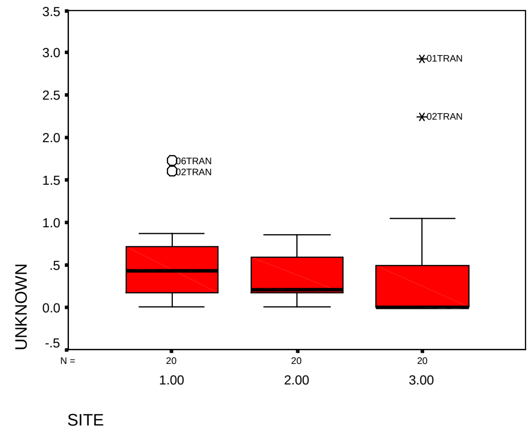
f) Sand; pave; rubble % cover (1-Discovery Bay; 2- Portland; 3- Port Royal)



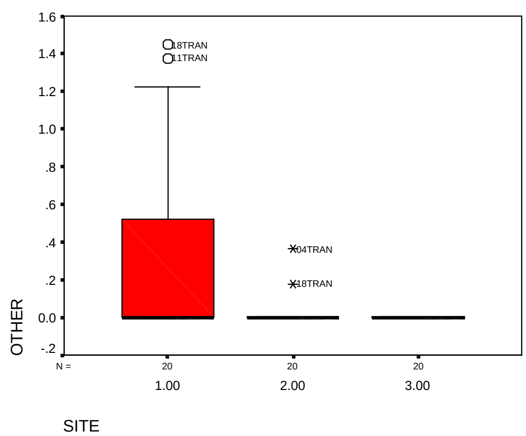
g) Fleshy algae % cover (1-Discovery Bay; 2-Portland; 3- Port Royal)



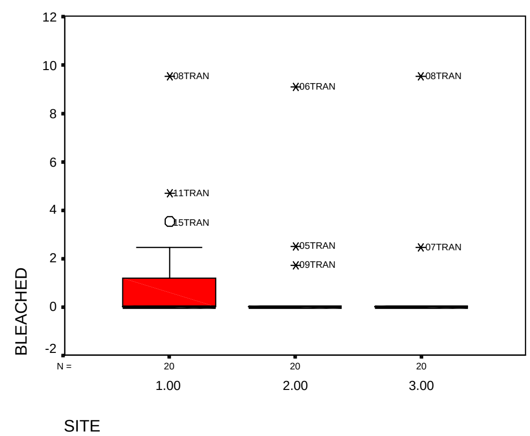
j) Unknown % cover (1-Discovery Bay; 2-Portland; 3- Port Royal)



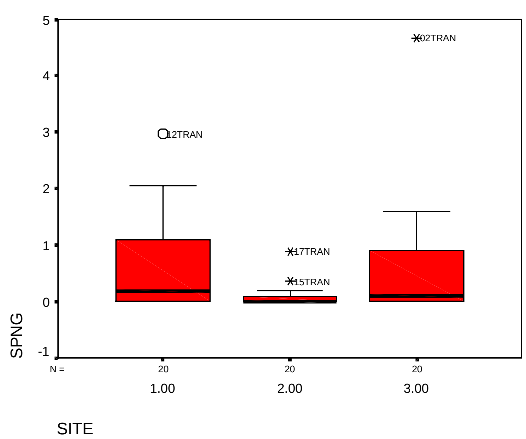
h) Others, living, % cover (1-Discovery Bay; 2-Portland; 3- Port Royal)



k) Bleaching coral % cover (1-Discovery Bay; 2- Portland; 3- Port Royal)



i) Sponge cover % (1-Discovery Bay; 2-Portland; 3- Port Royal)



d) Diseased coral % cover (1-Discovery Bay; 2- Portland; 3- Port Royal)

