

TOBAGO COASTAL ECOSYSTEMS MAPPING PROJECT

Annual Report RESULTS OF COMMUNITY AND SCIENTIFIC WORK

MARCH 2007 – JULY 2008

Coral Cay Conservation
Elizabeth House, 39 York Road, SE1 7AJ London
www.coralcay.org
info@coralcay.org

Project Partners



Report by

Jan-Willem van Bochove, Senior Field Scientist
Simon Harding, Head of Marine Science
Peter Raines, Founder and CEO

Coral Cay Conservation, January 2009

Executive Summary

Coral Cay Conservation (CCC), in close collaboration with the Buccoo Reef Trust (BRT) and the Tobago House of Assembly (THA), has been operating in Tobago as part of the Tobago Coastal Ecosystems Mapping Project (TCEMP) since March 2007. One of the main aims of the project is to gather baseline data on the coral reef, mangrove and seagrass habitats of Tobago. Between April 2007 and July 2008, CCC survey teams conducted 285 50-metre transects and 31 coral disease surveys on fringing coral reefs along the north-west coast of Tobago between Store Bay and Castara. Initial findings from 150 selected survey sites at 7 and 12 metres indicate that these reefs are all showing varying signs of stress.

Hard coral cover has dropped significantly from 22% in 2005 to 16% in 2008 with many sites showing less than 5% live hard coral cover. Coral diversity has also decreased and shallow water reefs have shifted from *Montastrea* dominated reefs to *Millepora* dominated ones. Macroalgal cover was low (<5%) and no phase shifts to a macroalgal-dominated state have taken place along the northwestern coast of Tobago. There is a high availability of bare substrates for corals to settle on although coral recruitment has not been observed on any significant scale. The presence of relatively high abundances of reef herbivores is hypothesised as the main reason for the lack of macroalgal cover.

Reef fish densities and biomass for a number of commercially fished families such as Groupers and Snappers and reef herbivores such as Parrotfish were low at all depths surveyed. Sites around Buccoo Reef generally displayed the highest abundance and biomass of these fish. Key invertebrate species such as Queen Conch and Lobsters displayed very low densities of overall abundance indicating severe over-harvesting. *Diadema* sea urchin densities were highly variable but overall abundance was relatively high compared to other Caribbean reefs.

High levels of coral disease, particularly Yellow Band Disease, have been observed. Most reef areas surveyed had over a third of coral colonies infected with coral diseases. *Aspergilliosis* affected over half of sea fans observed. Sites with high coral cover had lower disease prevalence. Coral health also appeared to be inversely related to depth, with the highest levels of disease recorded at the shallowest depth band surveyed.

Buccoo Reef, Mount Irvine, Arnos Vale, Back Bay, Plymouth, Culloden, Washerwomen's Bay and King Peter's Bay all had high *Conservation Management Values*. Therefore, the fringing reefs of these areas should be considered priority sites for effective conservation management.

To date, the TCEMP has received a total of 49 scholarship students from Trinidad and Tobago whom have taken part in a variety of scholarship programmes offered by CCC. In addition to the highly successful scholarship programmes, a range of other outreach and educational initiatives has been undertaken. A notable highlight was a visit by HRH Prince Charles to BRT's marine research centre where he met with CCC volunteers and scholars.

Management recommendations include the incorporation of adequate sewage treatment plants, minimizing land runoff and enforcing strict fisheries protection mechanisms on key reef herbivores and highly vulnerable key predators. A network of large-scale, effectively managed marine reserves would help to protect vulnerable populations of reef fish and invertebrates and the coral reef habitats they live in. As conservation measures take hold the

harvesting of these species will become more sustainable, aiding the long-term protection of coral reefs around Tobago.

Acknowledgements

The establishment and success of the *Tobago Coastal Ecosystems Mapping Project* would not have been possible without: the vision and leadership provided by the Tobago House of Assembly; the generous hospitality of the Arnos Vale Hotel Resort; and the guidance, encouragement and generous support provided by the following project partners and supporters (listed in alphabetical order):

Alvin Douglas of the Tobago Divers Association
The Arnos Vale Hotel
The Buccoo Reef Trust
Department of Natural Resources and the Environment, Tobago
Department of Fisheries and Marine Affairs, Tobago.
Environmental Logistics
Environment Tobago
Global Environment Facility/Small Grants Programme
The Integrated Watershed and Coastal Area Management in Small Island Developing States of the Caribbean (IWCAM)
Giancarlo Lalshing and the rest of the staff at Save Our Sea Turtles Tobago
Jennie Mallela, Coral Reef Ecologist, University of the West Indies, Trinidad
The United Nations Development Program

All the dedicated staff and volunteers that joined the TCEMP and made this possible

Table of Contents

1	Introduction.....	1
1.1	Threats to Tobago's coral reefs	1
	Global and Regional-Scale Threats and Impacts.....	1
	Coral Bleaching.....	2
	Ocean Acidification	2
	Coral Diseases.....	2
	Precipitation and Storm Damage	3
	Intermediate and Local-Scale Threats and Impacts	3
	Nutrification.....	3
	Sedimentation.....	4
	Overfishing	4
1.2.	Project Background and Need.....	4
1.3.	Coral Cay Conservation	6
	Aim of report.....	7
2.	Progress of Community Work and Capacity Building Programmes	8
2.1	CCC Scholarship Programme	8
2.2	Summary of Meetings and Community Activities	9
2.3	Careers Days	10
3	Scientific Methods	14
3.1	TCEMP Baseline Surveys	14
	History and rationale	14
	Survey Technique	15
3.2	Coral Disease Surveys.....	17
	History and rationale	17
	Survey Technique	18
3.3	Data Analysis	18
3.4	Geographical Information System.....	19
3.5	Survey Progress.....	20
4.	Results	22
4.1	Benthic Composition.....	23
4.2	Coral Cover.....	25
4.3	Reef Fish.....	32
	Predatory Reef Fish.....	32
	Herbivorous Fish	33
4.4	Invertebrates.....	36
4.5	Coral Disease and Bleaching	38
5.	GIS Contour Mapping.....	43
5.1	Benthic Cover.....	44
5.2	Invertebrates.....	48
5.3	Reef Fish.....	51
5.4	Conservation management values	57
6.	Discussion	59
	Benthic composition	59
	Reef Fish	59
	Invertebrates	60
	Coral Disease and Bleaching	60
	General Conclusions and Management Recommendations	61
	References.....	63
	Appendix: TCEMP target species	66

Table of Figures

Figure 1	Satellite map of Tobago.....	6
Figure 2	CCC 'Reef Conservation Scuba Award' scholars and volunteers.....	9
Figure 3	CCC volunteers and teachers and local schoolchildren.	10
Figure 4	HRH the Prince of Wales speaking to CCC volunteers and scholars.	11
Figure 5	EMA's School Competition, 2007.	13
Figure 6	Science Development Programme.....	14
Figure 7	Schematic representation of TCEMP baseline surveys.....	17
Figure 8	Schematic representation of a TCEMP coral disease assessment survey.....	18
Figure 9	Number of CCC baseline and coral disease surveys conducted.....	20
Figure 10	CCC baseline survey stations between Buccoo Reef and Castara.....	21
Figure 11	Selected sites used for comparisons of coral reef habitats.....	22
Figure 12	Benthic composition of selected reef sites.....	25
Figure 13	Hard coral cover during and 3 years after the 2005 bleaching event.....	26
Figure 14	Hard coral composition at 4 survey depths for 2005 and 2008.....	29
Figure 15	Mean number of hard coral species	30
Figure 16	Mean hard coral cover for selected survey sites.....	31
Figure 17	Biomass of three key predatory reef fish at selected sites.....	33
Figure 18	Abundance of two main herbivorous fish families.	34
Figure 19	Biomass of Parrotfish at selected sites and three survey depths	35
Figure 20	Abundance and adults to juvenile ratio's of <i>Diadema</i> sea urchins	36
Figure 21	Abundance of selected invertebrate targets.	37
Figure 22	Percentage of coral colonies affected by 4 coral diseases.....	38
Figure 23	Most common and abundant diseases affecting three main hard coral categorie	39
Figure 24	Percentage of unhealthy coral colonies in relation to the hard coral cover	40
Figure 25	Percentage of diseased coral colonies in relation to the % cover.....	40
Figure 26	Overall coral reef health (all coral diseases combined).....	41
Figure 27	Disease prevalence of 4 coral diseases at 5 survey sites	42
Figure 28	Percentage hard coral cover.....	45
Figure 29	Percentage bedrock cover.....	46
Figure 30	Percentage cover of macroalgae cover.....	47
Figure 31	Sea urchins (<i>Diadema antillarum</i>).....	49
Figure 32	Common seafans (<i>Gorgonia ventalina</i>)	50
Figure 33	Biomass of Parrotfish (<i>Scaridae</i>)	52
Figure 34	Biomass of Groupers (<i>Serranidae</i>).....	53
Figure 35	Biomass of Snappers (<i>Lutjanidae</i>).....	54
Figure 36	Biomass of Grunts (<i>Haemulidae</i>).....	55
Figure 37	Biomass of commercial fish.....	56
Figure 38	Conservation management value for reef areas in northern Tobago	58

1 Introduction

Tobago's coral reefs are an integral part of the islands economy and cultural heritage. They provide its people with food and livelihoods through coastal fisheries and tourism, attracting thousands of visitors to the island, and help to protect its coastlines from storms. Coral reefs and their associated habitats furthermore provide various 'ecosystem services' such as food, shelter and a nursery grounds for many other species as well as playing an important role in chemical cycles.

A recent economic valuation conducted in Tobago by the World Resource Institute estimated that the value of coastal resources derived from tourism, coastal protection and fisheries in 2006 was between \$100-130 million (Burke et al., 2008). This amounts to nearly half of the GDP for Tobago in that year and underlines the vital importance of benefits derived from coral reef goods and services.

Disturbingly, the coral reefs of Tobago, like many of those throughout the wider Caribbean region, are in crisis (see Gardner et al., 2003) and the overriding cause is thought to be human activity (see Mora, 2008). Nearly two-thirds of reefs in the Caribbean are potentially at risk from human activities, with over 40 per cent at 'high' or 'very high' risk (Burke and Maidens, 2004). Tobago has been identified as a high-risk area. The current rate of loss of coral reefs, mangrove habitats and seagrass beds could prove disastrous to the economy of Tobago and the livelihoods of its people. There is an urgent need to mitigate local, human induced pressures in Tobago and responsibly manage the existing reefs for the enjoyment and benefit of future generations.

1.1 *Threats to Tobago's coral reefs*

Threats to reef health in Tobago caused by both natural and anthropogenic factors include overfishing, habitat degradation, land-based pollution stresses and climate change induced events. The impact of natural threats has been illustrated recently with the destructive force of Hurricane Ivan, which caused considerable damage to coastal areas and the shallow marine environment in 2004. The large-scale bleaching event of 2005 is also an example of a major climate change induced event that has significantly affected the coral reefs around Tobago. The range of threats applicable to coral reefs in Tobago is described in some detail below.

Global and Regional-Scale Threats and Impacts

Carbon Dioxide (CO₂) levels in the earth's atmosphere have been rising steeply since the industrial revolution, mainly due to the burning of fossil fuels. Based on realistic scenarios of future emissions this trend will continue and atmospheric CO₂ concentrations are expected to reach double pre-industrial levels by 2065 (Houghton et al., 2001). Global temperatures are expected to rise anywhere between 1.8 – 4.0°C by the year 2100 (IPCC, 2007).

Climate change is regarded as one of the major threats to the future of coral reefs (Hughes et al., 2003). Coral reefs have evolved in relatively stable climatic conditions for the last tens of thousands of years. It is this relative climatic stability that has allowed them to develop into a complex ecosystem comprised of thousands of species and many intricate inter-specific relationships. Coral reefs can recover from acute stress (e.g. bleaching events) and also tolerate chronic (e.g. sedimentation) ones to a certain degree. However, chronically stressed

reefs are far less likely to recover from an acute stress (Kinsey, 1988). A series of acute stresses against a backdrop of continued chronic ones can result in a phase shift and the replacement of the coral dominated community by one dominated by macroalgae or some other non-reef system. Such ecosystem shifts are well advanced in the Caribbean (Buddemeier et al., 2004) and in some cases; the combination of stresses has brought coral reefs to the point of local extinction. Coral reefs have accordingly been dubbed the “canaries in the coalmine of climate change”. What follows is a summary of some of the most concerning climate change induced phenomena that are predicted to have an impact on the coral reefs around Tobago.

Coral Bleaching

Coral species and their associated microscopic algae are highly sensitive creatures with a limited ‘tolerance zone’ within which they can thrive. Stressors such as increased UV light and thermal stress can threaten their survival. Coral bleaching refers to the loss of the symbiotic algae (zooxanthellae) from the coral tissue as a result of stress. Without these algae, the coral colony appears white. The zooxanthellae provide the bulk of the coral’s nutrition via photosynthesis. If a coral colony is not able to regain its population of symbiotic algae, it will starve.

Although there have been records of coral bleaching since 1870 (Glynn, 1993), extensive or regional bleaching appears to be a relatively new phenomenon, with a significant increase in the levels and extent of bleaching recorded in the past 20 years or so (Winter et al, 1998). Recent examples of corals reefs’ responses to elevated sea surface temperatures in the Caribbean were demonstrated by two large-scale regional bleaching episodes. In 1998 (*El Niño* Southern Oscillation, ENSO) bleaching effectively killed 16% of the worlds coral reefs and the mass bleaching event of 2005 resulted in on average 66% coral bleaching in the Caribbean (see Wilkinson and Souter, 2008). Such events are expected to become bi-annual within the next 20-50 years if drastic measures are not taken to reduce carbon emissions (IPCC, 2007).

Ocean Acidification

In addition to rising sea surface temperatures, another phenomenon is expected to affect the very structure and growth capabilities of hard corals through a process known as oceanic acidification. As the oceans soak up more carbon dioxide the marine chemistry of the ocean changes. Dissolved in water, CO₂ becomes carbonic acid, reducing the amount of carbonate available to calcifying organisms such as reef building (Scleractinian) corals that need carbonate to create a calcium carbonate (limestone) skeleton. In the last 200 years the surface ocean has absorbed about half of the CO₂ produced by industry, causing a fall in pH of 0.1, which equates to a 30% increase in H⁺ ion concentration (Royal Society, 2005). The predicted changes in seawater chemistry could have severe consequences for calcifying organisms, making it increasingly difficult for hard corals to maintain their limestone skeletons (Orr et al. 2005).

Coral Diseases

Disease outbreaks and subsequent mortality among corals and other reef organisms have been a major cause of the recent increase in coral reef degradation (Buddemeier et al., 2004). Coral disease frequency has been linked to thermal stress (Bruno et al., 2007) and there have been

local reports of disease outbreaks following on from bleaching events, as is the case in Tobago (see van Bochove et al., 2008). There is a lack of knowledge about the causative agents of many diseases affecting corals but studies have shown that microbial pathogens are a source of coral diseases such as Yellow Band Disease, Black Band Disease, Aspergillosis and White-Band disease (Cervino et al., 2004). The latter disease is responsible for more than a 90% reduction in populations of Elkhorn (*Acropora palmata*) corals, which was once the dominant shallow-reef building coral in the Caribbean but is now listed on CITES as an endangered species. Some of these pathogens have been linked to sewage and agricultural outputs (Voss et al., 2006, Smith et al., 1996) providing strong evidence for the effectiveness of proper waste management schemes in order to minimise disease impacts on coral reefs.

Precipitation and Storm Damage

Another concerning effect of global climate change is the expected dramatic changes in weather systems. Tropical precipitation has increased over the past century by 0.2–0.3 % per decade in the 10°S–10°N region (Houghton et al., 2001). The frequency of heavy precipitation events is expected to increase (IPCC, 2007). Increases in precipitation can lower salinity and increase sediment discharge and deposition near river mouths, sometimes leading to mass mortalities on nearby coral reefs (Wolanski et al., 2003). Proper management and restoration of natural watersheds can greatly minimise direct runoff from rainwater.

Hurricanes are also becoming both stronger and more unpredictable (Webster 2005). Healthy reefs can recover from infrequent damage caused by tropical storms but already weakened and stressed reefs may be further degraded with little opportunity for recovery. The impact of natural threats have been illustrated recently with the destructive force of Hurricane Ivan, which caused considerable damage to coastal areas and the shallow marine environment.

Intermediate and Local-Scale Threats and Impacts

Although climate change is now considered to be the overarching threat to tropical marine ecosystems, impacts to coral reefs are exacerbated by local, anthropogenic events. To maintain hard coral populations on reef systems around the world it will be necessary to carefully manage direct pressures such as pollution, sedimentation, overfishing and coastal development, and hope that some coral species are able to adapt to the warmer environment (Wilkinson and Souter, 2008). Studies conducted on relatively undisturbed coral reefs in the absence of direct human pressures have indicated that these reefs have a greater ability to recover from bleaching events. This was demonstrated in the remote archipelago of Chagos following the 1998 ENSO event (Sheppard et al., 2008). Threats to reef health, caused by local anthropogenic factors include:

- Changes in water quality due to input of nutrients
- Siltation from construction, dredging and runoff from upland deforestation and agriculture
- Overfishing to the extent where key groups of species are removed and it is no longer sustainable.

These are briefly discussed below.

Nutrification

Coral reefs thrive in regions where the waters are clear and devoid of nutrients and are sometimes referred to as the marine deserts of the tropical oceans. The addition of nutrients

from land-based agricultural runoff and/or untreated sewage discharge can create a situation which promotes the growth of phytoplankton and seaweeds (macroalgae), the latter of which can out-compete corals for space and light. This effect is further exacerbated if overfishing removes key herbivores that normally help to keep algae in check. Knock-on effects have been known to weaken the physiological resistance of corals and make them more susceptible to disease. Recent studies have shown a link between increased nutrient levels and the rate of disease spread (Voss et al., 2006)

Sedimentation

High levels of sediment from land-based sources such as vegetation removal mining and coastal construction as well as resuspension of marine sediment by dredging or trawling can interfere with the coral polyps' ability to feed. Corals under stress from sedimentation have to divert much of their energy actively removing sediment particles (Riegl and Branch, 1995). Stressed corals are also more susceptible to disease. When suspended in water, sediment can limit the amount of light available to corals and this can seriously hamper coral growth and ultimately their survival. Coral reefs in naturally turbid waters, such as many of those in Tobago, are generally more resilient to sediment loading (Larcombe and Woolfe, 1999). However, increased sediment run-off from various small-scale construction projects, upland deforestation and increased sediment loading from the Orinoco river system are driving Tobago's corals beyond their normal threshold levels.

Overfishing

Overfishing, the unsustainable fishing or collection of marine resources, like conch shells and lobsters, and with them, the ecosystem functions they perform, is a global problem with a long history of impacts across the entire marine ecosystem (Jackson et al., 2001). In parts of the Caribbean, widespread overfishing of reefs has removed many of the herbivorous fish that keep algae in check, upsetting the competitive balance between corals and seaweeds, often leading to a fundamental change in the community. Consequently, management of fish stocks is a key component in preventing phase shifts and managing reef resilience (Hughes et al., 2007). There is now evidence that chronic overfishing of top predators such as sharks can have top-down effects on reef productivity (Myers et al., 2007).

Local stewardship of fisheries, under guidance of management experts, can be an effective means for conservation of reefs and improved local fish stocks. Recommendations, including implementing and enforcing permanent closures, seasonal protection of spawning sites, fishing gear restrictions and catch limits can all guide effective conservation and management of nearshore fisheries.

1.2. Project Background and Need

After the 2005 Caribbean-wide bleaching event, Coral Cay Conservation (CCC) assisted the Tobago House of Assembly (THA) and the Buccoo Reef Trust (BRT) by providing technical resources and manpower to assess the extent of this event on the coral reefs of Tobago.

Following this successful collaboration, CCC and the BRT established a programme of systematic study with the THA and with support from the United Nations Development

Programme (UNDP). This study, named the Tobago Coastal Ecosystem Mapping Project (TCEMP), was initiated in March 2007 with three aims, to:

1. Provide baseline data on the current status of coral reef, mangrove and seagrass ecosystems surrounding Tobago;
2. Increase awareness about Tobago's marine resources through environmental education programmes;
3. Build in-country capacity through CCC's scholarship programmes.

The coastal assessment programme was designed to provide relevant information for effective policy-making and management of coastal resources. Information collected will be used by the Integrated Watershed and Coastal Area Management in Small Island Developing States of the Caribbean (IWCAM) programme to provide the necessary knowledge to government bodies for effective decision making (see Figure 1). The TCEMP also has strong community education and capacity-building components. These include training opportunities for local counterparts through the CCC scholarship programme, as well as environmental awareness programmes for schoolteachers and students. Such initiatives are increasing public awareness and building lasting local capacity to assist in the effective management of Tobago's valuable coral reefs.

The range of threats listed in the previous section have resulted in widespread degradation of coral reefs in the Caribbean, and an estimated decline in live coral cover from 50 to 10% over the last 30 years (Gardner et al., 2003), not including the damaging effects of the 2005 mass bleaching event. In order to curb this trend and maximise the resilience of coral reefs to predicted climate change events, it is crucial to minimise local man-made stressors resulting from coastal zone development, untreated wastewater discharge and overfishing. The mitigation and minimisation of these pressures can be achieved through an integrated sustainable management approach to the use of the coastal zone and its associated marine resources. Action taken to reduce these pressures on Tobago's reefs will give them a greater chance of withstanding and recovering from regional stressors such as coral bleaching episodes. It is imperative that such initiatives strive to include all stakeholders (local and national government agencies, NGOs and resource users such as fisherfolk and tourism operators).

Management decisions and sustainable initiatives however, require accurate and current information on the status of the resources in question. At present, baseline data on Tobago's coastal resources are limited primarily to the Buccoo Reef area in the southwest. The condition of the remainder of Tobago's extensive reef network is virtually undocumented.

The ever-increasing demands placed on government agencies responsible for the management of the coastal zone will require (1) a scientifically sound database of natural resources, (2) increased capacity for the use of decision-support tools (e.g. GIS) and (3) improved public awareness. The ***Tobago Coastal Ecosystem Mapping Project*** encompasses activities to address all three needs.

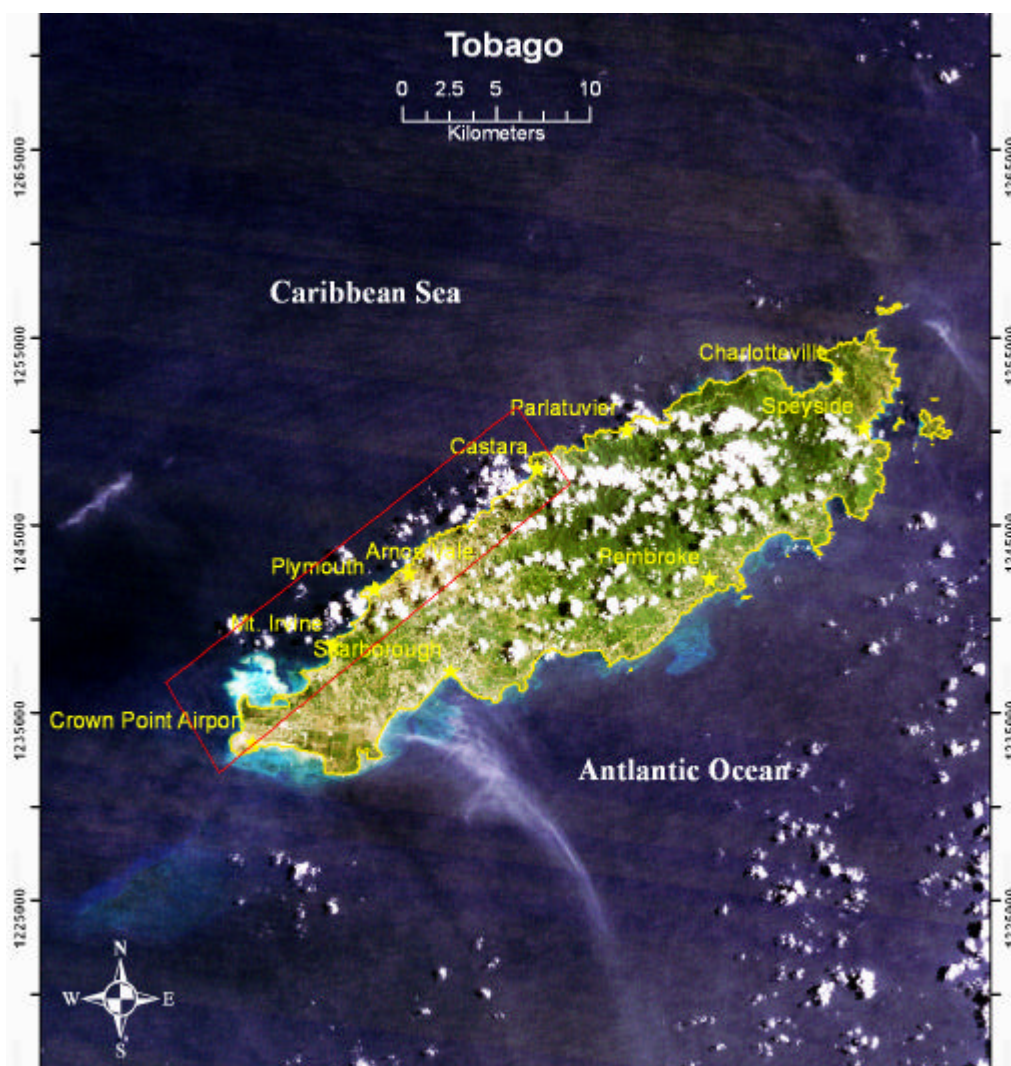


Figure 1 Satellite map of Tobago including the IWCAM project area of focus (red rectangle).