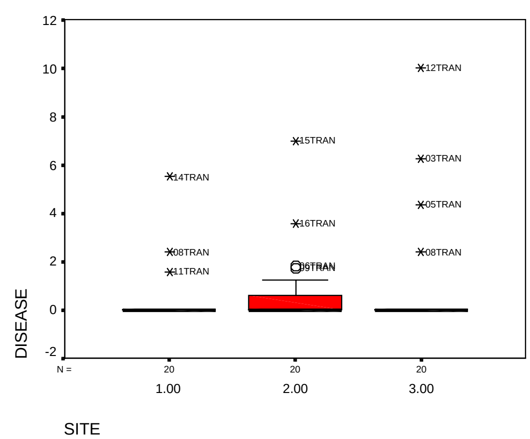


Table 5.1 Descriptive statistics for 12 variables at each site in Jamaica (Valles, 2001)

Site	Statistic	Hard Coral	Soft coral	Sponge	Recently Dead Coral	Fleshy Algae	Dead Coral & Algae	Coralline Algae	Sand, rubble and pavement	Other	Unknown
Discovery Bay	Mean	6.7	0.14	0.61	3.98	49.49	15.63	9.86	12.74	0.3	0.53
	Standard Error	0.75	0.07	0.19	0.84	2.09	2.12	1.29	1.51	0.11	0.1
	Median	6.3	0	0.17	3.09	50.61	14.13	10.63	11.92	0	0.42
	Standard Deviation	3.35	0.32	0.86	3.76	9.36	9.47	5.76	6.76	0.51	0.46
	Sample Variance	11.2	0.1	0.73	14.17	87.56	89.6	33.22	45.69	0.26	0.22
	Minimum	1.17	0	0	0	23.97	1.01	0.84	3.13	0	0
	Maximum	14.97	1.4	2.97	13.89	68.68	39.9	20.96	27.74	1.45	1.72
	Count	20	20	20	20	20	20	20	20	20	20
Portland	Mean	7.06	0.29	0.09	1.99	52.25	17	14.35	6.59	0.03	0.35
	Standard Error	0.86	0.08	0.05	0.45	2.6	2.52	2.31	1.09	0.02	0.06
	Median	7.13	0.11	0	1.57	54.63	13.62	12.82	4.74	0	0.2
	Standard Deviation	3.87	0.37	0.21	2	11.64	11.25	10.31	4.89	0.09	0.27
	Sample Variance	14.95	0.14	0.04	4	135.45	126.59	106.34	23.91	0.01	0.07
	Minimum	1.08	0	0	0	17.11	1.27	4.59	0	0	0
	Maximum	17.34	1.27	0.88	7.33	70.15	50.71	42.5	15.94	0.36	0.85
	Count	20	20	20	20	20	20	20	20	20	20
Port Royal	Mean	2.15	0.1	0.62	0.23	43.04	22	26.88	4.57	0	0.41
	Standard Error	0.31	0.06	0.25	0.09	1.93	2.46	2.5	1.74	0	0.18
	Median	2.24	0	0.1	0	44.65	19.19	23.69	0.3	0	0
	Standard Deviation	1.4	0.27	1.13	0.4	8.63	10.98	11.19	7.79	0	0.8
	Sample Variance	1.96	0.07	1.27	0.16	74.51	120.59	125.31	60.69	0	0.65
	Minimum	0	0	0	0	28.17	7	9.07	0	0	0
	Maximum	4.43	0.99	4.67	1.6	61.51	43.96	50.46	30.81	0	2.93
	Count	20	20	20	20	20	20	20	20	20	20

Appendix 5.2 Results of ANOVA tests

ANOVA (Analysis of Variance) is a very powerful and used parametric procedure for multisample testing. It examines the relationships between within-sample variances and among-sample variances to compute a value. This value is compared to a critical value determined (in a Fisher table) by the number of samples and replicates at a given significance level (i.e. 0.05). If the value computed (i.e. F statistic) is higher than the critical value, the hypothesis of equality of means among samples for a given variable can be rejected.

Significant differences among sites were found for Hard living coral % cover (ANOVA test: degrees of freedom: 2, 57; F=21.197; P<0.001), in which Port Royal exhibited significant lower % cover than the two other sites (Tukey test: P<0.001 for Port Royal vs Discovery Bay and Portland; P>0.05 in all other cases).

Significant differences among sites were found for Calcareous algae % cover (ANOVA test: d.f: 2, 57; F=17.708; P<0.001), in which Port Royal exhibited higher % cover than the two other sites (Tukey test: P<0.001 for Port Royal vs Discovery Bay and Portland).

Significant differences among sites were found for Fleshy algae % cover (ANOVA test: d.f: 2, 57; F=4.506; P=0.015) in which Port Royal exhibited lower % cover than Portland (Tukey test: P=0.014 for Port Royal vs Portland; P>0.05 for all other cases).

However, Dead coral with algae % cover did not differ significantly among sites (ANOVA test: d.f: 2, 57; F=2.213; P=0.119).

Significant differences among sites were found for Number of species (ANOVA test: d.f: 2, 57; F=4.506; P=0.015) in which Port Royal exhibited lower number of species than Portland and Discovery Bay (Tukey test: P<0.001 for Port Royal vs Portland and for Port Royal vs Discovery Bay; P>0. 05 for all other cases). Similarly, significant differences among sites were also found for Number of categories (ANOVA test: d.f: 2, 57; F=25.232; P<0.001) in which Port Royal exhibited again lower number of categories than Portland and Discovery Bay (Tukey test: P<0.001 for Port Royal vs Portland and for Port Royal vs Discovery Bay; P>0. 05 for all other cases).

Appendix 5.3 Results of the DFA

A discriminant function analysis (DFA) was performed using the four cover type variables that exhibited normality and homogeneity of variance. The DFA correctly classified 68 % of the transects into their correspondent sites. The sites seemed to differ only along one significant function (squared canonical correlation coefficient: 0.821) that separated Discovery Bay and Portland from Port Royal according mainly, to amount of Hard living coral % cover (discriminant loading=-0.592) and Calcareous algae % cover (d.l.=+0.543) and, to a lesser extent, to amount of Dead coral with algae % cover (d.l.=+0.194) (Figure 6). In other words, for the four variables, Discovery Bay and Portland are similar, and any given transect of Discovery Bay and Portland seems to have more Hard living coral than any given transect of Port Royal. Also, any given transect of Port Royal, seems to have more Calcareous algae and, to a lesser extent, Dead coral with algae, than any given transect of the two other sites.