1.3. Coral Cay Conservation

Effective coastal zone management, including conservation of coral reefs, requires a holistic and multi-sectoral approach, which is often a highly technical and costly process and one that many developing countries cannot adequately afford. With appropriate training, non-specialist volunteer divers are able to provide useful data for coastal zone management at little or no cost to the host country (Hunter and Maragos, 1992; Mumby et al., 1995; Wells, 1995; Darwall and Dulvy, 1996). This technique has been pioneered and successfully applied by Coral Cay Conservation (CCC), a British not-for-profit organisation.

Founded in 1986, CCC is dedicated to *‘providing resources to protect livelihoods and alleviate poverty through the protection, restoration and sustainable use of coral reefs and tropical forests’*. CCC works in collaboration with government and non-governmental organisations within a host country and does not charge that country for the services provided. CCC is primarily self-financed through a pioneering volunteer participatory scheme whereby international volunteers are given the opportunity to join a phase of each project in return for a financial contribution towards the project costs. Upon arrival at a project site, volunteers undergo a training programme in marine life identification and underwater survey techniques, under the guidance of qualified marine scientists, prior to assisting in the acquisition of data.

Finances generated from the volunteer programme allow CCC to provide a range of services, including data acquisition, assimilation and synthesis, conservation education, technical skills training and other capacity building programmes. CCC is associated with the Coral Cay Conservation Trust (the only British-based charity dedicated to protecting coral reefs). CCC has been successfully running volunteer based conservation programmes in developing countries over the past 20 years with notable conservation successes in Belize (significant contribution to the formation of the Belize Reef Marine Park and World Heritage Site) and the Philippines (creation of the Danjungan Island Marine Reserve in Negros Occidental).

For further information regarding CCC's aims and achievements, please visit our website at: www.coralcay.org

Aim of report

The primary aim of this report is to provide a summary of the progress of the *Tobago Coastal Ecosystems Mapping Project* over the first 17 months of the project. Progress on baseline and coral reef monitoring surveys is provided. An initial analysis of survey data collected is given in both chart format and through Geographical Information Systems (G.I.S.), plotted on satellite imagery. Local community work has been summarised on a thematic basis including notable achievements.

2. Progress of Community Work and Capacity Building Programmes

This section provides a summary of the community educational work and capacity building programmes that CCC has developed alongside the biophysical survey programme. These project components are designed to raise environmental awareness of the local community, provide marine science training to local scholars and strengthen ties with local counterparts and government bodies. CCC's community and capacity building programmes are key aspects of the TCEMP project and have been adapted from successful and proven initiatives, tried and tested in other host countries where CCC operates. These programmes continue to be improved and expanded upon. New initiatives are discussed in the future activities sub-section.

2.1 CCC Scholarship Programme

CCC is currently running three scholarship programmes in Tobago. The scholarships are open to residents of Trinidad and Tobago wishing to make an active contribution towards the protection and sustainable use of Tobago's coral reefs. This includes tourism professionals, local fishers, government employees, university students, graduates and educators.

Each programme runs once every four weeks. CCC can also run additional one-day 'Coastal Zone Management (CZM)' workshops for particular groups if required. The structure of these workshops is flexible and can be adapted to suit a particular audience. As of July, 2008, 15 Reef Conservation Scholars, 4 Reef Check Scholars and 30 Coastal Zone Management Scholars have been trained. Names and contact details of the scholars can be obtained upon request.

The three main types of scholarships offered are:

- Coastal Zone Management Workshop (CZM)

This one-day course includes training in snorkelling, identification of reef invertebrates, major fish and coral groups plus discussions of coral reef ecology, threats to the marine environment and potential management options through a series of lectures and case studies.

- Reef Check Scuba Award

This two-week award includes certification to PADI Advanced Open Water Diver, identification of target marine life forms and training in Reef Check survey techniques.

- Reef Conservation Scuba Award

This intensive four-week programme involves scholars staying at the expedition site seven days a week. Training includes PADI Advanced Open Water Diver certification, identification of over 300 marine life forms and rigorous scientific surveying of coral reef ecosystems.



Figure 2 CCC 'Reef Conservation Scuba Award' scholars and volunteers posing with their survey equipment before heading out to the survey site. Image taken by Mike Green

2.2 Summary of Meetings and Community Activities

This section provides a list and short description of the main meetings and events that CCC field staff and volunteers have attended between February and July of 2008. Please see the TCEMP bi-annual report for a summary of activities from the first six months of the project.

School Visits

CCC staff and volunteers regularly visit primary schools where they introduce students to basic coral reef ecology and conservation through a series of fun interactive lectures and games. The visit is finished with a puppet show that reemphasizes the lessons learned. Popular with both the volunteers and the children, the school visits now form an integral part of the project. The following schools were visited over the past six months:

- 15th February – Bethesda Primary School, standards 3 & 4
- 18th February – Bethesda Primary School, infants 1 & 2
- 21st February – Bethesda Primary School, standards 1 & 2
- 26th February – Step up International
- 13th March – Montgomery Primary School Standards 3 & 4
- 17th April – Infants 1 & 2 Montgomery Primary School
- 13th May – Standards 3 & 4, 2 puppet shows - Whim Primary School on Turtle Beach
- 14th May – Table piece primary school on Turtle Beach



Figure 3 CCC volunteers and teachers and local schoolchildren posing with the characters of the 'Danny the Damselfish' puppet show.

2.3 Careers Days

CCC makes an effort to attend career days wherever possible in order to provide students from Tobago an opportunity to speak to marine biologists and encourage them to pursue careers in environmental conservation.

- 30th April – Speyside Secondary School
- 15th May – Mason Hall Secondary School with the Buccoo Reef Trust (BRT)
- 12th June – Bishop's High School with BRT, including a presentation on Coral Reef Conservation
- 20th of June - Tobago Science Expo 2008 'Science is Fun!' with BRT

6th March 2008 - HRH Prince Charles and the Duchess of Cornwall's visit to BRT's new marine research centre

Three schools; Step-up International, Montgomery Government Primary School and Bethseda Government Primary School all helped to make carnival themed reef creatures using recycled materials. These were displayed from the trees around the event ground. One teacher and 5 pupils from each of these schools were invited to take part in the day. Montgomery Primary School students performed a "Coral Polyp Calypso" which was received with much enthusiasm by the royal couple. HRH Prince Charles spoke to CCC volunteers and scholars and commended them on their noble efforts to help conserve coral reefs around Tobago.



Figure 4 HRH the Prince of Wales speaking to CCC volunteers and scholars.

19th March - Walk-a-thon with Montgomery Primary School – Save our Coral Treasures

CCC volunteers joined school children to partake on a walk '*against crime and preservation of our coral treasures*'. The protesters were carrying signs and pictures of reef creatures which they waved in the air whilst shouting "Save the reef, respect the reef!". The day was covered by the local papers.

19th April - Open day at Arnos Vale for Secondary School pupils

The Open day was run to let pupils see for themselves where we live, what we do and what is involved in the programs. Four pupils from Bishop's High School attended and the pupils all showed an active interest in marine conservation.

29th April - UNESCO Youth Summit, Trinidad

The Project Scientist and Educational Officer attended the UNESCO Youth Summit on Climate Change and Disaster Reduction and did a presentation on the effects of climate change for school children from Trinidad & Tobago, Japan, Taiwan, Iran, Turkey and others as well as for UN and UNICEF delegates. The Educational Officer worked closely with Speyside High School to help the pupils prepare their own presentation on coral bleaching which was very well received.

15th May - Queen's Birthday Celebration with the British High Commissioner

The British High Commissioner gave CCC and its "young volunteers" a specific mention in his opening speech.

28th May - Montgomery Primary School, Community Evening on Coral Bleaching

Pupils performed a puppet show, read out poems they had written and shared their experiences based on recent field trips. The BRT presented a film they had produced on climate change in the Caribbean. Parents, school children and teachers attended the event which was aired on the local news that evening.

28th May – Meeting at Works Division, “How to Protect our Coral Reefs”

CCC attended a meeting of the Tobago House of Assembly Works Division which was also attended by the Minister for Agriculture, Hilton Sandy, the Secretary for Agriculture, Ray Sandy, the Secretary for Fisheries Mr. Kenneth Caesar and representatives from the tour operators industry, including the president of the tour operators association, Hewlette Hazel. Steps to conserve the island’s coral reefs were discussed and an agreement to ban reef walking was made. This decision was later announced in the local media.

4th June – Montgomery Primary School, Final Judging

Judges from the Environmental Management Authority and other environmental charities came to judge the project pupils from the Montgomery School had done on Coral Bleaching. Pupils were quizzed on what they had learnt, the activities they had taken part in and the work they had produced

8th June – Beach Clean up, Arnos Vale

In association with the Arnos Vale Hotel, a beach cleanup was organised to help celebrate World Ocean Day and to provide members of the local community with the opportunity to learn how to take action to protect the ocean in their daily lives. Local school children came to take part and over 15 large garbage bags were filled with rubbish.

13th June – Environmental Management Authority Final – Climate Change, Trinidad

Montgomery Primary school were awarded the overall winners of this event as well as picking up four other prizes - best small school, best Tobago school, best cultural presentation and best first time entrant.



Figure 5 Students and teachers from Montgomery Primary School posing with Secretary Hilton Sandy and CCC and BRT staff after winning the EMA's School Competition, 2007.

13th June – BRT Climate Change Symposium

CCC was invited to present at the BRT symposium, “Counting Costs: Communities, Coral Reefs, Climate Change”. The event was held to commemorate the International Year of the Reef 2008. Guests were invited from local government and NGO's along with students and teachers from Tobago's schools. The Minister of Housing, Planning and Environment, Dr Emily Gaynor Dick- Forde attended to give the main address. CCC gave an update on the TCEMP work which was warmly received

14th June – Teacher workshop at Arnos Vale

Two teachers from Speyside High School attended the first teacher workshop at Arnos Vale. They joined CZM scholars to learn about coral reef ecology, marine species identification and had the opportunity to go snorkeling. They were also introduced to educational resources such as lesson plans and background information. These were later provided to them on CD.

14th–25th July – Sea Sun and Science

CCC helped out with this popular summer science program organised by the BRT, conducting species identification snorkels and creating a treasure hunt with a conservation theme.

8th of July – Channel 5 ‘Campout’ program interviews

William Nana aka ‘Will I Am’ from Channel 5's ‘Campout’ program came to the expedition site to interview CCC staff and volunteers about their work

3 Scientific Methods

3.1 TCEMP Baseline Surveys

History and rationale

CCC's quantitative baseline survey technique was designed to provide a comprehensive assessment of shallow coastal ecosystems quickly and effectively. Originally used on CCC projects in Fiji, it has been adapted for use on the TCEMP. CCC survey data are used primarily to describe and classify the nature of shallow subtidal habitats. Surveys are performed mainly on the fore reef but it is often necessary to conduct back reef and lagoon surveys as well. Regardless of the location on the reef, the technique used does not vary. Aerial or satellite imagery is used extensively to guide the survey work in the field, since this allows ground surveys to be positioned for efficient classification of the habitats visible on the image. Survey sites are located at set 'stations', every 250 metres (m) along the coastline. Surveys are conducted parallel to the reef crest, which is usually parallel to the coast. Surveys are run contiguously, and in the direction of the next survey location. For example, a survey starting at site AV01 would be conducted towards AV02 (usually in a north-easterly direction for the north coast of Tobago). Some areas of known sandy bottoms (such as Stonehaven beach) have been omitted but otherwise, surveys were conducted every 250m between Buccoo Reef and Castara.

The survey technique has been developed in order to make it compatible with existing, regional survey methods conducted in the wider Caribbean such as AGRRA (Steneck *et al.* 2003) and Reef Check (www.reefcheck.org) reef monitoring protocols. This will allow us to compare and contrast results from Tobago with other island states around the region as well as ensuring that the data collected here contributes to reef status reports for the Caribbean. Survey depths have been chosen at intervals where coral cover and diversity is generally highest. In addition to this, the 7 and 12 metre depth bands are the same as those used for the bleaching surveys carried out by CCC in 2005 (see O'Farrell *et al.*, 2005). This makes it ideal for long-term monitoring of coral reef recovery around Tobago.



Figure 6 CCC volunteers learning how to identify corals as part of their Science Development Programme.

Survey Technique

The technique itself uses teams of four divers comprised of two buddy pairs. The team surveys along a set number of replicate transects at five pre-determined depth bands. Two 50m transect lines are laid along every depth contour for each station. Each survey team can complete one 50m transect on a dive. Each depth band will therefore require a minimum of two survey teams to complete it. The start position of each 50m transect is indicated by the survey team by releasing a Surface Marker Buoy (SMB) to the surface which is marked on the support vessel using a Global Positioning System (GPS).

Individual reef transects are orientated parallel to the reef crest (perpendicular to reef slope). Each transect is surveyed at a pre-determined depth band: 2m, 7m, 12m, 16m and 22m. Whether a particular depth band is completed depends on the substrata present. At some locations, not all depth bands may be available for surveying due to a lack of suitable reef area or limitations in depth.

The survey team collects baseline data on coral reef fauna and flora, focussing on a range of target organisms representing the main functional groups present on Caribbean reefs, including sessile benthic organisms, motile invertebrates and reef fish.

Buddy pair 1

Diver 1 is responsible for recording the abundance of all the targeted commercial and pelagic fish species along the 50m transect in a belt 5m wide and 5m high (Figure 7). Diver 1 also records the size of selected fish families and target species into four size categories (5-10 cm, 11-20 cm, 21-40 cm and >40 cm). Diver 2 records the abundance of demersal and more cryptic reef fish families and targeted species along the same belt transect. Fish of less than 5cm length are generally not included unless the adult phase is less than this size. The fish surveyors swim slowly in a straight line at about 4m per minute (12-13 min per 50m transect), being directed by diver 3 (diver 3 of buddy pair 2 – see below) behind them.

Buddy Pair 2

Diver 1 of buddy pair 2, known as the physical diver, is responsible for leading the dive and indicating to the rest of the survey team where the transect is to be undertaken. Diver 1 is responsible for finding the right depth contour and bearing as well and guiding the fish observers along the correct contour and heading. They note the abiotic factors and underwater impacts. Diver 1 furthermore estimates the percentage of colonies affected by coral bleaching and coral diseases within four, ten-metre belts within each 50m transect. The coral colony species is recorded as well as the coral disease present on that coral colony. In addition to this, the number of infected colonies and the total number of colonies is recorded. Diver 2 is responsible for correctly laying down the survey line along the pre-determined depth band.

On the return run back along the 50 metre line, Diver 1 records the type of substratum or benthic organism (sessile) under each 50 cm point along the transect line for 2 x 20m transects with a 5m gap between transects (45-25m and 20-0m). Each transect consists of 40 points. Each depth contour has four transects and thus contains 160 benthic survey points in total. Coral recruits and bleached corals are also recorded along if they are found directly underneath a point. Diver 2 becomes responsible for recording the abundance of all motile invertebrates, sea fans, sea rods,

black corals, sea plumes and anemones on the return run. This is done along two 20 m belts, which are 2m wide (45-25m and 20-0m).

During the course of each survey, certain oceanographic data and observations of obvious anthropogenic impacts and activities are recorded at depth by the divers and from the surface support vessel. Sea surface temperature, tide level and a salinity sample are taken from the survey boat. The survey team below records the depth of the transect, the temperature at the maximum survey depth (i.e. at the start of the survey), reef rugosity and the reef zone. Visibility, a surrogate for turbidity (sediment load) is recorded both vertically and horizontally. A Secchi disc is used to measure the vertical visibility. Horizontal visibility through the water column is measured by divers' estimates while underwater. A water sample is taken at the survey depth to measure salinity after the survey.

Survey divers qualitatively assess the strength and direction of water currents at each survey site. Similarly, the boat marshal on the support vessel qualitatively estimates the strength and direction of the wind at each survey site. Cloud cover is measured by the boat marshal on a scale of 1 to 8 Octas.

Natural and anthropogenic impacts are assessed both from the surface from the survey boat and at depth by the divers during each survey. Surface impacts are categorised as 'driftwood', 'algae', 'litter', 'sewage', 'nets' and 'other'. Sub-surface impacts are categorised as 'coral fragmentation', 'major overgrowth', 'fish bite damage', 'litter', 'human' and 'other'. All data is collected as 'present/absent' and then converted to binary data for analysis. Any boats seen during a survey are recorded along with information on the number of occupants and its activity.

Data from each survey are recorded onto data forms and checked prior to being entered into the TCEMP database, which is compatible with a range of Geographical Information Systems (GIS) software used for data analysis.



Figure 7 Schematic representation of TCEMP baseline surveys conducted at each depth band.

3.2 Coral Disease Surveys

History and rationale

Baseline surveys over the initial 6 months of the TCEMP project indicated that a variety of coral diseases were prevalent on Tobago's coral reefs and, in some cases, there were indications that coral diseases were becoming increasingly dominant. Although CCC's baseline surveys do include a disease component, it was decided to focus some of the survey effort on looking specifically at coral disease prevalence at different locations and depths in order to gather baseline disease data, in addition to monitoring several permanent transects set up by the BRT at Culloden, Arnos Vale and Mount Irvine.

These data were used to assess whether particular sites or depths are more resilient to coral diseases as well investigating whether there are links between coral disease and sources of pollution and sedimentation. These findings enable us to gather a more comprehensive picture of the coral reef health and adapt our management recommendations accordingly. The survey methods have been adopted from disease monitoring survey protocol recommended by Willis, 2006.

Survey Technique

To estimate coral disease prevalence, a pair of divers conducts surveys along a 10m line that is laid out before the survey commences (either along permanent transect stakes or at a chosen location and depth which is geo-referenced by GPS on the boat). Each of the two divers then proceeds to lay down a 1m² quadrat alongside the transect line and count all the different corals to species level and any coral diseases on those corals within that quadrat (Figure 8). Once this is complete, the divers move up one meter and lay down the quadrat again, making the same observations. This is repeated until the divers have completed at least 10 meters of survey, translating to 20m² of reef surveyed. The divers may then continue this for as many quadrats as there is dive time.

The divers also take a water sample for salinity and record abiotic features similar to baseline surveys such as current strength and temperature at depth.

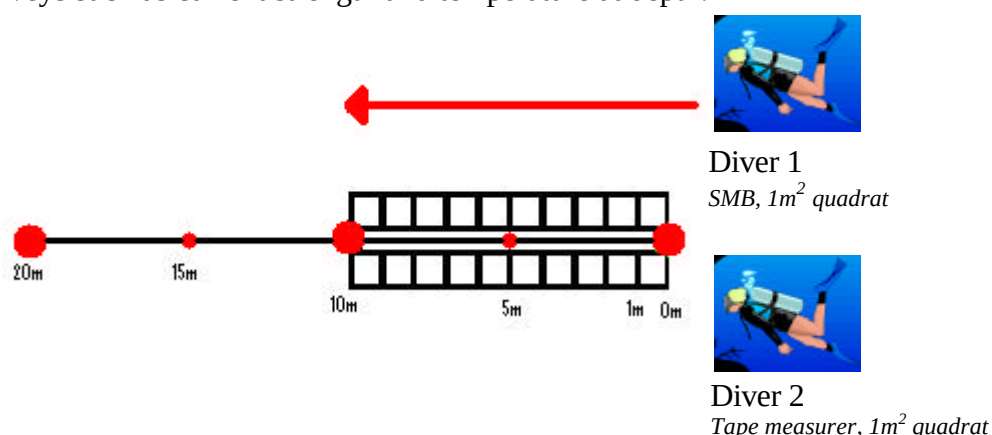


Figure 8 Schematic representation of a TCEMP coral disease assessment survey

3.3 Data Analysis

In order to analyse outputs from reef surveys and make comparisons between sites, some of the sand surveys were omitted from the analysis. As a rule, only those surveys where there was >5% hard coral cover were included in the reef survey analysis. In total, 150 reef surveys were included (see results section).

Comparisons between benthic composition, coral cover and coral diversity were made using data from 2005 bleaching assessments conducted by CCC and BRT with recent data from the TCEMP. Only those surveys which were conducted on the same depth bands and locations were used for these comparisons.

Where relevant, comparisons of reef fish and benthic abundance and diversity were made with similar data collected from Bonaire National Park, Dutch Antilles, in 2007 using AGGRA methodologies (Steneck et al., 2007). This allowed us to compare and contrast reef health indicators from Tobago's Caribbean coast to a well-managed island of similar size in the Caribbean.

All data analysis was carried out using Microsoft Excel and Minitab. Fish abundances were converted to biomass (kg/ha) using published length weight relationships from FishBase (www.fishbase.org).

One-way ANOVA was used to test for differences between samples after testing for a normal distribution. Samples were converted to a normal distribution through an angular or Log10 transformation. Fisher's Least Significant Difference Test was used to see which samples were significantly different from which. If data could not be transformed to a normal distribution, a non-parametric Kruskal-Wallis test was used to test for significant differences.

If these were found, further investigations were done with a pairwise Mann-Whitney U test. A Pearson's Correlation Analysis was used to test for relationships between two variables.

3.4 Geographical Information System

Survey data is entered into a database, which is connected to GIS software where it can then be manipulated geographically. Once appropriate analysis techniques have been applied to the data, managers and decision makers can use the final product to make informed decisions concerning coastal zone management. The visual nature of GIS outputs facilitates the interpretation of such data by non-technical persons who may nonetheless be key decision-makers. CCC survey teams record the start position of each survey with a handheld GPS unit, which allows the surveys to be positioned relative to each other on a satellite image.

Relationships between the data from various survey sites can then be explored to highlight geographical regions of key interest. Information can be represented in many ways in a GIS, from simple placement techniques ("this was found here") to more intricate mapping techniques such as data contour mapping ("this area is 'better' than that area"). It is important to bear in mind that the outputs are produced from the data themselves; the maps are not merely 'coloured in' at particular places. This is because the GIS links the map and the database intrinsically, and any data that are required for visual examination can be 'called up' on the screen. GIS is therefore not just a mapmaker; it is a tool that allows ongoing interaction between the decision maker and the data. When further geographic/ ecological data are gathered in the future, they can be added to the GIS, making a custom built instrument for visual interpretation of any data that can be represented at any point on Earth, above or below the sea.

When sufficient data has been collected for a sector of coastline, extensive habitat maps can be created. The GIS contour maps contained in this report were created using the Inverse Distance Weighted function in the Spatial Analyst of ArcView 8.3 (ESRI software).

3.5 Survey Progress

Between April 2007 and July 2008, CCC survey teams conducted 285, 50-metre transects on fringing coral reefs along the northwest coast of Tobago between Buccoo and Castara (Figure 10). This amounted to a total of 24,188 benthic survey records, 24,680 invertebrate records and 38,202 fish records. In addition to this, 31 coral disease surveys were completed from March-July 2008. Figure 9 illustrates the total number of surveys completed each month over the 16 months of the TCEMP.

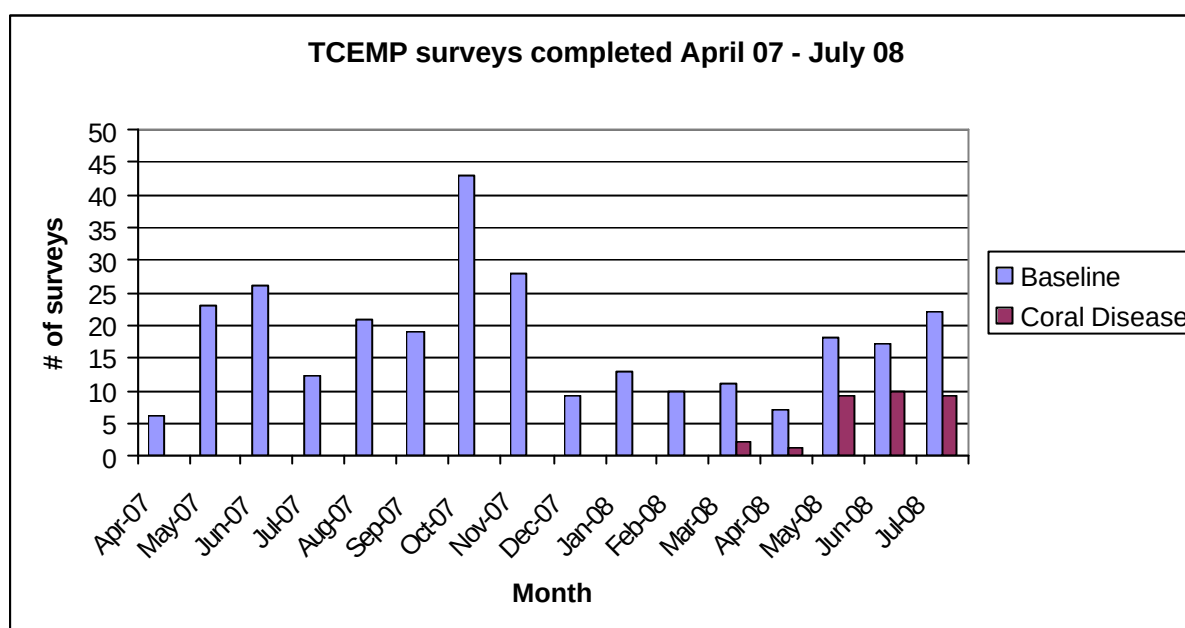


Figure 9 Number of CCC baseline and coral disease surveys conducted between April of 2007 and July of 2008.

Although not all surveys have been completed at this stage of the project, the data analysis and GIS outputs for this report will aim to provide a general picture of the status of coral reefs between Buccoo and Castara and draw some initial management recommendations from this. The GIS outputs will include all surveys conducted whereas the data analysis may focus on one particular depth band or survey sector, depending on completeness of the data and the management questions being addressed.

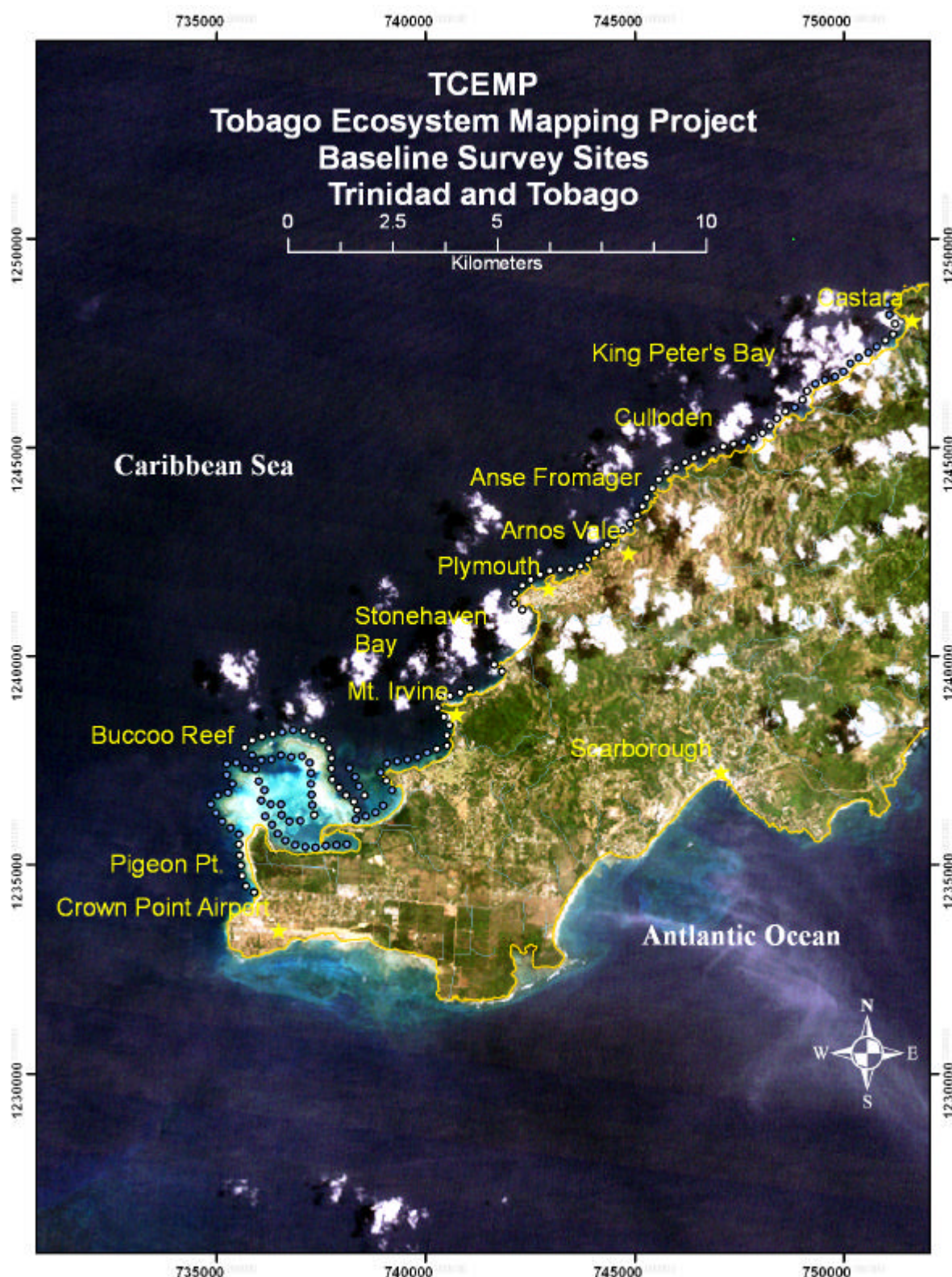


Figure 10 CCC baseline survey stations between Buccoo Reef and Castara. White points indicate stations visited between April 2007 and July 2008. Blue points indicate stations still to be visited. *Note – A white point does not necessarily mean that the station has been completed as there are 5 depth bands to be surveyed at each station*

4. Results

At this stage of the TCEMP, there is not enough survey data to produce a complete conservation assessment of the coastal areas between Buccoo and Castara on the Caribbean side of Tobago. For this reason, several key sites were selected where coral reef cover was extensive and a nearly complete dataset had been acquired (see Figure 11). A number of key biophysical variables have been selected to illustrate trends found in those selected areas.

Certain target taxa or abiotic categories have been shown to be effective indicators of overall reef health (Hodgson, 1999) and a number of these have been selected here to outline initial findings. Depending on the particular target, these variables can indicate a history of overfishing, nutrient pollution, sedimentation and the removal of organisms for the curio or aquarium trade. In this analysis, the indicator organisms have been adapted from those defined by the Reef Check Foundation (Hodgson, 1999) as well as those used in a report by Steneck et al., 2007. These indicators are recognised as robust gauges of general reef health. In addition to these indicators, some focus has also been given to coral disease prevalence in the area, as this is currently a subject of great concern for the reefs of Tobago.

Unless otherwise stated, the depth contours analysed were at 7, 12 and 16 metres as these provided the most consistent datasets. As further surveys are completed, a more complete picture can be formed of the coastal resources of Tobago. Given that most of the main reefal areas have been assessed and there is an urgent need to address our findings over the past year and a half, initial management recommendations have been made on the basis of this data.



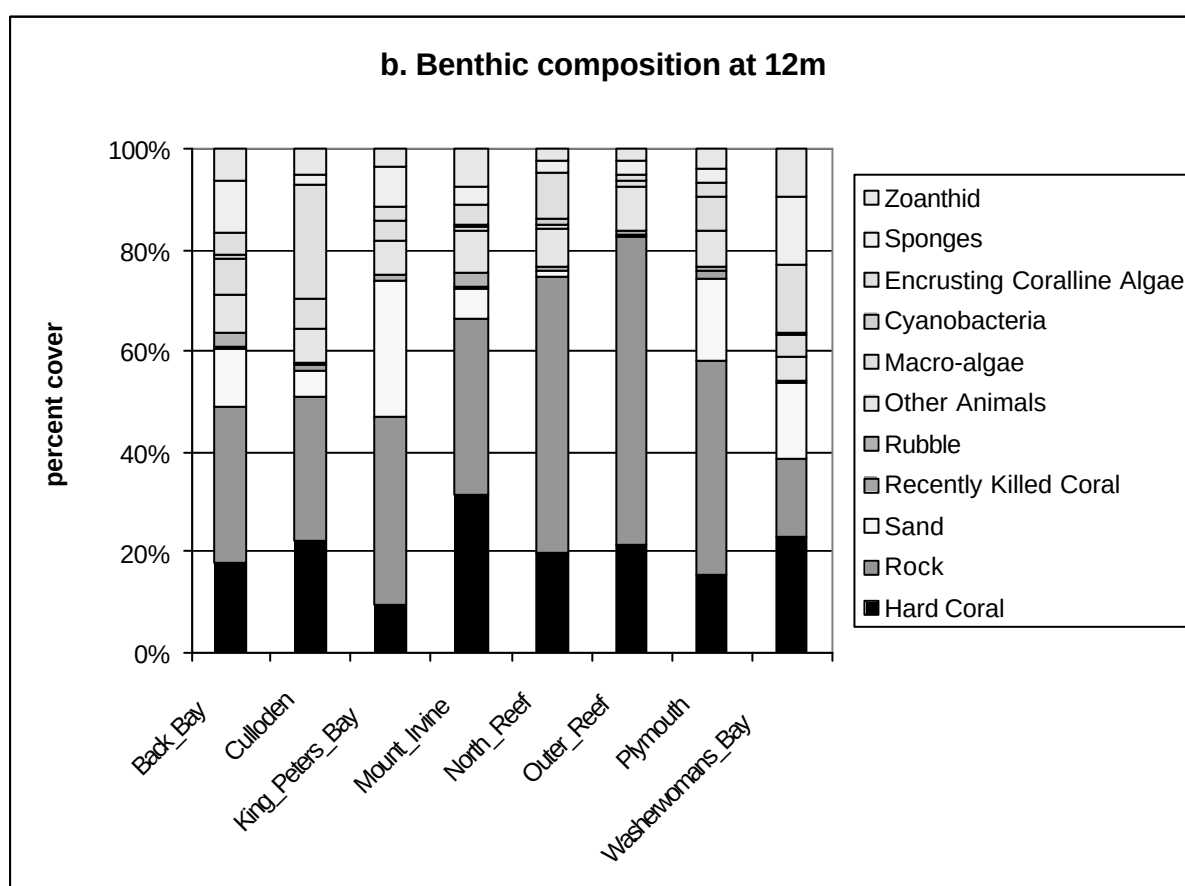
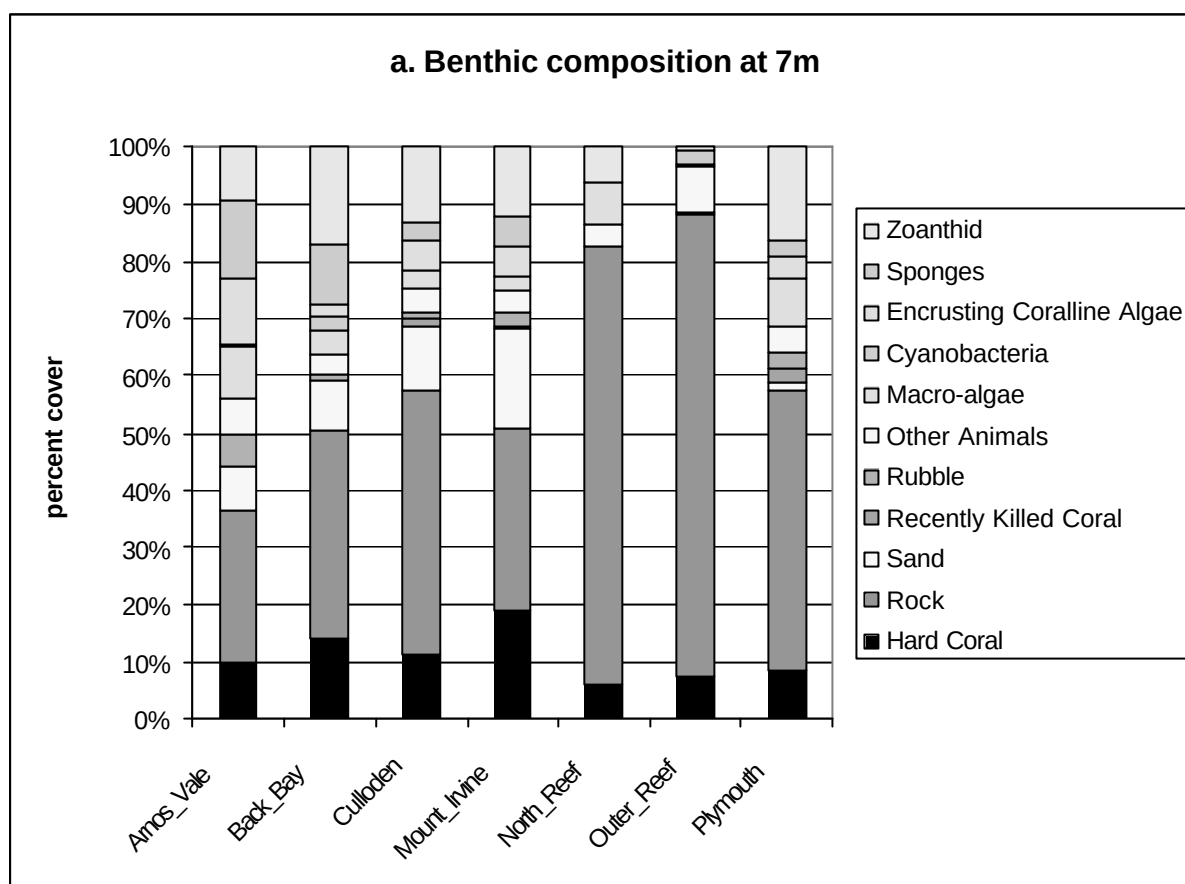
Figure 11 Selected sites used for comparisons of coral reef habitats

Table 1 Selected survey stations used for further analysis in this report. The number of surveys completed for each depth band at each station is given. 150 reef surveys were selected in total.

Station	7 metres	12 metres	16 metres
North Reef	5	7	4
Outer Reef	4	14	0
Mount Irvine	8	8	6
Plymouth	6	7	2
Back Bay	6	6	6
Arnos Vale	6	2	0
Culloden	8	12	8
Washerwoman's Bay	0	4	8
King Peter's Bay	2	6	5
Total	45	66	39

4.1 Benthic Composition

The most common benthic substratum found at all depths and surveys was sand. Other main substrata were rock, rubble and macroalgae. Figure 12 shows the composition of benthic substrata at 3 depth bands for selected reef sites. Hard coral cover is investigated further in the next section. Bare rock substrate (which includes dead coral skeletons and turf algae) was abundant for all 3 survey depths and sites. The reefs of Buccoo showed particularly high levels of rocky substrate. The most northern and outers reefs of Buccoo had 56% and 65% rock cover. Zoanthids (mostly *Palythoa caribaeorum*) were a dominant substrate on shallow reefs, particularly around Plymouth and Back Bay (16% and 17% respectively). Algae species have been pooled into functionally important groups – macroalgae, turf algae, encrusting coralline algae and Cyanobacteria (also known as Blue-Green Algae). Many Caribbean coral reefs have become macroalgal dominated reefs since the 1980s, undergoing ‘phase shifts’ from a coral dominated to an algae dominated state (see Gardner et al., 2003, Bak et al., 2005). Macroalgal cover for selected sites consisted mostly of *Dictyota* species and was low for all reef surveys and depths (5% at 7m and 4% at 12 and 16m). These results indicate that Tobago’s Caribbean reefs appear to be an exception to the situation on most other Caribbean reefs where many reefs have become dominated by macroalgae with mean macroalgae cover of around 23%. Bonaire’s reefs average about 5% macroalgae cover but have far higher hard coral cover (see next section). Cyanobacteria, an important indicator species for eutrophication, had low mean cover (<2%) for all sites. Encrusting Coralline Algae cover was around 8% at 12 metres depth. This is higher than Bonaire’s reefs (3.5%) and it should be noted that Tobago’s Caribbean coastal reefs have lower macroalgae coverage and higher rock and rubble cover. These are potentially suitable habitats for the settlement of coral recruits and therefore important substrates for potential reef recovery. Variation in encrusting coralline algae was high but generally increased with depth – 5% at 7 metres, 8% at 12 metres and 9% at 16 metres. The ‘Other animals’ category includes Octocoral species and Seafans. These were further assessed by means of a belt transect.



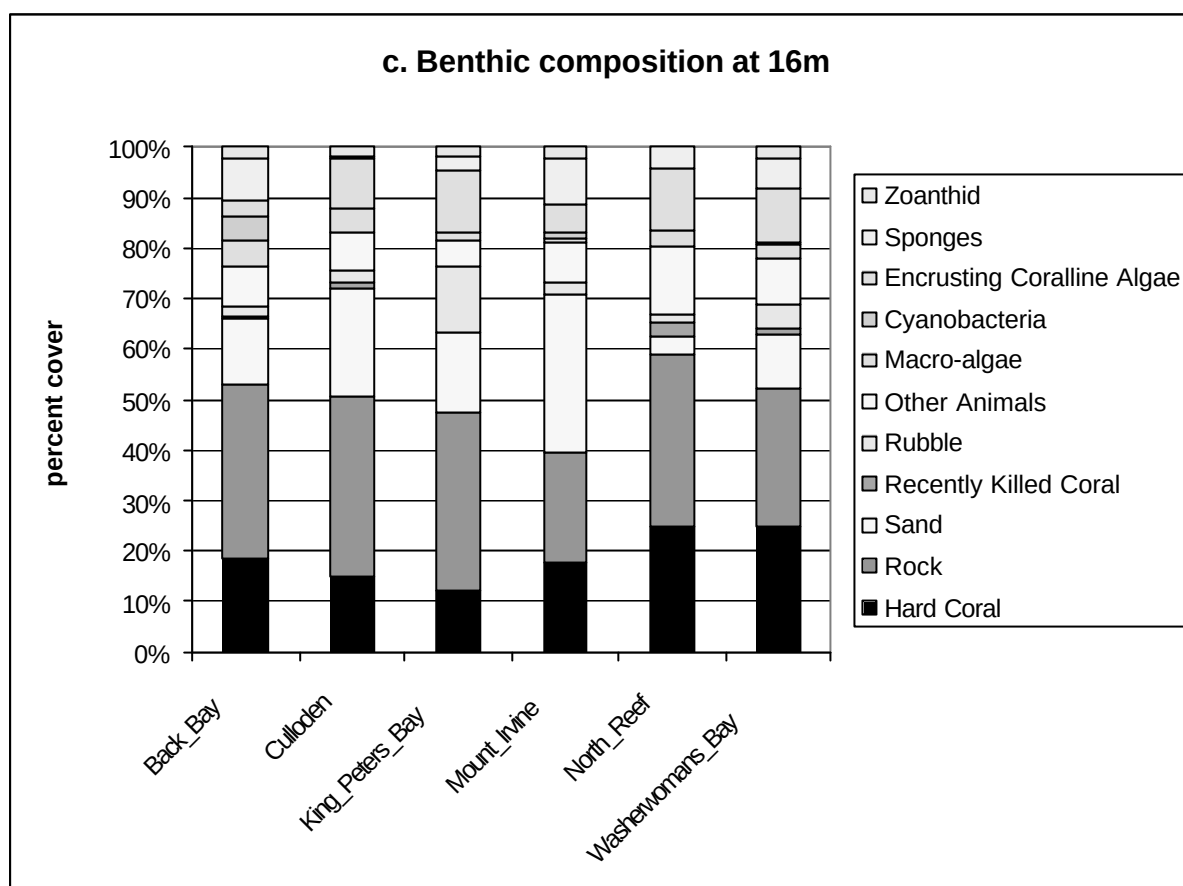


Figure 12 Benthic composition of selected reef sites at 7m (a.), 12m (b.) and 16m (c.) survey depths. Some sites for particular depths were not included as there was not enough data available to develop an accurate picture.

4.2 Coral Cover

Hard (scleractinian) coral cover has shown to be declining since CCC conducted reef surveys to assess the bleaching impact on Tobago's reefs in 2005. Comparisons between surveys conducted during the 2005 bleaching event and baseline surveys over 2007-2008 at the same sites and depth indicate that mean coral cover at 7 and 12 metres has dropped significantly from 22% in 2005 to 16% in 2008 (ANOVA: $F_{1, 118} = 5.16$, $P = 0.025$, Figure 13). At 7 metres, there was a significant decline over the two survey periods (ANOVA: $F_{1, 50} = 4.46$, $P = 0.036$). At 12 metres, a similar trend was found although this was not significant (ANOVA: $F_{1, 66} = 2.89$, $P = 0.094$). As coral cover is considered to be an indicator of reef health, this decline is concerning. The Caribbean average for coral cover was around 10% in 2003 (Gardner et al., 2003) but this includes reefs that have undergone significant phase shifts to algae dominated reefs, something which has not yet occurred on coral reefs on the Caribbean side of Tobago. Comparisons with the well-managed reefs of Bonaire reveal that Tobago's coral cover is well below the 7 year mean coral cover of 47%. Reef surveys over the next year will determine whether the reefs are beginning to recover from the bleaching event and disease outbreaks or whether the downward trend in coral cover will continue.