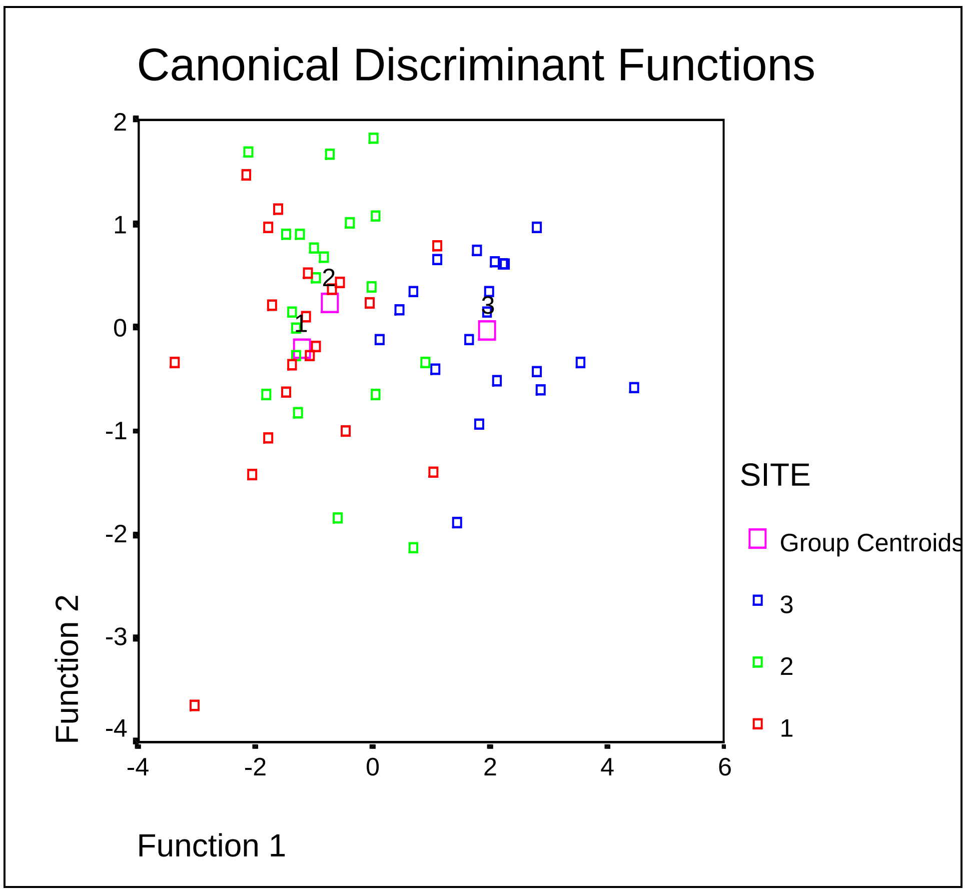
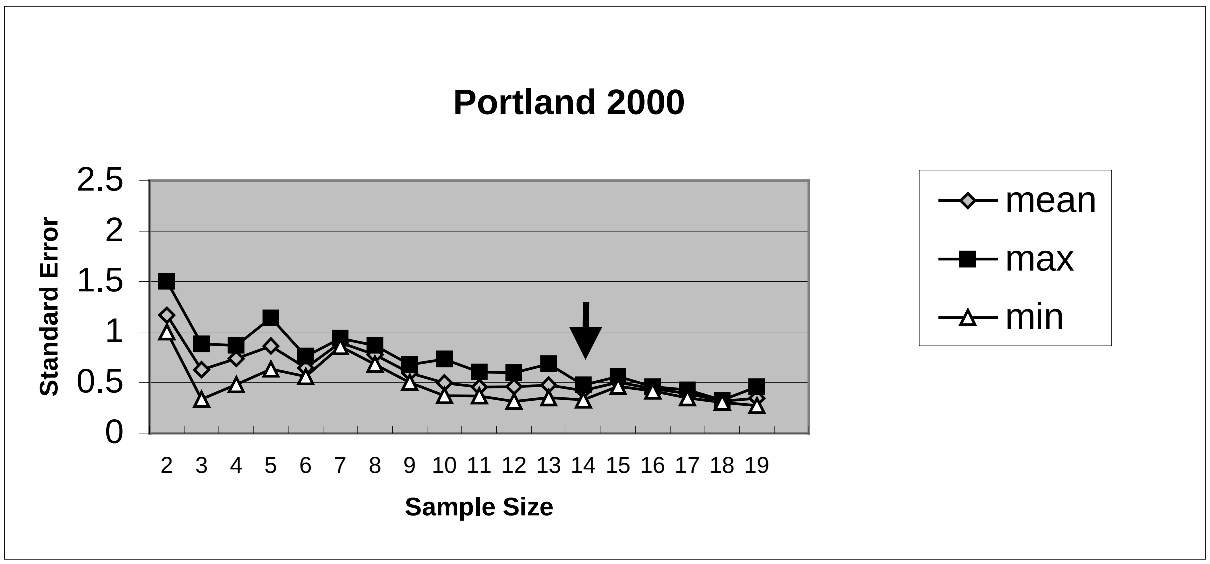
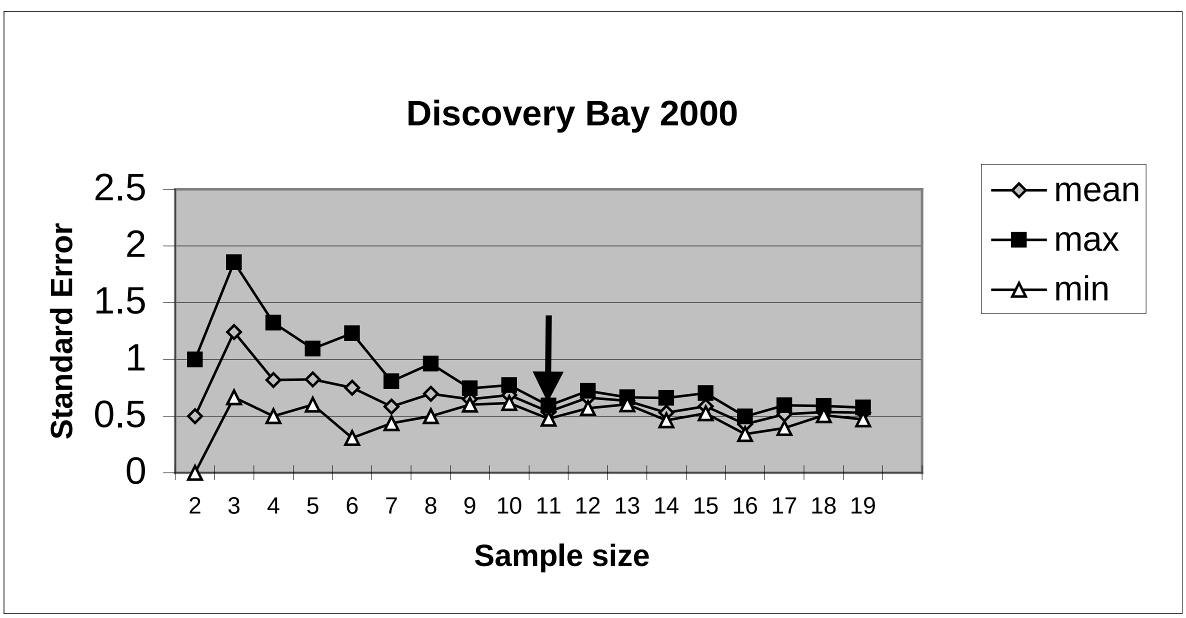