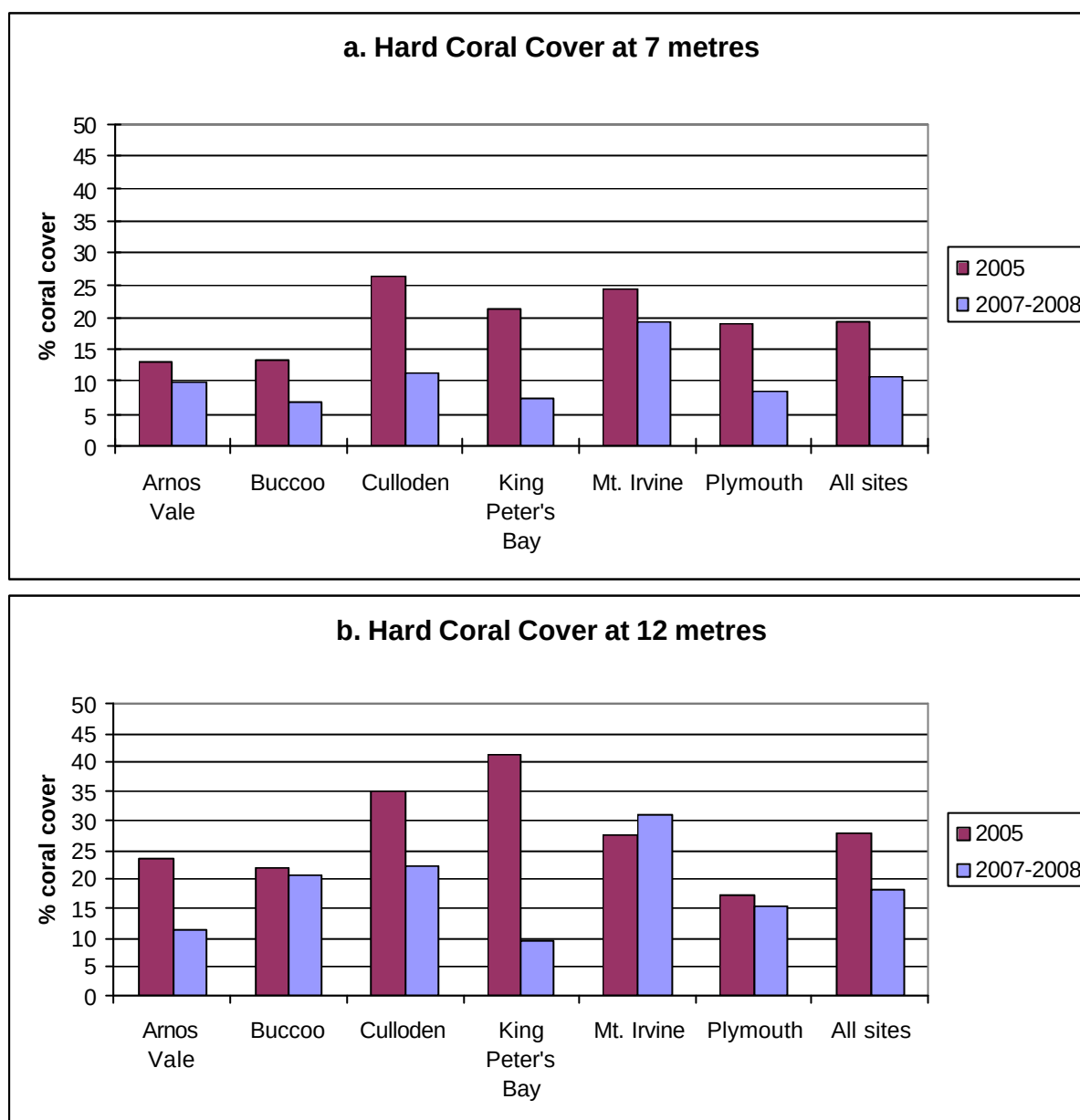


Figure 13 Hard coral cover during and 3 years after the 2005 bleaching event for two depth bands; a. – 7 metres, and b. – 12 metres.

Table 2 (next page) displays the different taxa of hard coral that have been recorded from all surveys to date. A total of 40 hard coral targets (for a list of target species, see Appendix A) were observed with *Millepora spp.* the most abundant, comprising 14% of corals seen. *Montastrea* was the most common genus comprising 22,5% of corals seen. *Montastrea* corals (apart from *M. cavernosa*) were not always identified to species level. Of the ones identified, *M. faveolata* and *M. franksi* were the most abundant (7,9% and 4,9%). *Siderastrea sideria* and *Diploria strigosa* were also relatively abundant corals (9,4% and 8,7%). These 7 species of coral dominate Tobago's northwestern reefs, comprising over 60% of reef-building hard corals. *Acropora palmata*, once an abundant species in the shallows but now the first coral acknowledged by CITES as a threatened species, comprised less than 1% of hard corals seen on all surveys. Before the White-Band Disease outbreaks between 1977 and 1982, they were the dominant family of reef building coral on shallow water reefs (Wilkinson, 2004).

Table 2 Hard coral species recorded during surveys on the northwest coast of Tobago.

Hard coral species	Percentage of all coral species
Montastraea spp.	22,5
<i>Montastraea faveolata</i>	7,9
<i>Montastraea annularis</i>	0,3
<i>Montastraea franksi</i>	4,9
<i>Montastraea cavernosa</i>	7,8
<i>Millepora spp.</i>	14,0
<i>Siderastrea siderea</i>	9,4
<i>Diploria strigosa</i>	8,7
<i>Colpophyllia natans</i>	4,7
<i>Diploria clivosa</i>	4,0
<i>Meandrina meandrites</i>	2,9
<i>Madracis decactis</i>	2,6
<i>Porites astreoides</i>	2,4
<i>Agaricia humilis</i>	2,4
<i>Madracis mirabilis</i>	2,1
<i>Siderastrea radians</i>	1,7
<i>Diploria labyrinthiformis</i>	1,7
<i>Agaricia agaricites</i>	1,2
<i>Dichocoenia stokesi</i>	1,0
<i>Helioseris cucullata</i>	0,6
<i>Agaricia spp.</i>	0,6
<i>Porites furcata</i>	0,5
<i>Acropora palmata</i>	0,5
<i>Stephanocoenia intersepta</i>	0,5
Other coral species (see below)	2,8

<i>Solenastrea bournoni</i>	0,3
<i>Dendrogyra cylindrus</i>	0,3
<i>Agaricia tenuifolia</i>	0,3
<i>Porites divaricata</i>	0,2
<i>Madracis formosa</i>	0,2
<i>Manicina areolata</i>	0,2
<i>Mussa angulosa</i>	0,2
<i>Solenastrea hyades</i>	0,2
<i>Favia fragum</i>	0,2
<i>Eusmilia fastigiata</i>	0,2
<i>Stylaster roseus</i>	0,1
<i>Acropora cervicornis</i>	0,1
<i>Mycetophyllia lamarckiana</i>	0,1
<i>Isophyllastrea rigida</i>	0,1
<i>Porites porites</i>	0,0
<i>Mycetophyllia aliciae</i>	0,0
<i>Mycetophyllia ferox</i>	0,0
Unidentified coral	0,2

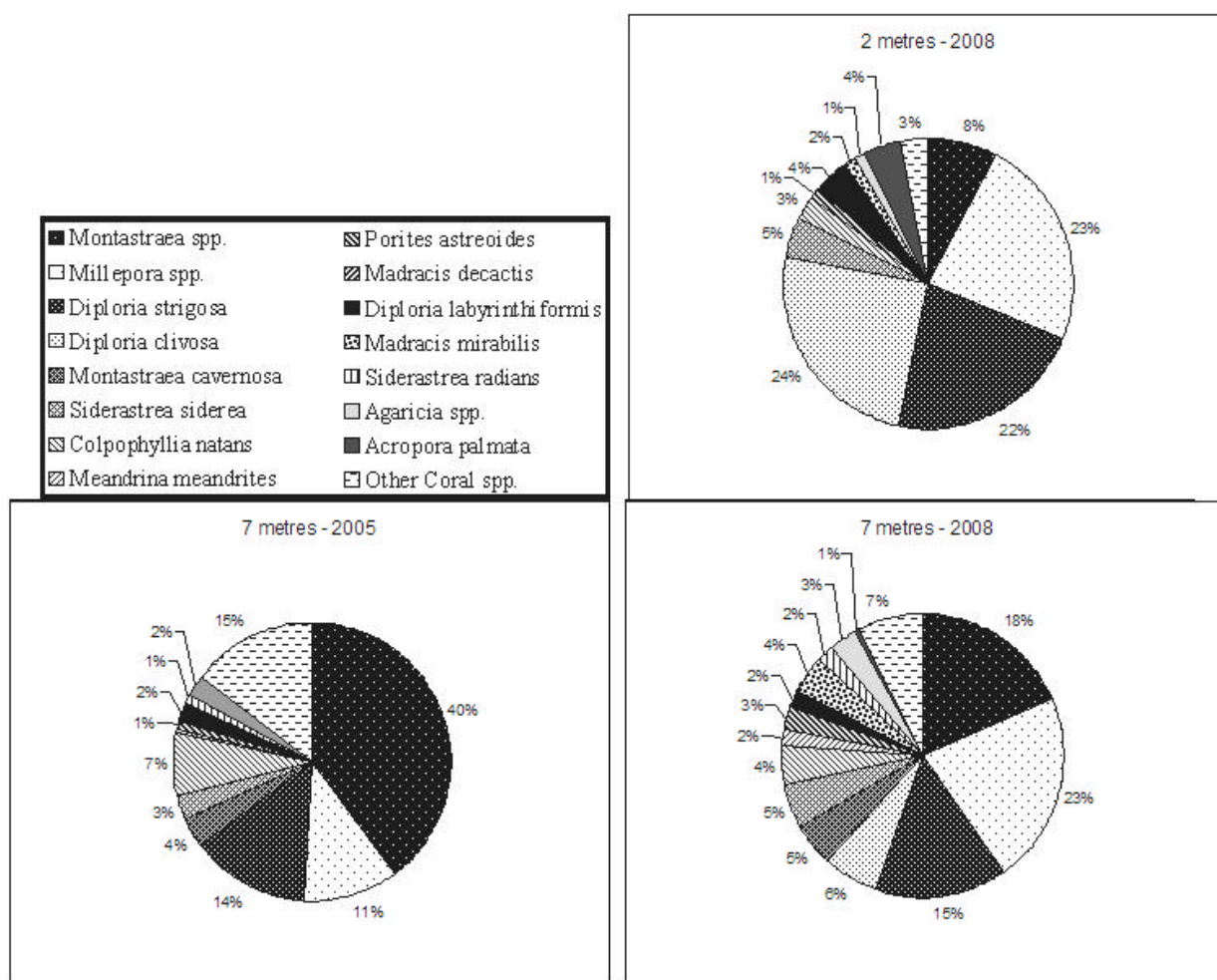


Figure 14a Hard coral composition of 15 of the most dominant groups of corals at 2 and 7 metres depth over two observation periods – 2005 (left column) and 2007/2008 (right column).

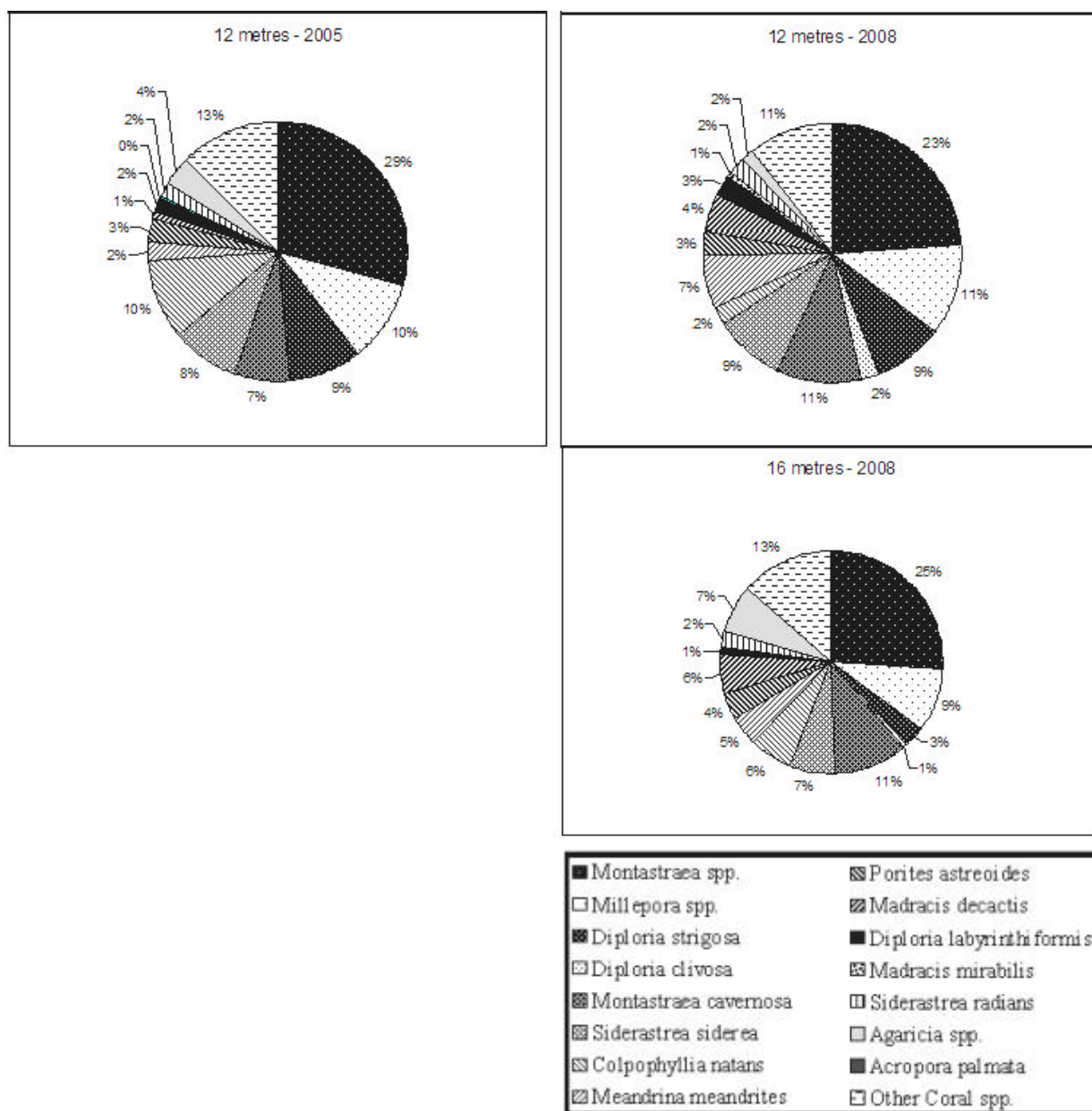


Figure 14b Hard coral composition of 15 of the most dominant groups of corals at 12 and 16 metres depth over two observation periods – 2005 (left column) and 2007/2008 (right column).

Figure 14 (previous pages) displays the hard coral composition at four survey depths; 2, 7, 12 and 16 metres. For 7 and 12 metre depth bands, comparisons have been made with 2005 surveys. *Montastrea spp.*, *Millepora spp.*, *Diploria strigosa* and *Diploria clivosa* were all dominant reef-building corals but their relative abundance decreased with increasing depth. In contrast, *M. cavernosa*, which was non-existent at 2m, becomes a dominant coral species at 16m (11%). The once dominant *Acropora* species covered only 4% of shallow, 2m reefs and were very rare on deeper reefs.

Hard coral composition at 12 metres was similar between 2005 and 2007/2008. At 7 metres however, there were some apparent changes in abundance of *Montastrea spp.* This genus of major reef building corals comprised 40% of hard corals in 2005 whilst surveys in 2007/2008 indicate a drop to just 18%. *Montastrea* corals suffered from over 70% bleaching and have since been heavily affected by coral disease (van Bochove et al., 2007). These corals have now been partially overtaken by *Millepora spp.* in terms of percent coral cover with levels for this genus increasing from 11 to 23%. *Millepora* suffered 53% bleaching in 2005 but its subsequent recovery is expected to be faster as it has a much higher growth rate than *Montastrea spp.* The contribution of other corals was also higher in 2005 than in 2007/2008 indicating that overall hard coral diversity has decreased in shallow reef waters. This is supported by coral diversity data from 2005, which indicates that the number of coral species at 7 and 12 metres was higher than in 2007/2008 (see figure 15). Coral diversity was inversely related to depth for 2007/2008 (Pearson correlation = 0,296, P-Value = 0,000).

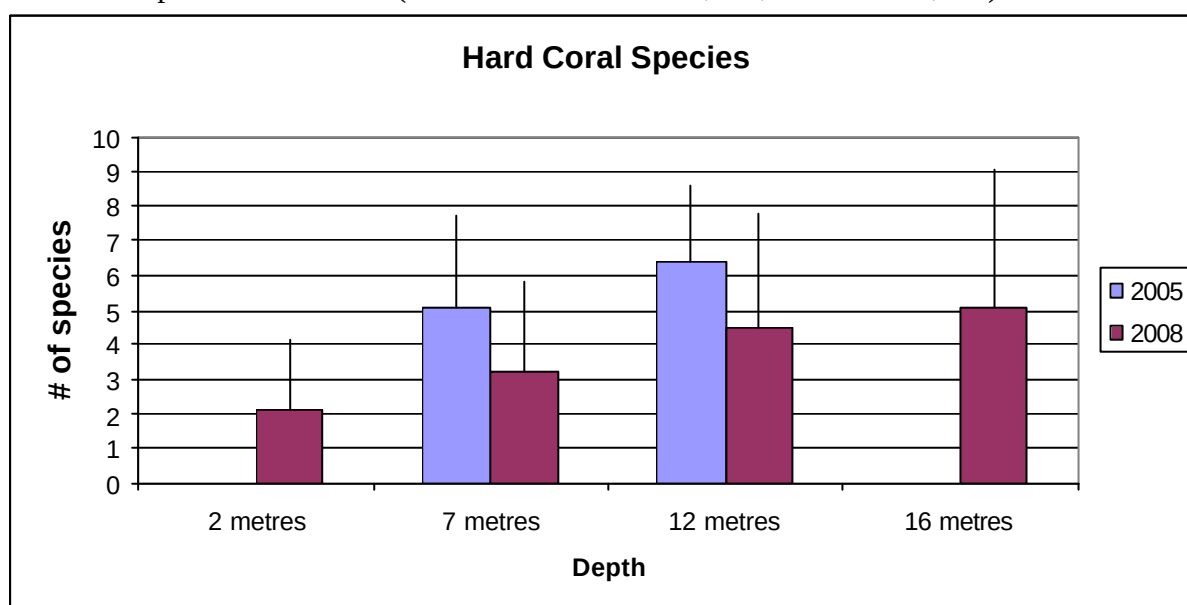


Figure 15 Mean number of hard coral species found per survey on 4 depth bands. Coral diversity means for 2005 are also presented for 7 and 12 metres. Error bars indicate standard deviation.

Pooled results from 11 selected sites indicated that coral cover at 7m (19%) was significantly lower than at 12m (26%) and 16m (24%) where coral cover was similar (ANOVA: $F_{2, 147} = 11,37$, $P = 0.000$). Mean coral cover from these sites was 17%. Washerwoman's Bay and Mt. Irvine had the highest coral cover (24 and 23% resp.) at the 3 depths analysed (Figure 16). Analysis of covariance (with depth as a covariant) showed significant differences between sites (ANOVA: $F_{7, 141} = 2,43$, $P = 0,022$). These results are outlined in the Table 3 below.

Table 3 Statistical comparison of differences in hard coral cover between selected sites. Sites in rows are significant over those in columns. + = significant difference ($P < 0,05$), n.s. = not significant.

Site	Arnos Vale	King Peter's Bay	Plymouth
Washerwoman's Bay	+	+	+
Mount Irvine	+	+	n.s.
Outer Reef Buccoo	n.s.	+	n.s.

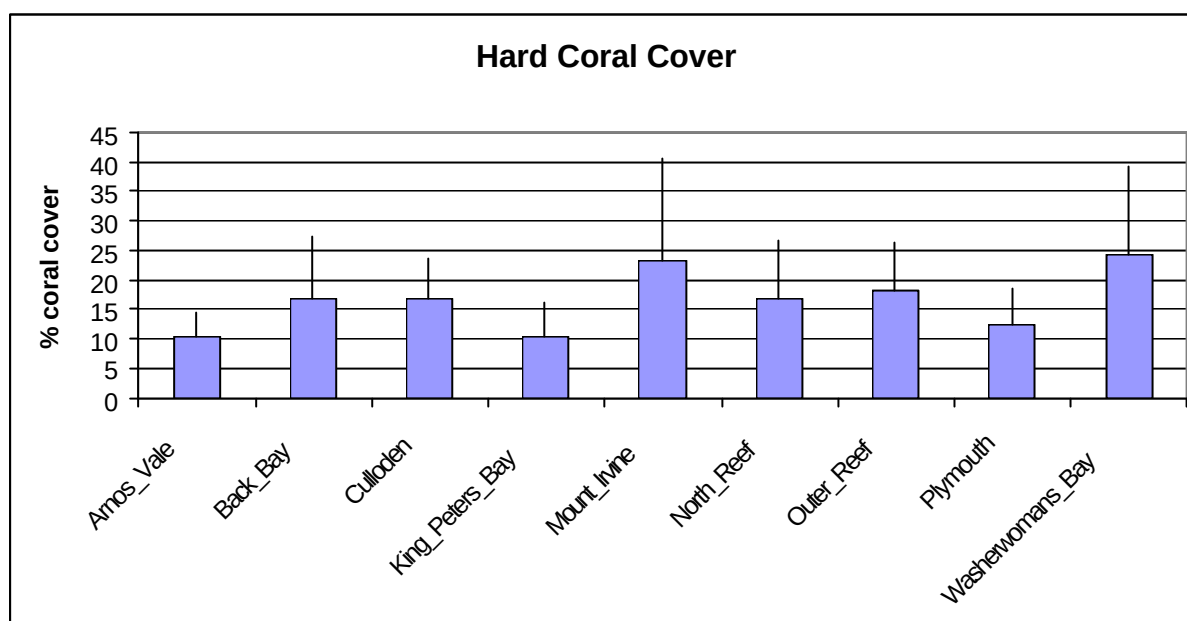


Figure 16 Mean hard coral cover for selected survey sites, pooled for 7, 12 and 16 metres. Error bars indicate standard deviation.

4.3 Reef Fish

Reef fish play an important role on coral reef ecosystems. Herbivorous reef fish help to reduce macroalgal cover, thereby increasing the amount of substrate available for coral recruitment (Lirman 2001). Parrotfish (*Scaridae*) are an important reef herbivore, and were particularly so after the *Diadema* die-off of the 1980's (Mumby *et al.* 2006). Much of the data analysis in this section has focused on the abundance and biomass of Scarids for selected reef sites.

Predatory Reef Fish

Grouper (*Serranidae*) densities were generally low (<90 individuals/hectare) with only two species (*Cephalopholis cruentatus* and *C. fulva*) comprising nearly 90% of all sightings for all surveys. Nassau Groupers (*Epinephelus striatus*) were not encountered on any surveys and may be completely depleted on the northwestern coast of Tobago. Snapper (*Lutjanidae*) densities were also low (70 individuals/hectare). Total biomass of three commercially targeted families, Groupers, Snappers and Grunts (*Haemulidae*), was 276 kg per hectare for reef areas between Buccoo and Castara.

Variation in biomass between sites for selected predatory fish families was high (Figure 17). Biomass was not significantly different at 3 depths. Differences were found between populations of Grunts at selected sites (ANOVA: $F_{8, 120} = 2.82$, $P = 0.007$). Significant differences are outlined in the Table 4 below.

Table 4 Statistical comparison of significant differences in biomass of Grunts between selected sites. Sites in rows are significant over those in columns. + = significant difference ($P < 0.05$), n.s. = not significant.

Site	Arnos Vale	Plymouth	Culloden	North Reef
Washerwoman's Bay	+	+	+	+
Back Bay	n.s.	+	n.s.	+
Mount Irvine	n.s.	+	+	+

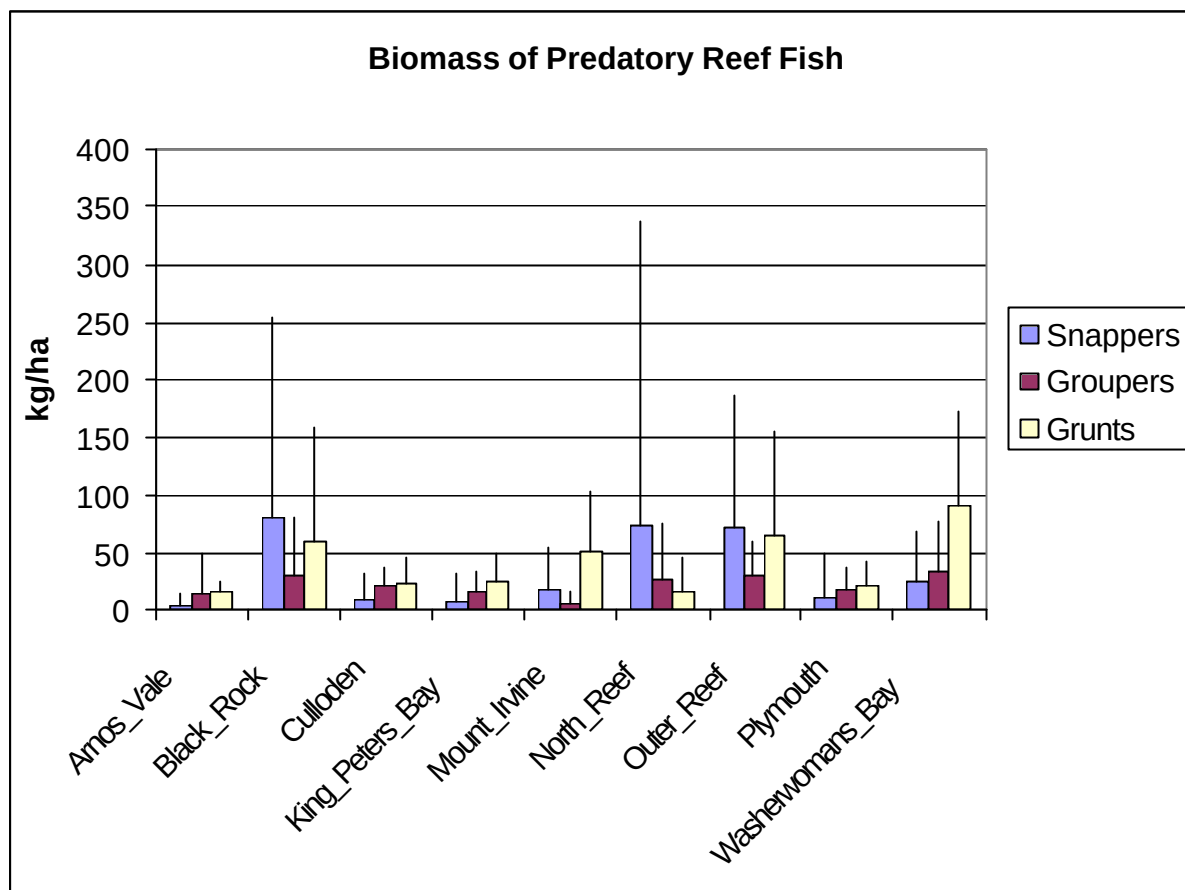


Figure 17 Biomass of three key predatory reef fish at selected sites. Error bars indicate Standard Deviation.

Herbivorous Fish

Being the dominant algae grazers on most Caribbean reefs, herbivorous fish have an important role to play within the reef ecosystem (Mumby *et al.* 2006). Their abundance and size were recorded in order to calculate biomass, which can be used as an indication of the main grazing pressure on the reefs. For all reef sites surveyed (>5% hard coral cover), mean densities of Parrotfish (*Scaridae*) were approximately 950 individuals per hectare. For Surgeonfish (*Acanthuridae*), mean density was 575 individuals per hectare (Figure 18). When comparing selected sites and depths, herbivorous fish densities were higher at 7 and 12m (~1800 indiv. / ha) than at 16m (~960 indiv. / ha) (ANOVA: $F_{2, 147} = 13.67$, $P = 0.000$). Analysis of co-variance between sites (with depth as a co-variant) showed significant differences in herbivore abundance between sites (ANOVA: $F_{8, 141} = 3.33$, $P = 0.002$) as outlined in Table 5.

Table 5 Statistical comparison of significant differences in biomass of herbivorous fish between selected sites. Sites in rows are significant over those in columns. + = significant difference ($P < 0,05$), n.s. = not significant.

Site	Amos Vale	King Peter's Bay	Mt. Irvine	Washerwoman's Bay	Plymouth	Back Bay
North Reef	+	+	+	+	n.s.	n.s.
Outer Reef, Buccoo	+	+	+	+	+	+

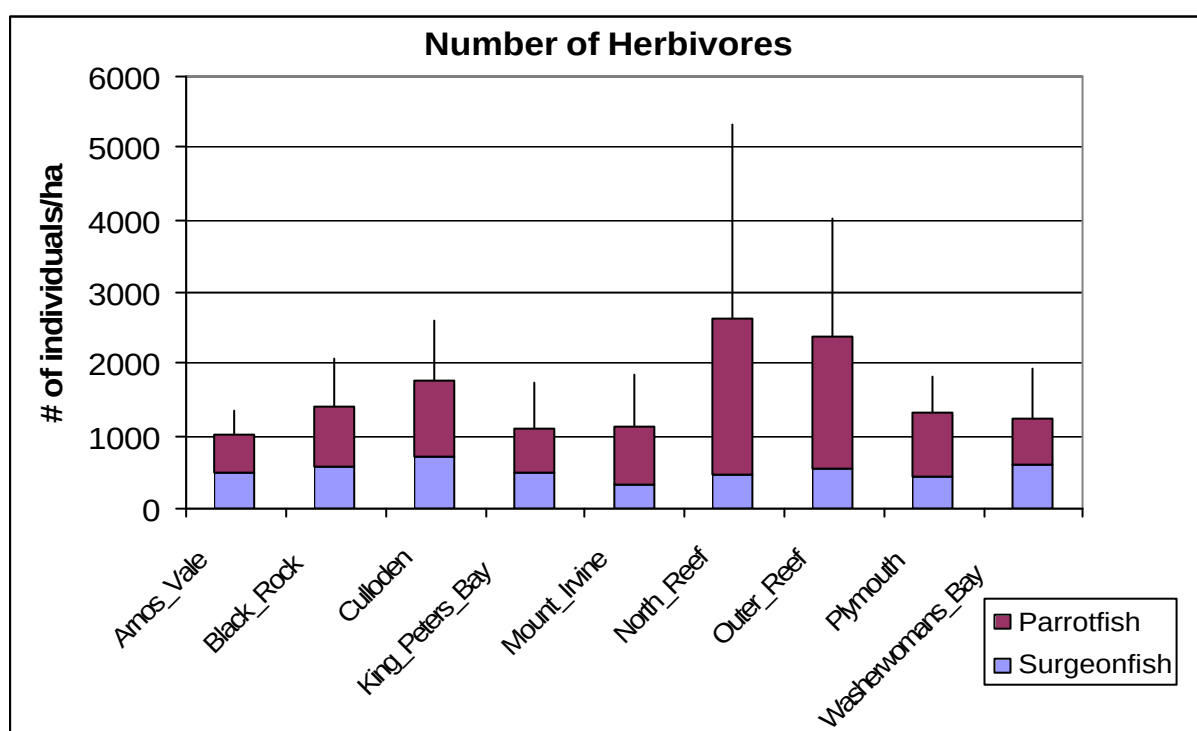


Figure 18 Abundance of two main herbivorous fish families – Parrotfish and Surgeonfish at selected sites. Error bars indicate Standard Deviation for both groups combined.

Mean Parrotfish biomass for the selected sites was 167 kg/ha. Parrotfish biomass at 16m was significantly lower than at 7 and 12m (ANOVA: $F_{2, 147} = 7,23$, $P = 0,001$, Figure 19). Analysis of co-variance between sites (with depth as a co-variant) showed significant differences in biomass between sites (ANOVA: $F_{7, 142} = 2,88$, $P = 0,008$). These differences are outlined in Table 6.

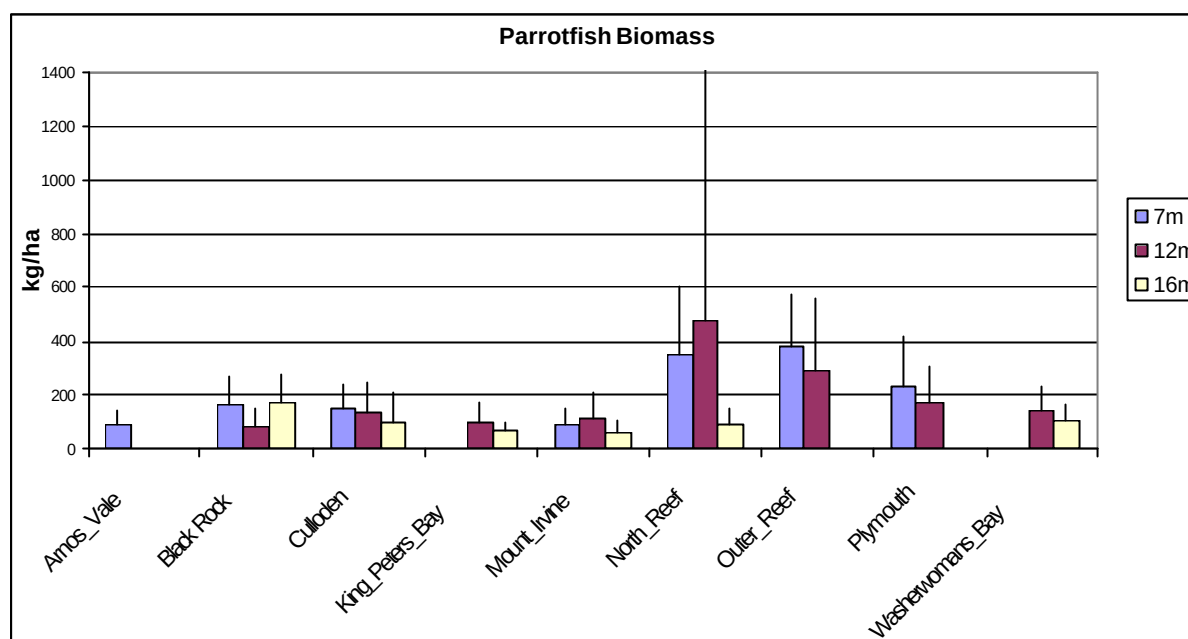


Figure 19 Biomass of Parrotfish at selected sites and three survey depths – 7, 12 and 16 metres. Error bars indicate Standard Deviation.

Table 6 Statistical comparison of significant differences in biomass of parrotfish between selected sites. Sites in rows are significant over those in columns. + = significant difference ($P < 0,05$), n.s. = not significant.

Site	Arnos Vale	Culloden	Mount Irvine	Plymouth	Back Bay
Outer Reef, Buccoo	+	+	+	+	+
North Reef Buccoo	n.s.	n.s.	+	n.s.	n.s.

4.4 Invertebrates

A number of important invertebrate indicator species have been selected which are either commercially harvested or ecologically important. Comparisons between local abundances and those of well-managed reefs of other Caribbean island states give an indication of the current status of these important reef fauna.

Long-spine sea urchins (*Diadema antillarum*) were recorded in two categories, namely “Adult” and “Juvenile” in order to monitor the recovery of these sea urchins after the disease outbreak in the 1980’s. A high proportion of juveniles to adults is generally a good indication of population recovery. Major population changes can possibly highlight shifts in the ecological balance of the ecosystem. A sudden decrease in *Diadema* populations may result in overgrowth by macroalgae, outcompeting corals for light and space on the reef. *Diadema antillarum* densities between and within sites were highly variable but overall combined abundance was about 67 individuals/ha for surveys conducted at 7, 12 and 16m (Figure 20).

At 12 metres, *Diadema* abundance was around 50 individuals/ha. This is substantially higher than *Diadema* numbers found around Bonaire National Park in the Dutch Antilles where mean abundances of 15 individuals/ha were found at similar survey depth (10 metres) in 2007 (Steneck *et al.* 2008). In 2005, no *Diadema* were seen on 84 reef surveys in Tobago. This indicates that the population of this important reef herbivore is recovering.

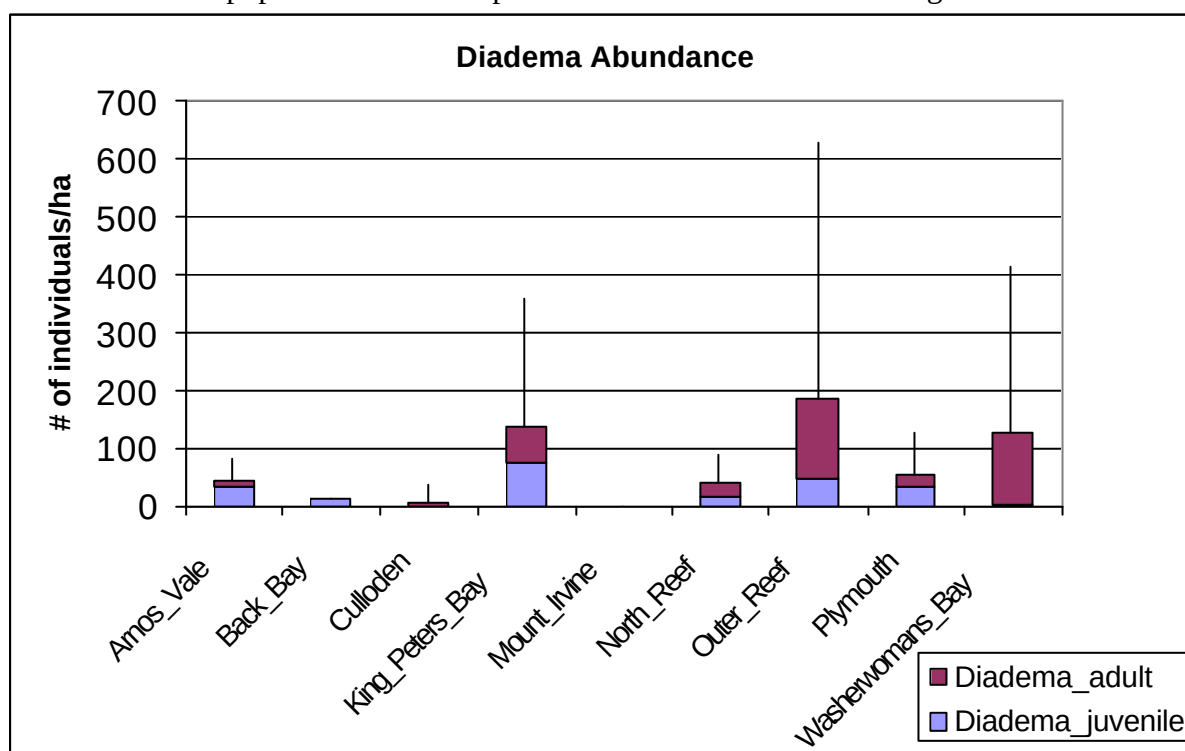


Figure 20 Abundance and adults to juvenile ratio's of *Diadema* sea urchins at selected sites. Error bars indicate Standard Deviation for both groups combined.

Key indicator species of invertebrates were pooled for all survey sites and depths, as abundances of most of these were very low (Figure 21). Pencil Urchins (*Eucidaris tribuloides*), Banded Coral Shrimps (*Stenopus hispidus*) and Queen Conch (*Strombus gigas*) species are often harvested for the curio trade and are becoming increasingly rare. Pencil Urchins are relatively common (19 per hectare) and Banded Coral Shrimps (just over 2 per hectare), although rare, are often missed on surveys due to their cryptic nature. Queen

Conch's were recorded on only 4 of the 283 survey dives indicating a severe over-harvesting of these gastropods.

Two other popular but endangered consumption invertebrates are Sea Cucumbers (*Holothurians*) and Lobsters (*Panulirus* spp.). Recorded densities of Sea Cucumbers were very low, with only 7 individuals observed on all surveys. Spiny Lobsters were also a rare sighting and 16 individuals were encountered on all surveys.

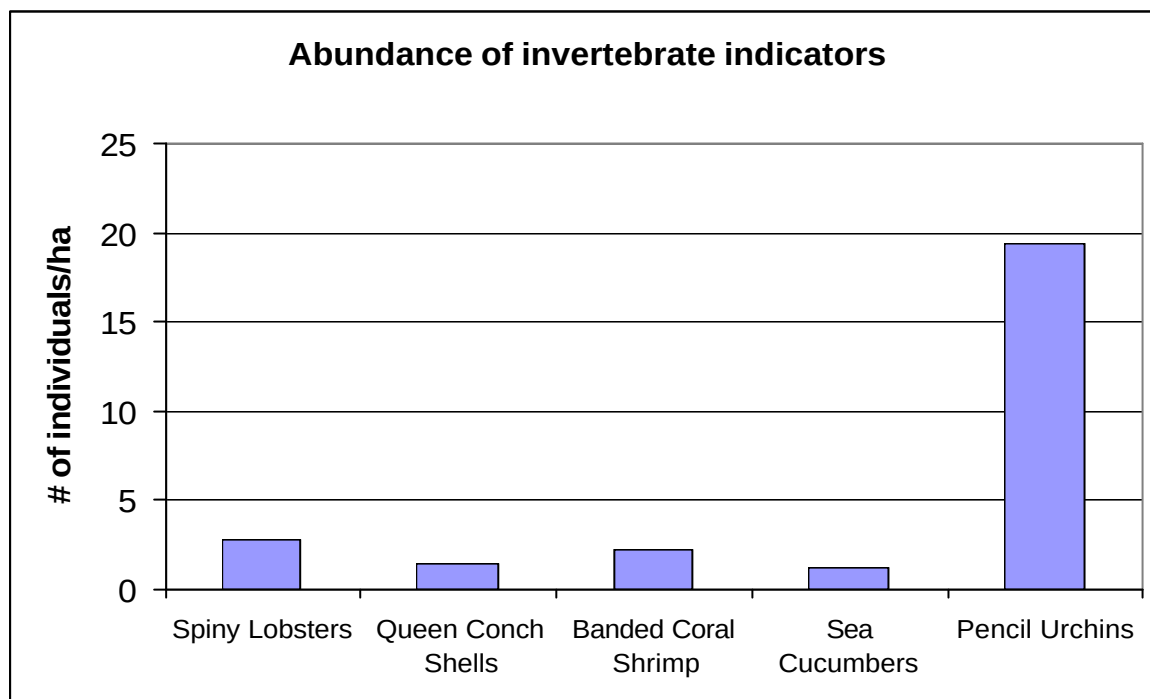


Figure 21 Abundance of selected invertebrate targets. Data is expressed as the total number of individuals per hectare for all surveys combined. As variation was high due to zero individuals being seen on most surveys, standard deviation of the mean was left out.

4.5 Coral Disease and Bleaching

Coral disease prevalence has become a serious contributor to coral reef degradation in Tobago following the 2005 bleaching event (see O'Farrell et al. 2005, www.buccooreef.org and www.coralcay.org for further reports). For this reason, CCC has been closely monitoring the prevalence and severity of coral diseases that are common and easily identifiable. Here we present some initial trends in disease prevalence for those diseases recorded on baseline surveys. Additional information has been presented by Harding et al., 2008. In addition to disease prevalence on baseline surveys, CCC has also set up monitoring stations of tagged coral colonies in Arnos Vale Bay and Plymouth in order to collect quantitative data on the spread rate of diseases. These results will be included in the final TCEMP report. A disease-specific methodology has also been developed (see methods section). Disease prevalence between sites was analysed with data collected by these methods.

Figure 22 depicts the prevalence of four of the most common coral diseases encountered on surveys as a percentage of the total amount of colonies observed. *Aspergilliosis* which is a fungal disease affecting sea fans was recorded on over half the sea fans observed. Yellow Band Disease (YBD), which is a bacterial induced disease infecting massive corals (mainly *Montastrea* spp.), Dark Spot Syndrome (DSS) which infects mostly *Siderastrea* spp. and White Plague Disease (WPL) were all observed on about a third of coral colonies they infect.

Figure 23 depicts the most commonly found diseases that are infecting three dominant hard coral species groups. *Montastrea* spp. are predominantly infected by two types of coral disease; YBD (82%) and WPL disease (14%) although some colonies are also affected by Black Band Disease (BBD) (3%). Most diseased Brain corals were infected with WPL disease (77.5%) and YBD (22.5%). Diseased *Siderastrea sideria* colonies suffered predominantly from DSS (71%) and some were infected by WPL disease (6%).

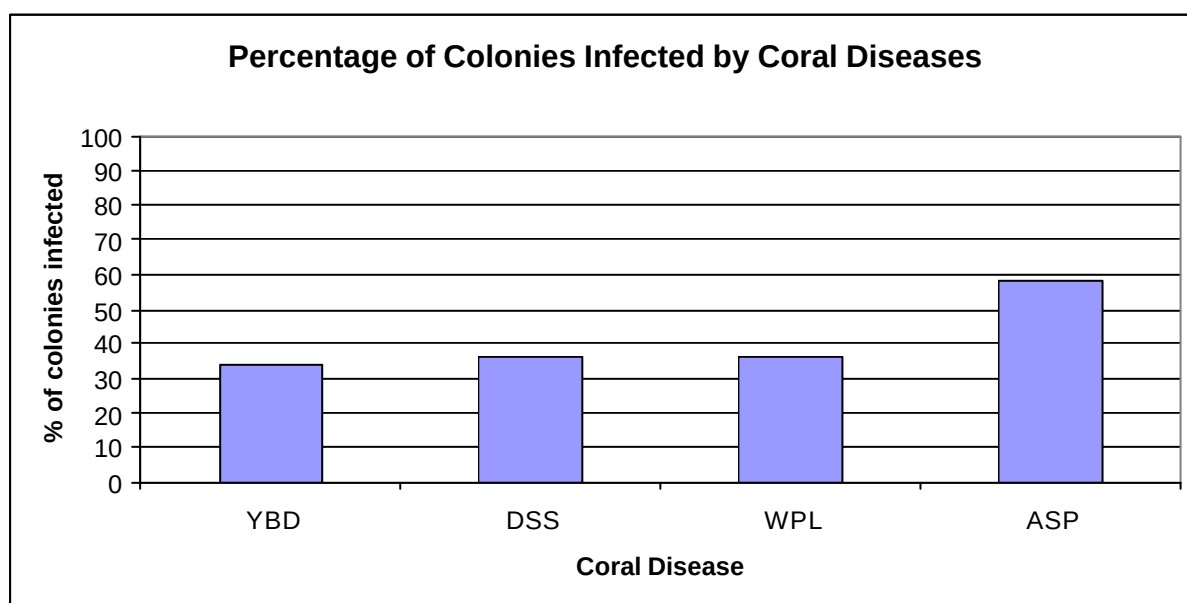


Figure 22 Percentage of coral colonies affected by 4 coral diseases expressed as a percentage of the colonies surveyed for disease. Where: ASP = Aspergilliosis, YBD = Yellow Band Disease, DSS = Dark Spot Syndrome, WPL = White Plague Disease. ASP is expressed as a ratio between diseased/healthy Seafans.

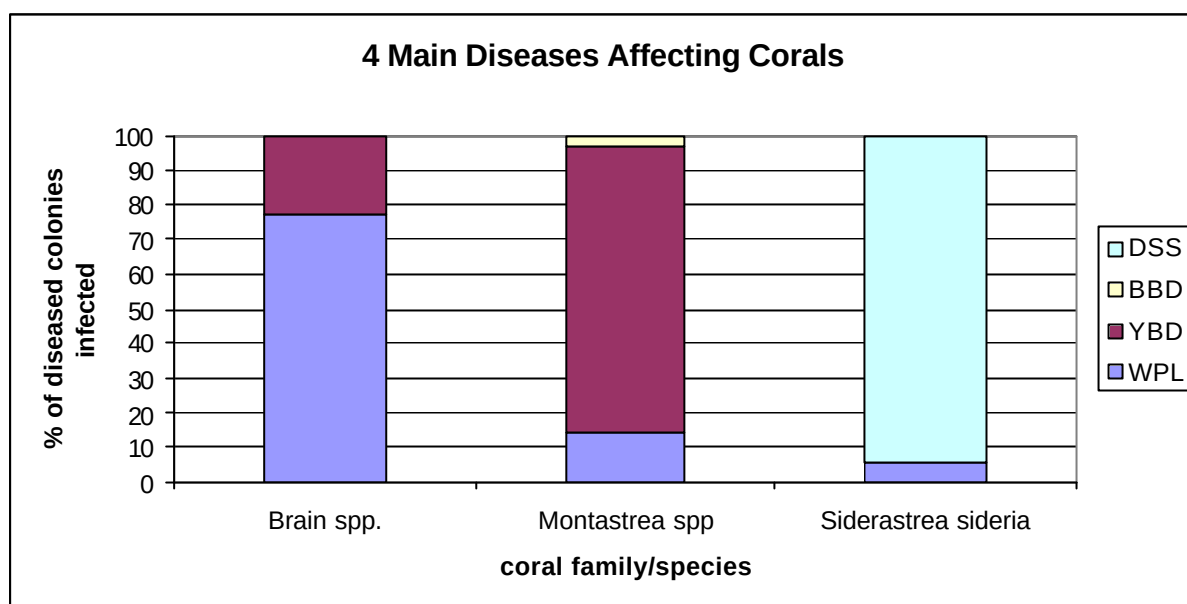


Figure 23 Most common and abundant diseases affecting three main hard coral categories. Where: ASP = Aspergillois, YBD = Yellow Band Disease, DSS = Dark Spot Syndrome, WPL = White Plague Disease, BBD = Black Band Disease

For further analysis, surveys were selected where coral cover was >1%. In some cases, coral cover under the line transect was <1% but diseased corals were found along the belt in which case the surveys were included. Surveys conducted prior to August 2007 were removed as they were considered to be unreliable. In total, 152 reef surveys were selected for this analysis: 51 for 7 metres, 65 for 12 metres and 35 for 16 metres.