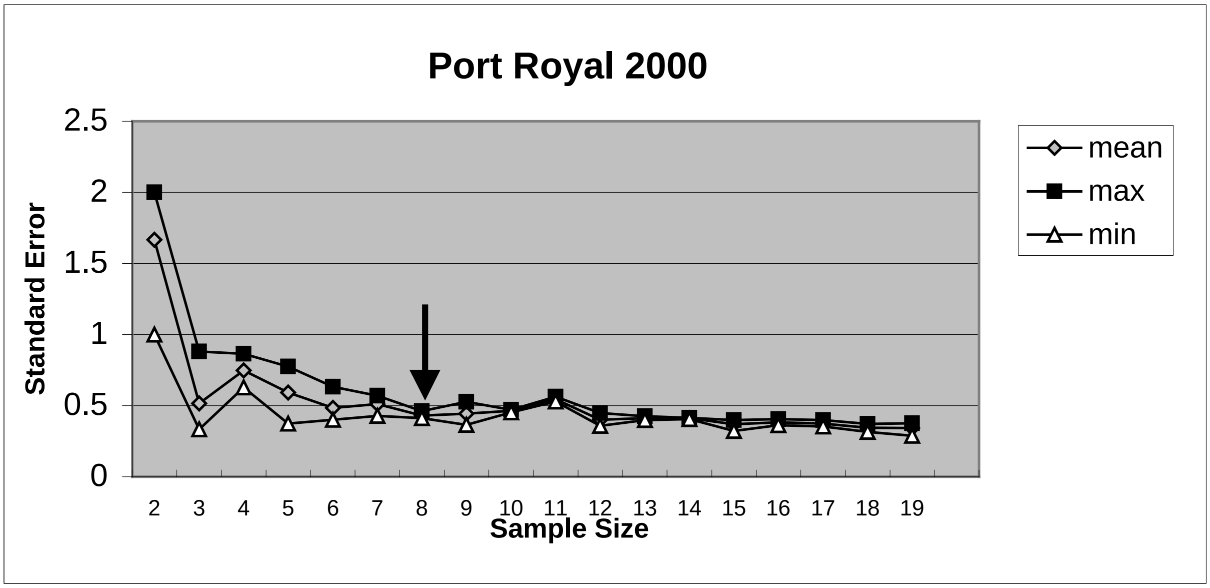
Figure 5.3 Results of the discriminant function analysis (DFA) with four variables showing discriminant distances between sites. (1-Discovey Bay; 2-Portland; 3-Port Royal).

Appendix 6

The graphs illustrate the calculation of the Standard Error (Bros & Cowell, 1987) estimate over a range of sample size (number of transects) drawn randomly from 20 samples (transects) for each of the monitoring locations (Portland, Discovery Bay and Port Royal). The arrows on the graphs indicate the minimum sample size for that location.






Port Royal 2000
2.5
2
1.5
1
0.5
0
Standard Error
mean
max
min
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Sample Size