Ratios of diseased colonies over total colonies could not be transformed to a normal distribution so a non-parametric Kruskal-Wallis test was used to test for significant differences. If these were found, further analysis was undertaken using a pairwise Mann-Whitney U test.

Figures 24 and 25 below compare the health of corals to the overall coral cover of that site. Figure 24 displays pooled data of all diseased colonies over the total number of colonies. Coral disease prevalence was negatively correlated to coral cover (Pearson correlation = -0,183, P-Value = 0,025). In other words, sites with high coral cover had lower disease prevalence. YBD and DSS showed similar trends for the corals they infect most – *Montastrea spp.* and *Siderastrea sideria* respectively (Figure 25).

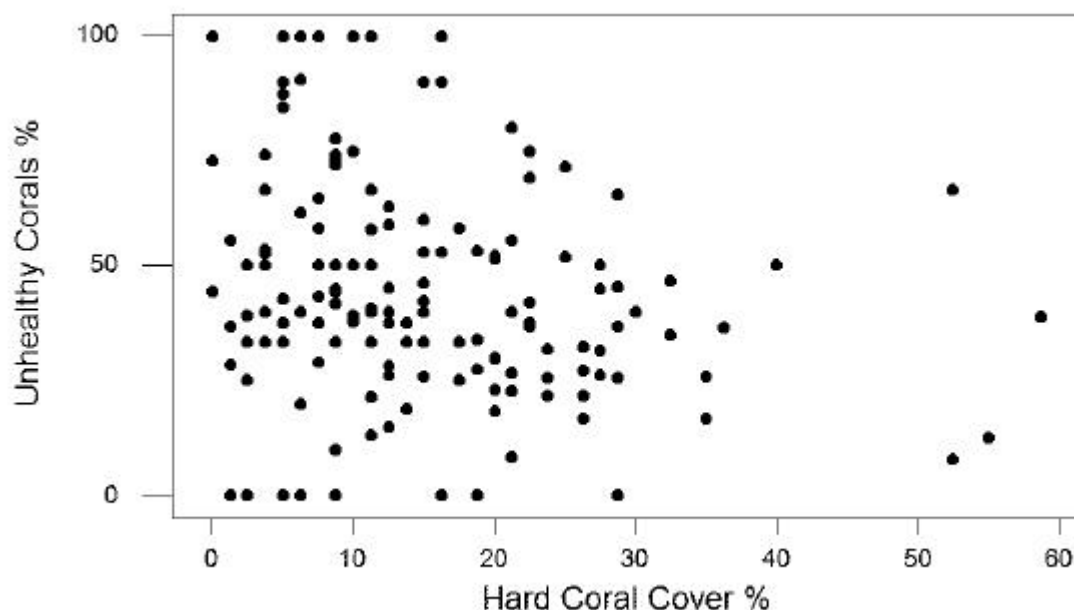


Figure 24 Percentage of unhealthy (disease and bleached) coral colonies in relation to the hard coral cover for that site. There was an inverse correlation between hard coral cover and coral health

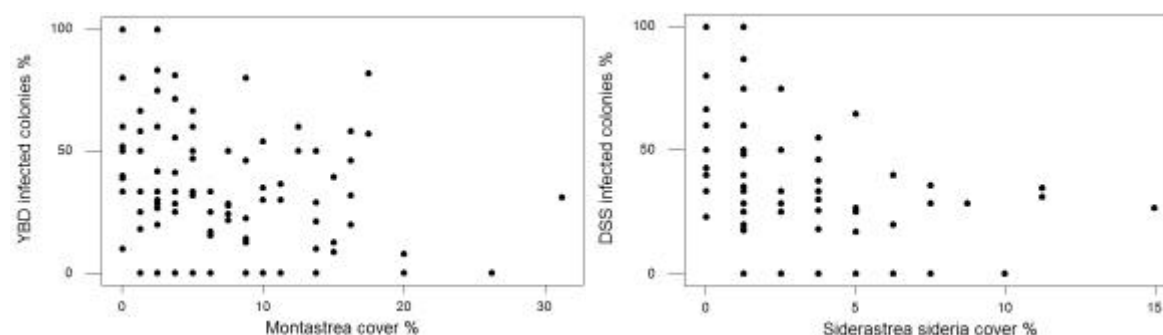


Figure 25 Percentage of diseased coral colonies in relation to the % cover for corals infected by that disease. Although not significant, there was an inverse relation between coral cover of *Montastrea* spp. (left) and *Siderastrea sideria* (right) and occurrence of YBD and DSS on these respective colonies (Pearson correlation for *Siderastrea sideria* cover and DSS infected colonies = -0,181, P-Value = 0,071 and -0,172, P-Value = 0,072 for *Montastrea* spp. and YBD)

Coral disease prevalence for the three main diseases is presented in Figure 26 for three depth bands (7, 12 and 16 metres) as a mean percentage value for all the coral types affected. In addition to this, the overall coral health was calculated as a percentage of all the diseased corals over the total number of colonies present. Coral health appears to be inversely related to depth, with the highest levels of disease recorded at the shallowest depth band surveyed (7 m).

This decrease with increasing depth is also apparent for YBD where disease prevalence decreases from 28% to 18%. DSS prevalence showed a similar pattern, dropping from 20% at 7m to 7% at 16m.

The Kruskal-Wallis test confirmed there were significant differences between depths and coral health ($P = 0,001$). Reefs were significantly more diseased at 7m then at 12 metres (Mann-Whitney $P = 0,000$). There was a trend for a decrease in coral health at 16 metres compared to 12 metres but this was not significant ($p = 0,078$). There were also significant differences in the amount of corals infected with DSS between 12 and 16 metres (Mann-

Whitney $p = 0,004$). No significant differences were found for YBD and WPL and survey depth.

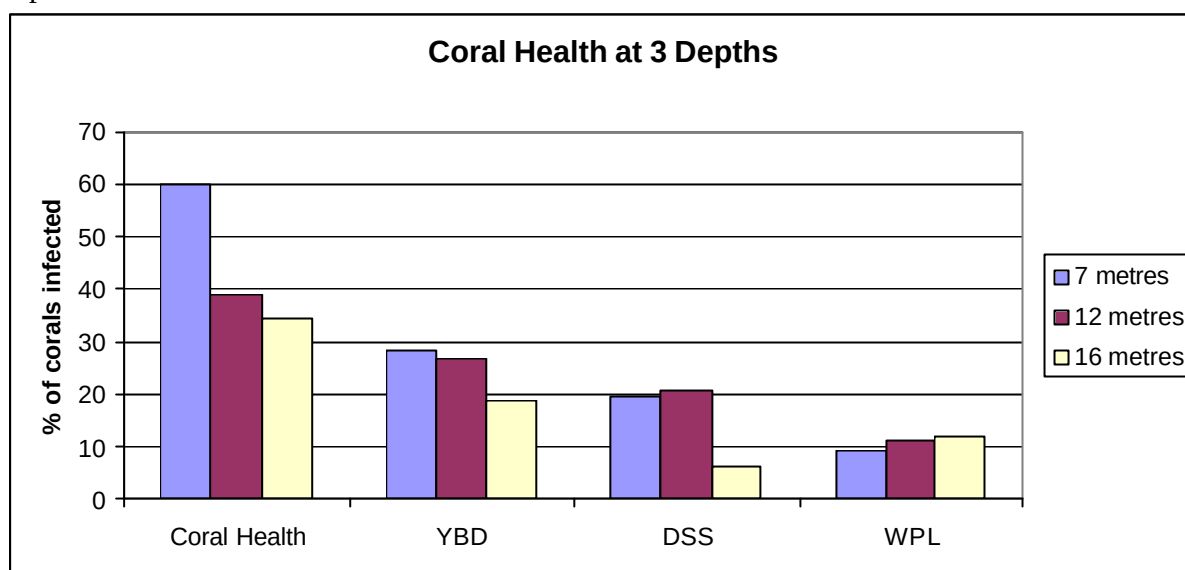


Figure 26 Overall coral reef health (all coral diseases combined) and prevalence of three main coral diseases at three depth bands (7, 12 and 16 metres).

Results from reef surveys looking specifically at coral disease prevalence are used in this analysis to compare between reef sites. As the number of surveys was limited, it is difficult to draw any conclusions at this time. Coral disease prevalence appeared to be higher at East Reef (Buccoo) than at other reef sites surveyed (Figure 27). This was the case for DSS (60%), WPL (3%) and coral bleaching levels. YBD prevalence appeared to be higher at Culloden.

Although NOAA has given several bleaching warnings for Tobago's waters, no major bleaching episodes have taken place since the mass-bleaching event affected the islands reefs in 2005 (<http://coralreefwatch.noaa.gov/satellite/bleachingoutlook/index.html>). Coral bleaching since 2005 was more often a result of high sedimentation levels smothering corals than major oscillations in temperature or UV stress.

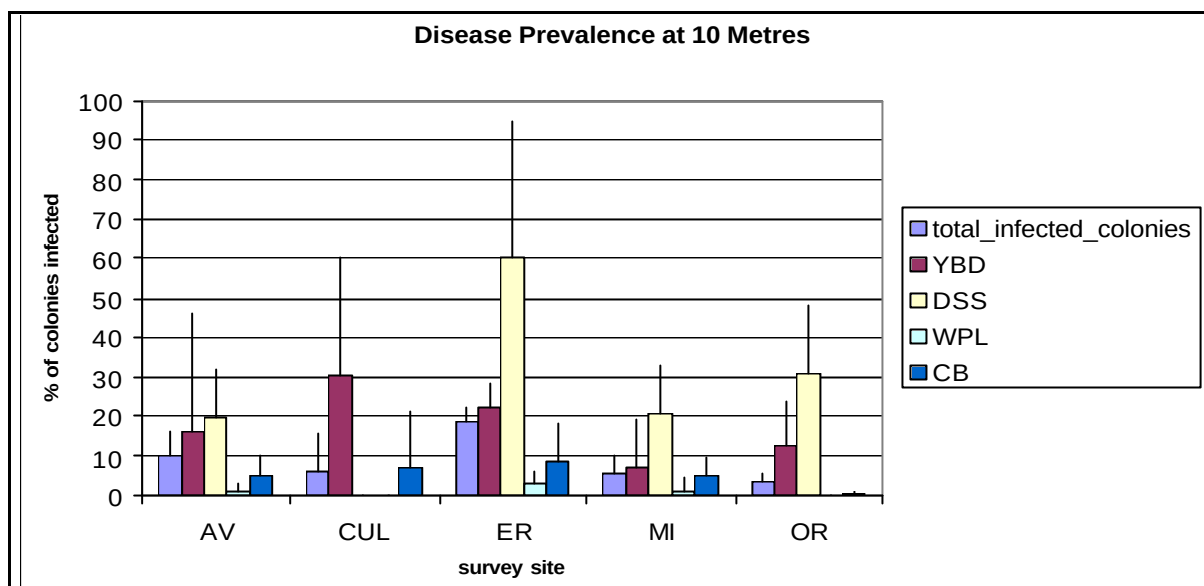


Figure 27 Disease prevalence of 4 coral diseases at 5 survey sites. Total infected colonies is given as a percentage of diseased colonies over all colonies. Disease-specific prevalence was a percentage of diseased colonies over the colonies they infect. The East Reef of Buccoo had significantly higher overall disease prevalence than Outer Reef of Buccoo (Mann-Whitney $p = 0.03$). AV = Arnos Vale, CUL = Culloden, ER = East Reef, MI = Mount Irvine and OR = Outer Reef.

5. GIS Contour Mapping

The previous sections provided information on mean values for selected ecological criteria at selected survey sites and depth bands on the northwest coast of Tobago. However, the data in this format does not pinpoint exactly where in the survey area there are high densities of reef fish or invertebrates or the parts of the reef systems with high coral cover.

Because the location of each survey has been recorded with a GPS unit, ecological values can be imported into a Geographic Information System (GIS) to enable spatial analysis. The density function in the Spatial Analyst of ArcView (ESRI software) can then be used to highlight areas displaying a particularly high or low density of the various criteria. These values can be represented on a colour ramp to facilitate visual interpretation. In the GIS outputs of this section, shades of red represent areas where lower values are dominant; the shades of green and yellow represent areas where higher values are dominant. Some survey areas have relatively low values due to the limited number of surveys conducted there thus far. As more surveys are conducted in these regions, a more accurate picture of the true values will develop. Presentation of data as a series of contour maps enables spatial comparison of ecological criteria across the study area.

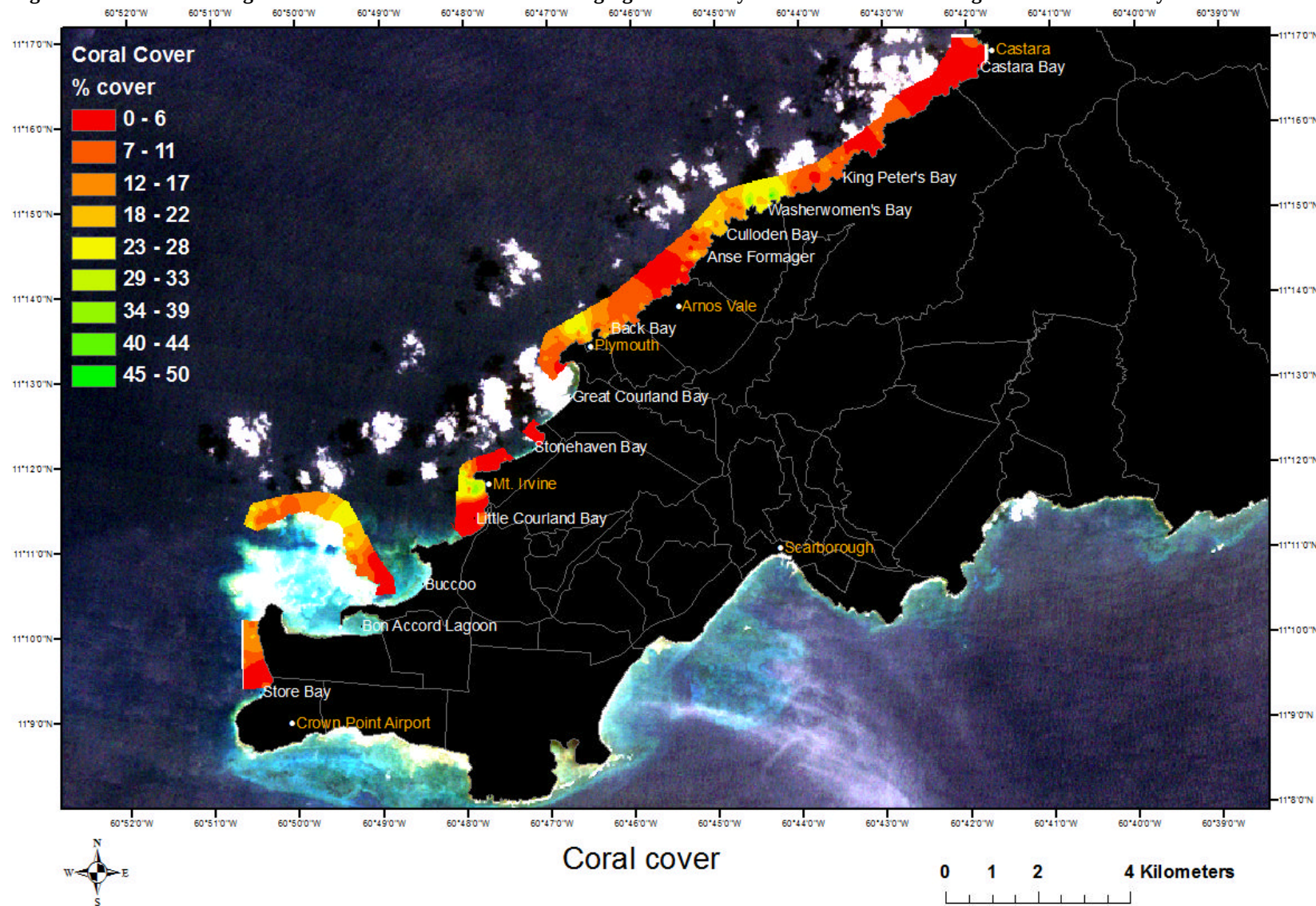
In this section we present contour maps for a range of coral reef criteria for a total of 11 biotic and abiotic coral reef variables from all surveys conducted at four of the depth bands surveyed (2, 7, 12 and 16 m.). These variables present a subset of the range of variables that will be presented in the final TCEMP report.

5.1 *Benthic Cover*

Percentage cover distributions of selected benthic categories are presented in Figures 28-30 below. Live hard coral cover is a significant indicator of overall reef health. Figure 28 displays the coral cover for all surveys conducted. Areas with less than 6% hard coral and rock/rubble cover can be considered to be mainly sandy areas. Relatively high coral cover was found around East Buccoo and the fringing reefs adjacent to Mt. Irvine, Back Bay and Washerwoman's Bay where hard coral cover was up to 50%. Most reef areas however, had low coral cover of less than 22%. Areas of high cover of bedrock were identified on fringing reefs adjacent to Culloden, King Peter's Bay and Plymouth with values of over 60% cover (Figure 29). The north and east of Buccoo Reef had substantial bedrock cover of over 75% at some sites. These are generally areas where corals have died and there has been little to no regeneration. Macroalgal (fleshy algae) cover was generally low for all areas (<5%, Figure 30). The exceptions were around Arnos Vale (10-30%) and the southeast of Buccoo Reef (15-25%).

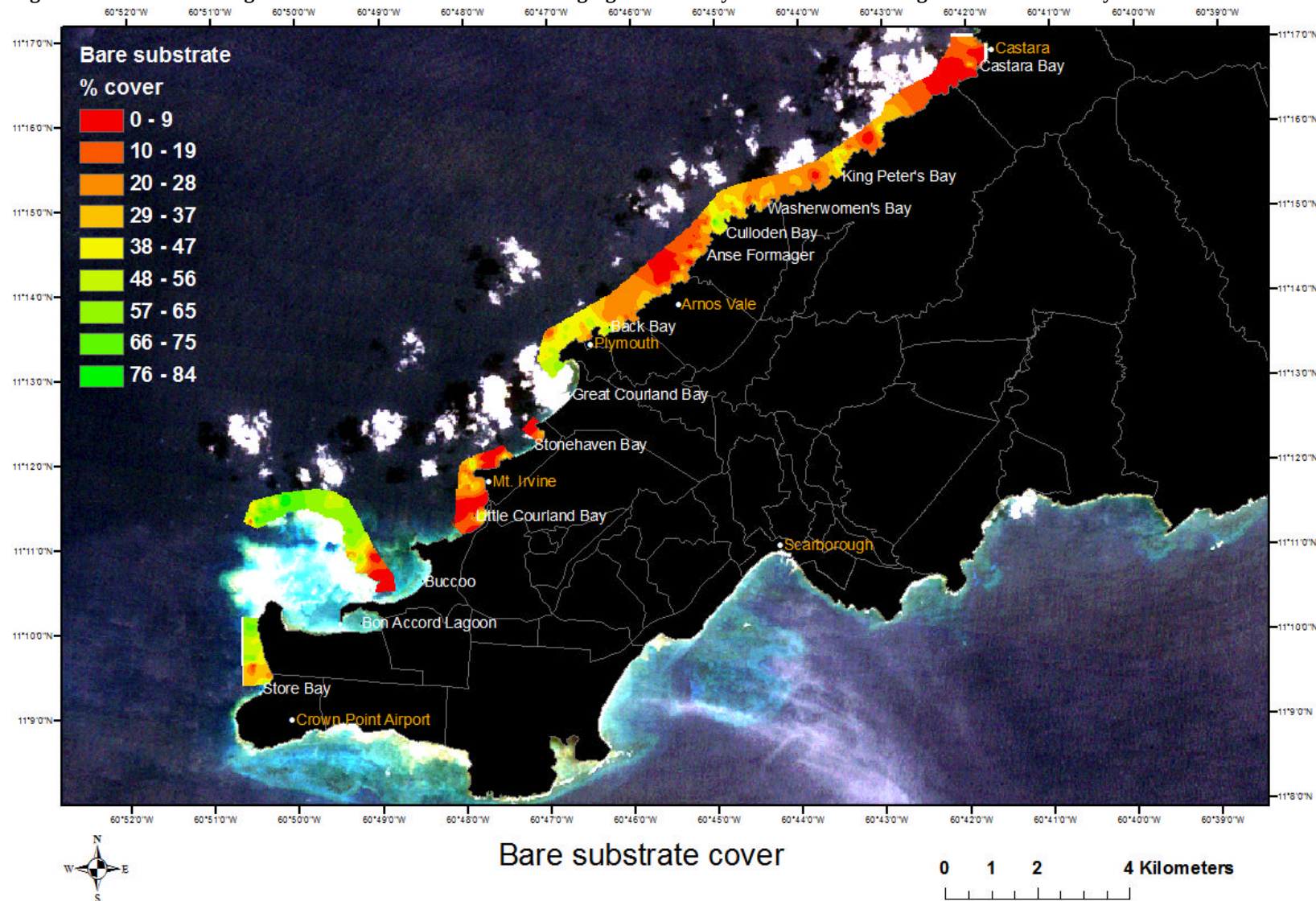
Tobago Coastal Ecosystem Mapping Project

Figure 28 Percentage hard coral cover for the area of fringing reefs surveyed in northwestern Tobago between Store Bay and Castara.



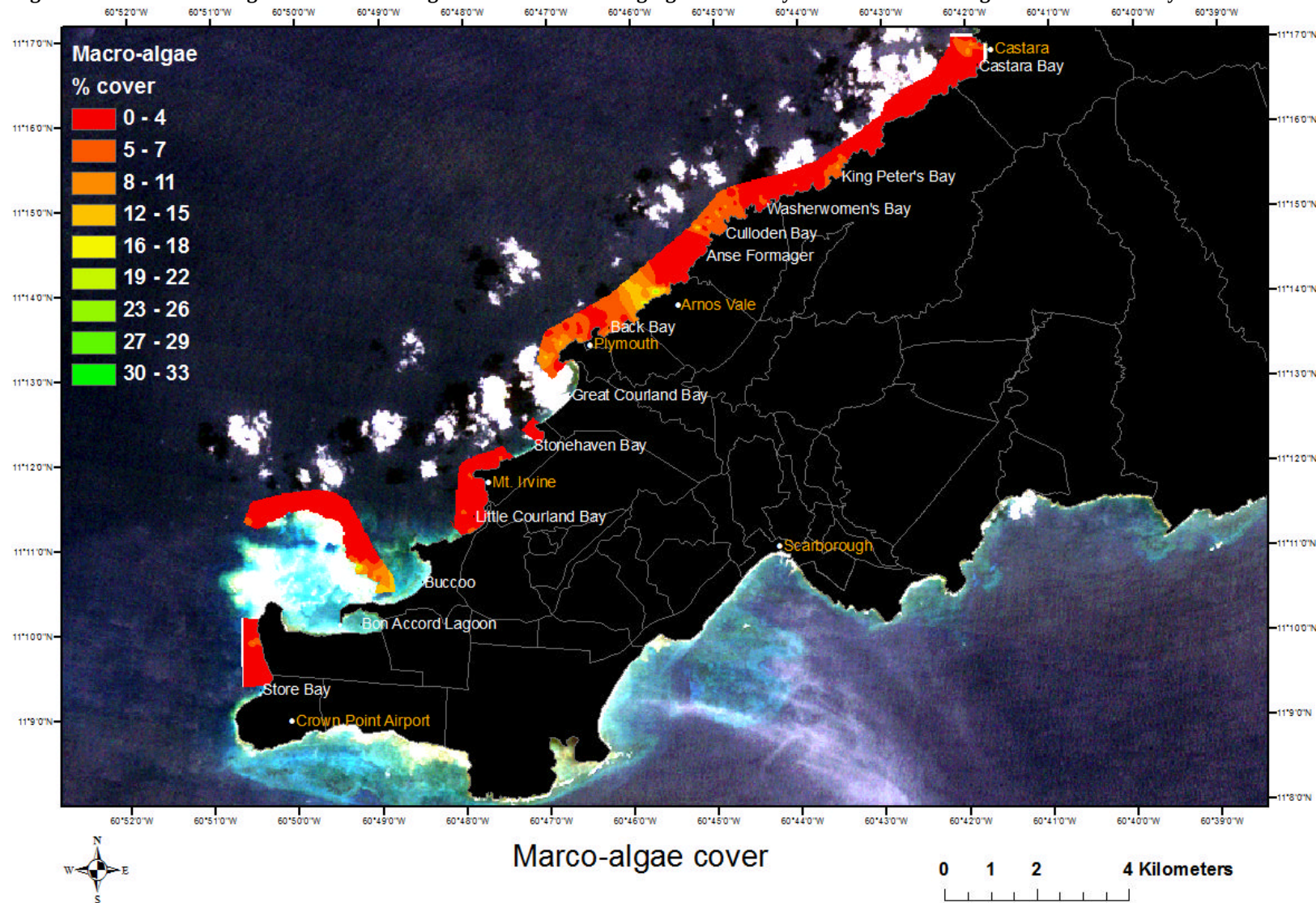
Tobago Coastal Ecosystem Mapping Project

Figure 29 Percentage bedrock cover for the area of fringing reefs surveyed in northern Tobago between Store Bay and Castara.



Tobago Coastal Ecosystem Mapping Project

Figure 30 Percentage cover of macroalgae for the area of fringing reefs surveyed in northern Tobago between Store Bay and Castara.



5.2 Invertebrates

The lack of sightings of a number of important motile invertebrates (e.g. Queen Conch, Lobster, Holothurians) on fringing reefs between Store Bay and Castara prevented the production of contour maps for these target organisms. However, we can present data for the distribution of the common sea fan (*Gorgonia ventalina*) and *Diadema antillarum* sea urchins.

Diadema antillarum sea urchins are important nocturnal herbivores that feed on algae, potentially helping to prevent algal dominated phase shifts (see Introduction). The density of *Diadema antillarum* sea urchins is presented in Figure 31. Densities were generally less than 150 individuals per hectare. Arnos Vale Bay had a high abundance of sea urchins, as did the east of Buccoo Reef where abundance was up to 1300 sea urchins per hectare. High densities may also indicate a lack of urchin predators such as Triggerfish (Balistidae)

Sea fans are currently susceptible to the fungal disease, *Aspergillosis*. The density of individual sea fan colonies per hectare is presented in Figure 32. Colony density was generally low (<500/ha.) for this coastline. Fringing reefs adjacent to the headlands at Plymouth and Gordon's Bay and King Peter's and Arnos Vale Bays revealed higher densities (~ 500-1000 colonies/ha.). The highest abundances of sea fans were found on the northern sections of Buccoo Reef where over a thousand colonies per hectare were common for several sites.

Figure 31 Abundance of Sea urchins (*Diadema antillarum*) for the area of fringing reefs surveyed in northwestern Tobago between Store Bay and Castara.

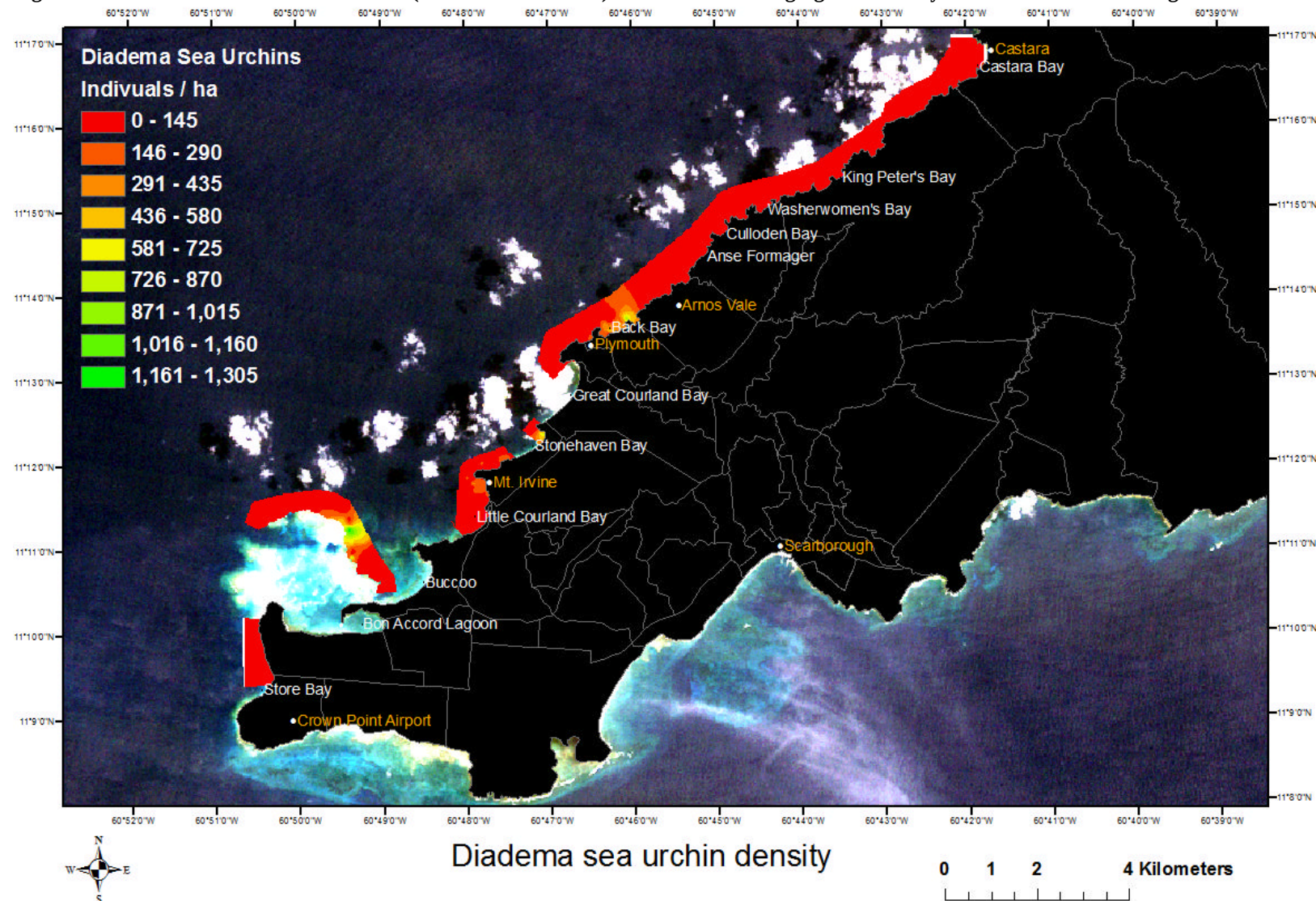
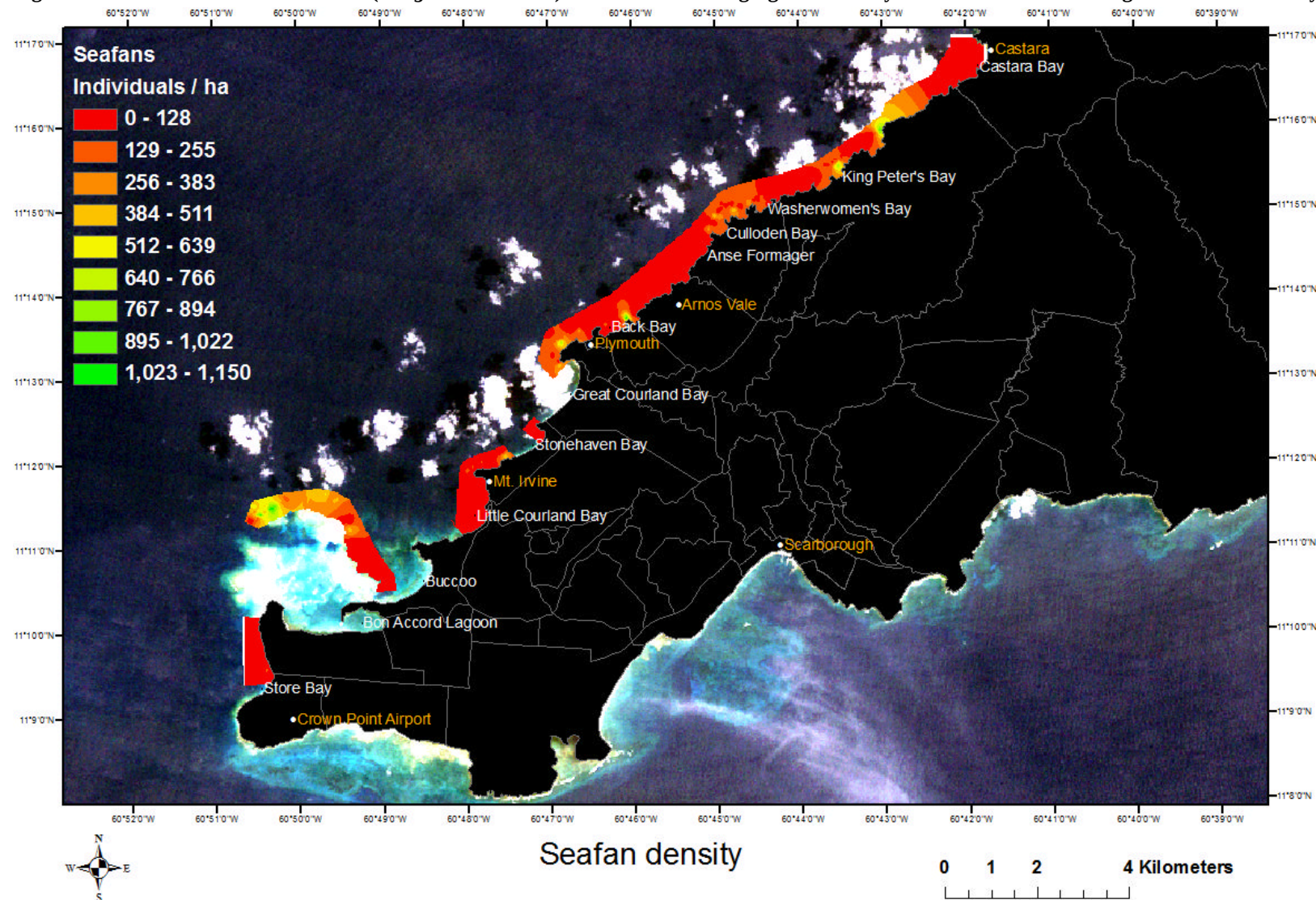


Figure 32 Abundance of seafans (*Gorgonia ventalina*) for the area of fringing reefs surveyed in northwestern Tobago between Store Bay and Castara.



5.3 Reef Fish

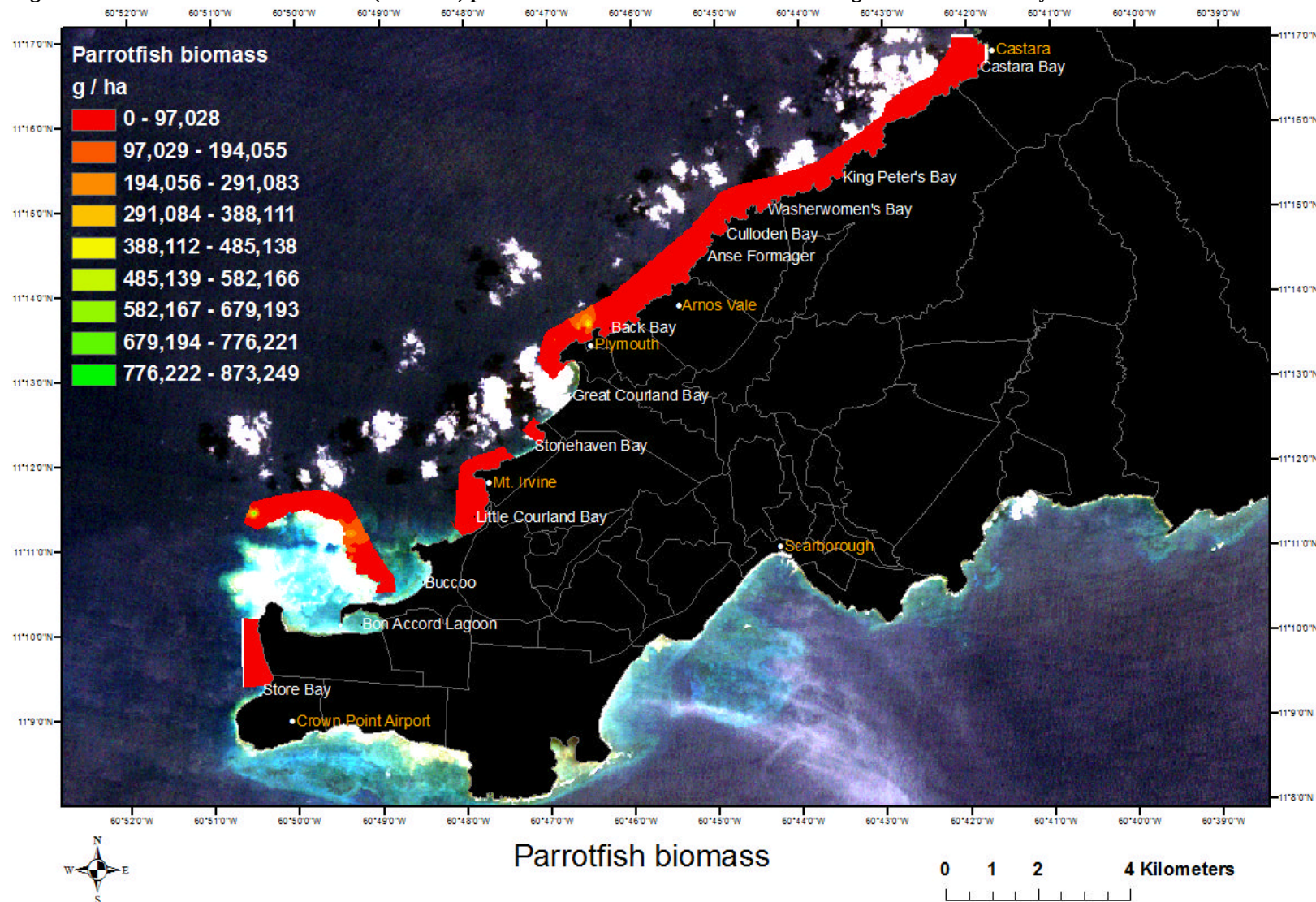
The mean biomass of five commercially targeted reef fish families are presented in Figures 33-37. Fish biomass is presented as the number of grams per hectare of reef area (g/ha) and fish density as the number of individuals per hectare. One of the key herbivores on coral reefs is the Parrotfish family (*Scaridae*). Parrotfish biomass generally ranged between 0-200 kg/ha in the areas surveyed. High Parrotfish biomass was recorded adjacent to Plymouth (300-500 kg/ha) and on the eastern side of Buccoo Reef (up to 500kg/ha). Highest densities were recorded on the far northern reefs of Buccoo Reef where biomass was over 800kg/ha for some survey sites.

Figures 34-36 depict the calculated biomass of three carnivorous reef fish families, Groupers, Snappers and Grunts, which are all commercially fished as a foodfish in Tobago. The biomass of Groupers (*Serranidae*) was generally low at 20kg/ha or less for most areas surveyed (Figure 34). Highest Grouper biomass was found on the reefs around Back Bay. The northern reefs of Buccoo Reef also had relatively high Grouper densities although below 100kg/ha. Snapper (*Lutjanidae*) biomass was generally low with very few large (>25cm) individuals observed for the whole coastline (Figure 35). Exceptions were Back Bay and isolated sites around Buccoo Reef where Snapper biomass was >300kg/ha. The distribution of Grunts (*Haemulidae*) was rather patchy (Figure 36) with most sites having <85kg/ha and some sites up to 600kg/ha.

The total biomass for all commercial and pelagic target species was generally high around the North and East of Buccoo Reef as well as isolated sites around Back Bay, Culloden and King Peter's Bay where fish biomass was up to 1,900kg/ha (Figure 37). Most of this biomass can be attributed to Parrotfish and Snappers encountered on surveys.

Tobago Coastal Ecosystem Mapping Project

Figure 33 Biomass of Parrotfish (*Scaridae*) per hectare of reef area in northern Tobago between Store Bay and Castara.



Tobago Coastal Ecosystem Mapping Project

Figure 34 Biomass of Groupers (*Serranidae*) per hectare of reef area in northern Tobago between Store Bay and Castara.

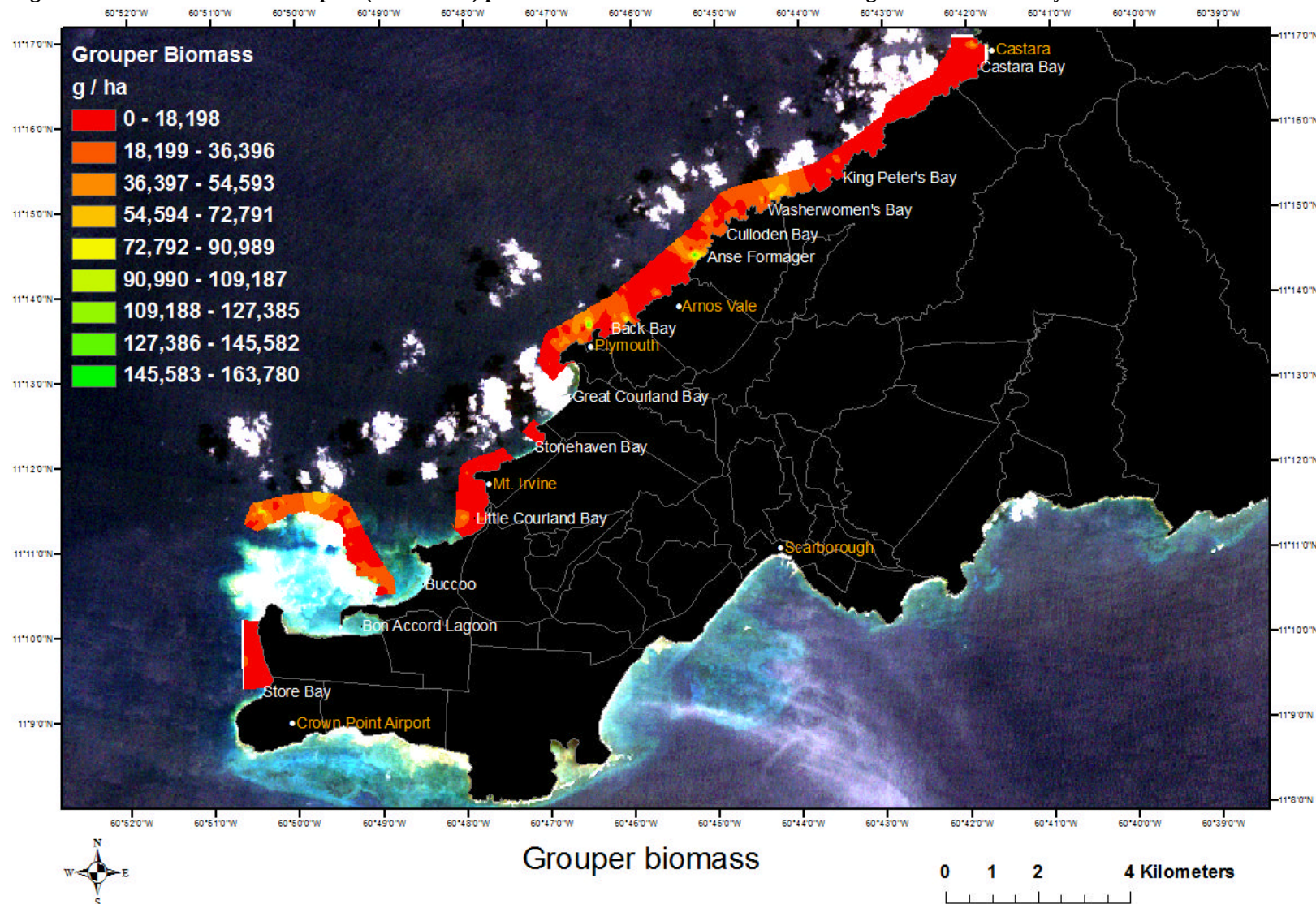
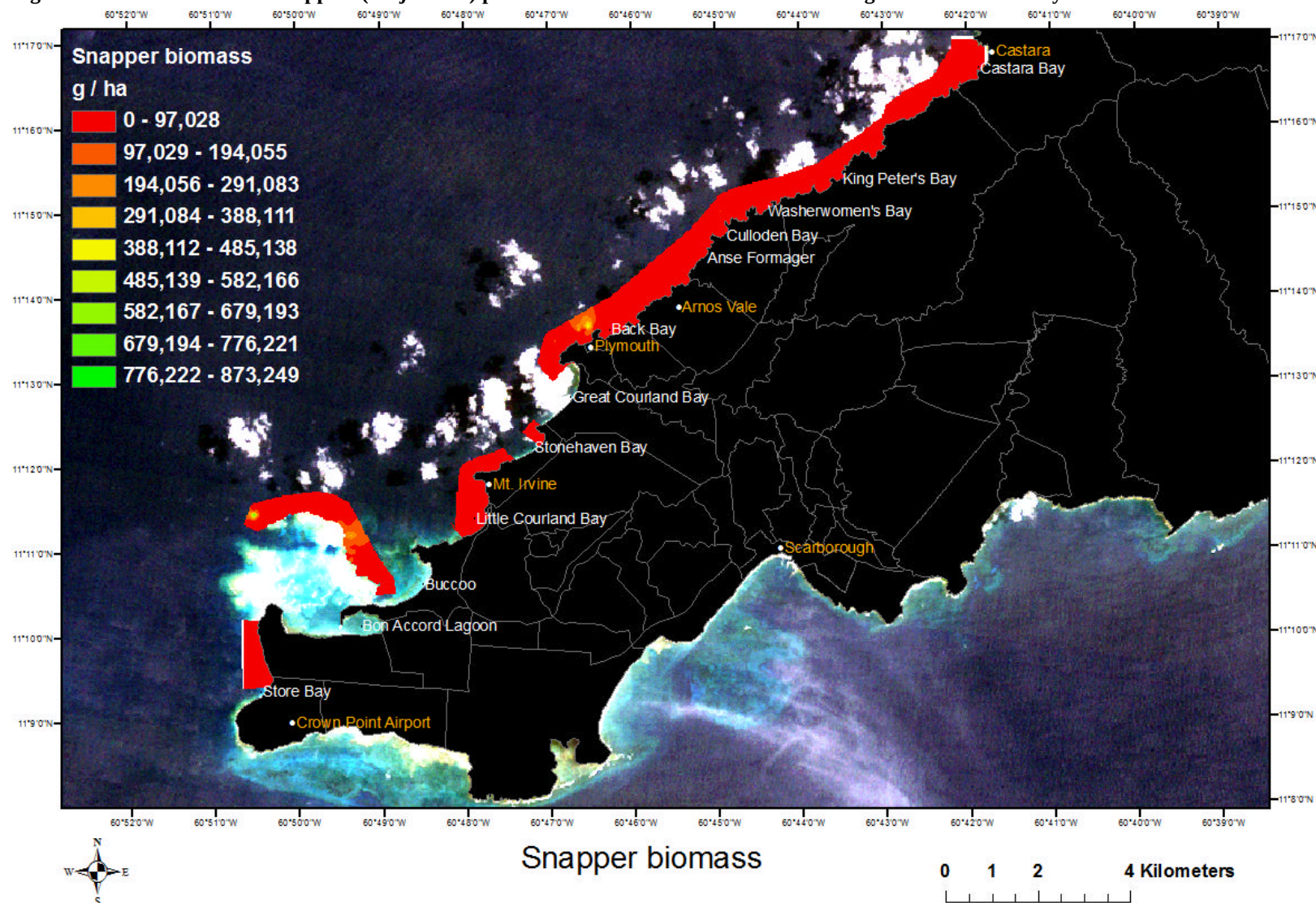


Figure 35 Biomass of Snappers (*Lutjanidae*) per hectare of reef area in northern Tobago between Store Bay and Castara.



Tobago Coastal Ecosystem Mapping Project

Figure 36 Biomass of Grunts (*Haemulidae*) per hectare of reef area in northern Tobago between Store Bay and Castara.

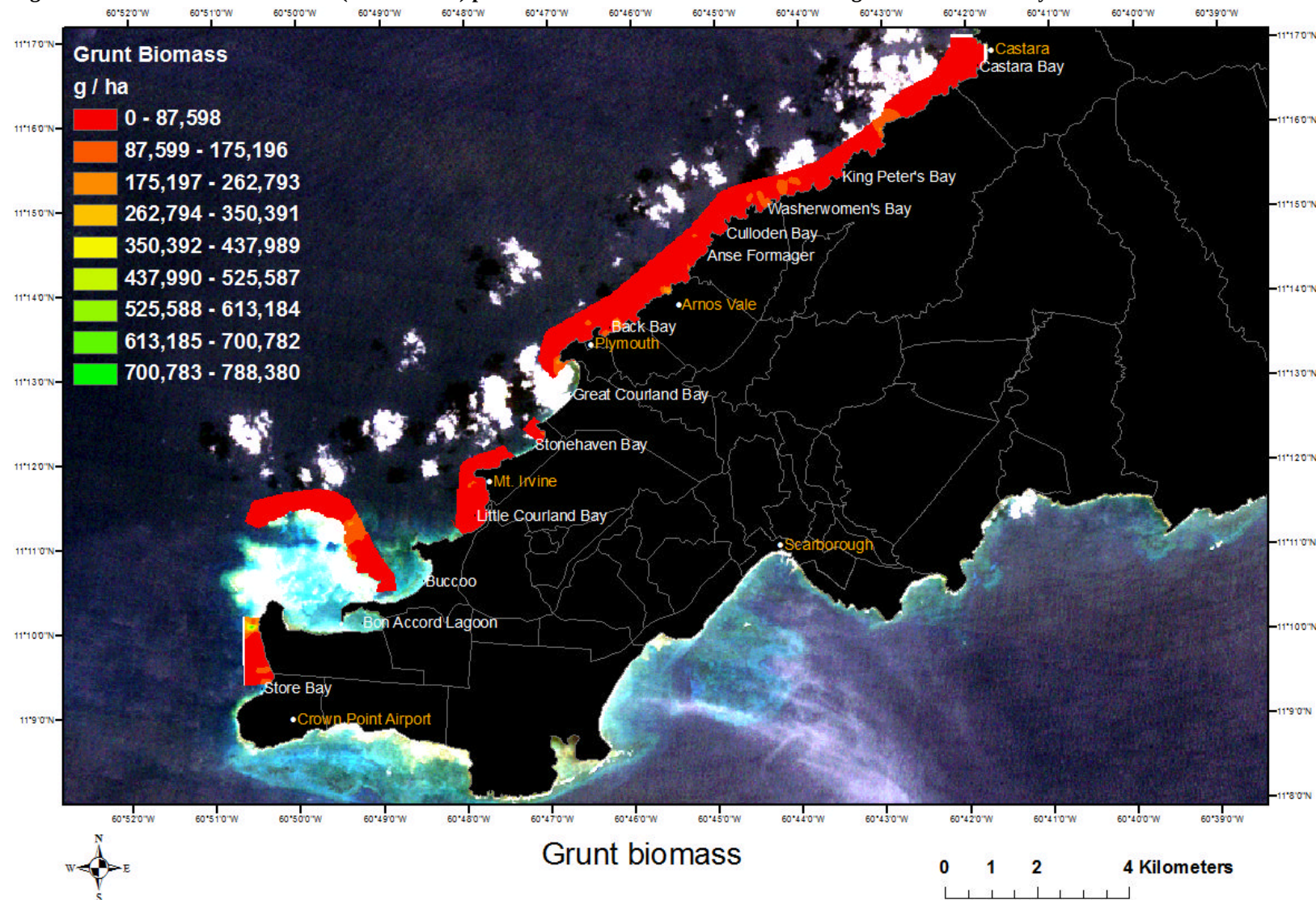
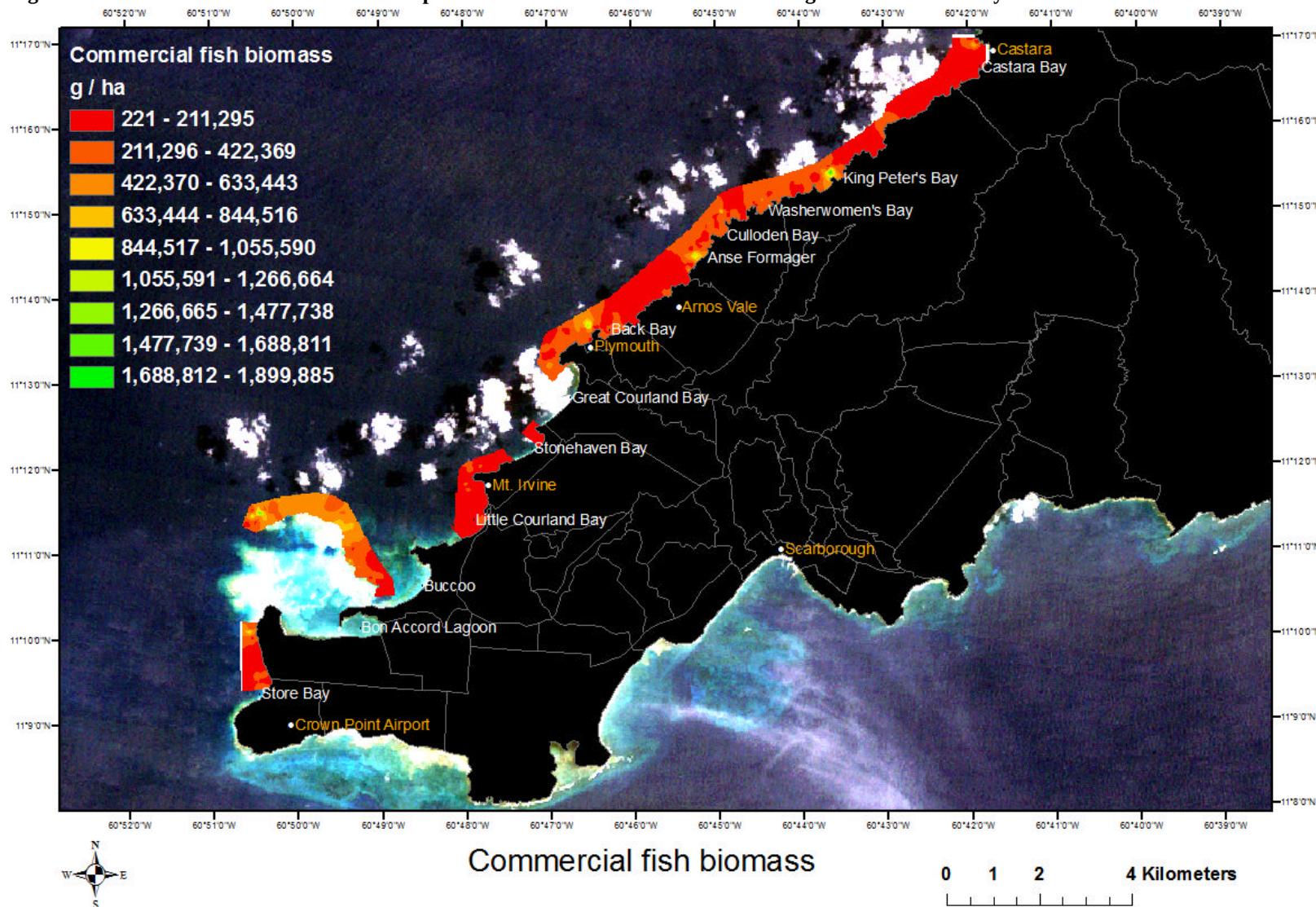


Figure 37 Biomass of commercial fish per hectare of reef area in northern Tobago between Store Bay and Castara.



5.4 Conservation management values

Using five ecological indices, comparisons between site records can now be made in order to highlight key areas of ecological importance. The indices used are the site record values for live hard coral cover, the total number of benthic targets (not including nutrient indicator algae), total number of reef fish targets and the Shannon-Weiner Biodiversity Indices for both benthic and reef fish targets.

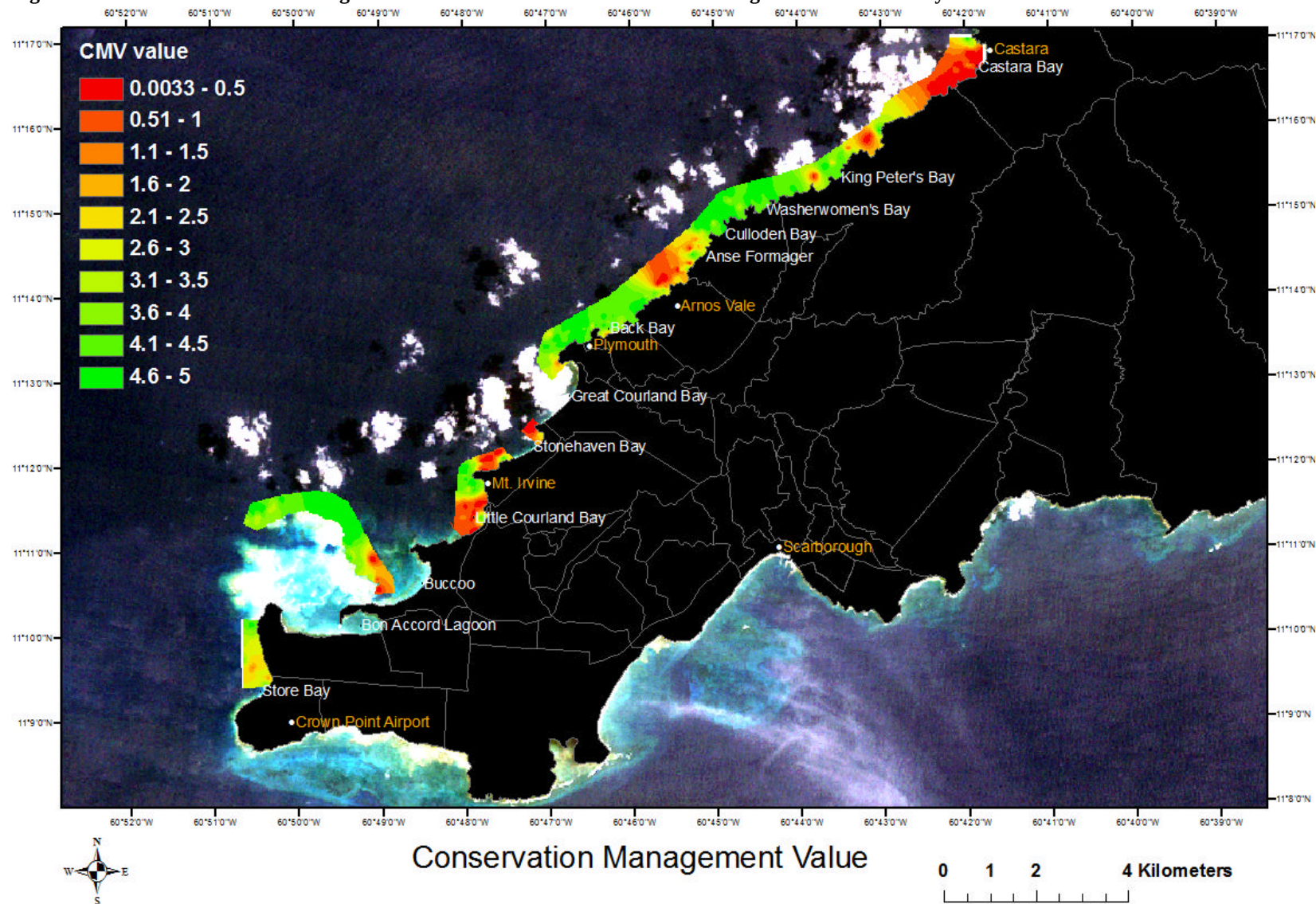
To calculate the Conservation Management Value (CMV) of each survey site, an inter-survey analysis is made to determine the ecological 'value' of each survey site relative to the others (see Harding et al., 2006). To do this, the average value for each of the 5 indices is calculated for each site, and these values are then used to determine the overall averages for each index across all sites. The sites are then compared against these overall averages to determine the number of indices in which each site is above or below the overall average. If, for example, a site is below average in all 5 indices, it would score a CMV value of 0; if it was above average in only 1 index, it would score a CMV value of 1, and so on up to a maximum CMV value of 5 (above average in all 5 indices).

Note that this technique compares each site against the other sites within a region, and thus it is a *relative value* for that region only. The fact that a site is displayed as a low CMV does not necessarily mean it is biologically 'poor', but simply that there are biologically 'richer' areas in the same region.

Buccoo Reef, Mount Irvine, Arnos Vale, Back Bay, Plymouth, Culloden, Washerwomen's Bay and King Peter's Bay all had high CMV values of 4+ (Figure 38). All sites had a combination of relatively high live hard coral cover, benthic diversity and fish abundances and diversity. Although a full management proposal will be written at the project end, the fringing reefs of these areas should already be considered initial priority sites for effective conservation management.

Tobago Coastal Ecosystem Mapping Project

Figure 38 Conservation management value for reef areas in northern Tobago between Store Bay and Castara.



6. Discussion

Benthic composition

The reefs of northwestern Tobago consist mainly of substrates such as rock and rubble, covered by filamentous and coralline algae. In spite of a reduction in hard coral cover and unlike many other Caribbean reefs and sites surveyed on the southern coast of Tobago, no major phase shifts to algae dominated habitats have taken place with macroalgal cover generally below 5%. Many shallow reefs are dominated by the zoanthid *Palythoa caribaeorum* indicating that in some cases, a phase shift has taken place from an Elkhorn coral dominated reef to one dominated by zoanthids.

Coral cover was generally found to be low (<25%) at most sites. The reefs furthermore show high variation in coral cover between sites. Some reefs such as those at Mount Irvine, Washerwoman's Bay and the reefs of Buccoo show good overall reef health, with relatively high coral cover and species diversity, whilst the condition of others such as Plymouth and Arnos Vale is highly concerning. *Millepora* and *Montastrea* corals were the most common families seen at 7, 12 and 16 metres depth with the latter showing an increase in abundance with depth.

Comparisons between bleaching surveys conducted in 2005 and baseline surveys over 2007-2008 provide evidence that there has been a rapid decline in hard coral cover at 7 and 12 metres depth on Tobago's north-western reefs. This has coincided with a decrease in coral diversity and composition with *Montastrea spp.* composition dropping 50% and *Millepora* abundance increasing by 50% on shallow reefs. If this rate of decline continues and no significant coral recruitment takes place, these reefs may reach their tipping point beyond which transition into an algal, sponge or zoanthid dominated state becomes unavoidable.

Influx of nutrients from agricultural and sewage sources as well as prolonged periods of high sedimentation loading of coastal waters from land runoff are thought to be major contributors to the overall degradation of the reefs surveyed. These local stressors have weakened the corals natural defence mechanisms and made them more susceptible to recent and future, regional impacts such as coral bleaching and hurricane damage. This was apparent during the 2005 mass coral bleaching event which killed many of the affected corals and led to the disease outbreaks that are currently prevalent. In addition, an unusually strong swell during April 2008 detached and destroyed many of the shallow water hard coral colonies, particularly the remaining *Acroporids*.

Reef Fish

Reef fish data presented indicates that a number of commercially fished families were rarely recorded on reef surveys. Of particular concern is the lack of Grouper biomass and diversity at all sites and depths, most likely to be a result of overfishing of these resources in combination with habitat loss along the northern coast of Tobago.

Snappers (*Lutjanidae*) are good indicators of fishing pressure as they are a highly valued food fish and susceptible to hook and line and spear fishing, both predominant fishing methods

used in Tobago. Their biomass was found to be very low for all sites and depths surveyed. Comparisons with well-managed reefs of Bonaire in the Dutch Antilles indicate that Snapper biomass in Tobago is only a fraction of that of Bonaire (~70 kg/ha vs. ~230 kg/ha).

Although the distribution of Grunts was very patchy, there were some indications that those sites that still have relatively good reef health and high reef rugosity such as Mount Irvine and Washerwoman's Bay contained the highest biomass of this fish family. Grunts use coral overhangs for shelter and protection during the daytime and disperse at dusk when they become active foragers for invertebrate prey. As with most reef-associated fish, a decrease on the availability of suitable habitat for shelter will directly correlate with a decrease in their population numbers. This may help explain why severely degraded reefs such as Culloden and King Peter's Bay harbour low Grunt populations.

Although their overall biomass was not as high as Bonaire's reefs, herbivorous fish densities did not appear to be as severely depleted as elsewhere in the region such as Curaçao (AGRRA, 2003). Relatively high Parrotfish biomass around Buccoo Reef merits fishery restriction and conservation measures for this key reef herbivore in order to enhance the resilience of coral reefs in this part of Tobago. The importance of herbivorous Parrotfish in keeping algae cover low in order to promote coral recruitment has been well documented (Mumby et al., 2006, Mumby et al., 2007, Bellwood et al., 2004, Bellwood et al., 2006, Williams and Polunin, 2007). We emphasise their importance in being able to facilitate reef recovery on Tobago's northwestern reefs if populations remain relatively high or increase through management measures.

Invertebrates

Low abundances of key invertebrate species, particularly Queen Conch, Spiny Lobsters and Sea Cucumbers were found throughout the survey area, indicating serious over-harvesting of these resources. With no management practices in place to protect the remaining populations and under sustained fishing intensity, most reefs have already been severely depleted. It is likely that more isolated reefs such as some of those on the Atlantic side of Tobago will see increased harvesting in the near future. We recommend that no-take zones are established at key reef sites in addition to imposing restrictions on the minimum size of queen conch and lobsters harvested as well as no-catch policies for egg-bearing female lobsters.

As well as herbivorous Surgeonfish and Parrotfish, an echinoid species, *Diadema antillarum* (long-spined sea urchin), plays a key role as a reef grazer potentially preventing phase shifts (Hughes, 1994). Abundances, although variable, were high on many reefs including the Outer Reefs at Buccoo, Washerwoman's Bay and King Peter's Bay. It is therefore hypothesised that *Diadema* sea urchins currently play an important role on Tobago's northwestern reefs in maintaining the low macroalgal cover typical of these reefs. Although there is little evidence of an increase in *Diadema* population numbers since the massive die-off in the 1980's, it is encouraging to see high numbers of individuals at several key reef sites. This is particularly so when considering that there were no sightings of this species at the same sites in 2005.

Coral Disease and Bleaching

A concerning level of coral disease has been observed. Initial findings suggest that disease is most prevalent in reefs adjacent to areas of higher coastal development, sewage outputs and/or agricultural land use. For example, sites where disease prevalence was particularly

high such as Buccoo East and Outer Reef, are exposed to a nearby untreated sewage outlet. It is worth noting that significant levels of coral disease were not observed on surveys conducted in 2005 during the mass coral bleaching outbreak (O'Farrell et al., 2005). This strongly indicates that the disease outbreaks currently affecting Tobago are directly linked to post-stress symptoms from the mass bleaching event of 2005.

The highest levels of coral disease were found in shallower waters suggesting a higher resilience to coral disease for deep-water corals. In addition to this, disease prevalence was negatively correlated to coral cover. If these findings are consistent for different reefs, it adds weight to the argument that management priorities need to be given to areas which are healthier and have the best chance of surviving and recovering from future impacts.

Yellow Band Disease, White Plague and Dark Spot Syndrome were the most prevalent diseases affecting hard corals and infected about a third of recorded corals. All three of these diseases attack massive, slow-growing hard coral colonies and can significantly lower the structural complexity of Tobago's reefs if this level of prevalence continues. These findings, combined with the likelihood of future bleaching outbreaks, are a major cause for concern considering current predictions on rising sea surface temperatures.

Elevated water temperatures have been shown to increase the rate of spread of Yellow Band Disease and induce greater coral mortality (Cervino et al., 2004). A similar effect has been noticed for White Plague, which seems to be more prevalent during the summer months. There were also high levels *Aspergillois* infecting Seafans. Levels of other diseases such as Black Band Disease and Red Band Disease were generally low to non-existent on most reefs surveyed. The few *Acropora palmata* stands that remain in shallow waters are susceptible to white pox and patchy necrosis. In addition to disease, coral bleaching has also been observed at several sites although high levels of bleaching like those experienced in 2005 have not occurred.

General Conclusions and Management Recommendations

Healthy coral reefs are an essential part of Tobago's economy and efforts must be made to ensure that reef health is improved. Disturbingly, all of the reefs visited for surveys are showing some signs of stress. Although the signs vary, they generally include: coral disease, low coral cover, high sedimentation, low fish density, reduced species diversity and direct physical damage such as anchor and trampling damage. Whilst current reef health is a cause for genuine concern, it is likely that the reefs observed still retain the capacity to recover. This is evident from the fact that although there has been a significant reduction in hard coral cover over the past three years, macroalgal levels have remained low and no overall phase shift to a macroalgal-dominated state has occurred. Unfortunately, this has not (yet) translated into a recovery of coral reefs after the 2005 bleaching event. It is likely that a combination of high disease prevalence and anthropogenic impacts are putting chronic stress on the coral reefs with little sign of coral recruitment.

Action to reduce local impacts such as overfishing, sedimentation and nutrification of the coral reefs and their associated habitats are therefore of primary importance in order to increase coral reef resilience and enhance the potential for recovery over the next years. Furthermore, areas of resilience to coral disease and bleaching episodes will need to be identified, protected and managed. These areas may then act as a source of coral larvae to enhance recruitment on damaged reef areas and enable ecosystem recovery.

In order to deal with the high and increasing levels of sedimentation and nitrification, management strategies will need to address proper treatment of sewage and agricultural runoff such as waste treatment facilities and by routing runoff through wetlands and artificially created sediment ponds before it enters the sea. Furthermore, upland and coastal construction projects need to undergo rigorous environmental impact assessments and effective mitigation measures must be implemented before construction is allowed to commence. Strategies may include minimizing construction during the rainy season and replanting schemes to hold soil in place on exposed slopes.

A complete ban of spearfishing on Groupers and Parrotfish on Tobago's near-shore reefs is proposed until there are indications of population recovery. Furthermore, a series of well-managed no-take zones should be implemented for those areas which have extensive and relatively healthy reef systems such as Washerwoman's Bay, Mount Irvine and Culloden, thereby increasing stocks of herbivorous and carnivorous reef fish and other endangered reef creatures such as conch shells and lobster. This in turn would lead to increased dive and snorkel related tourism which will also need to be managed carefully.

In order to assess the cultural, social and wider ecological implications of management measures proposed, fisheries assessments would need to be conducted within the communities in order to provide valuable data on catch composition, weight and effort. This kind of data is currently absent. These outputs would enable policy-makers to take into account the impacts that artisanal fishing is having on Tobago's reefs. These outputs would provide information on which trophic groups are currently being fished and to what extent the fishing is disrupting the structure and function of coastal marine food webs.

Tobago's only marine protected area, the Buccoo Reef Marine Park (BRMP) has had little success in enforcing its management policies. Survey results presented within this report have shown that in spite of this, fish densities and coral cover on the outer seaward parts of this reef complex have been higher than most of the other reef sites surveyed. Some excellent and viable short-term management strategies have already been proposed in a report distributed by the World Resource Institute (Burke et al., 2003) and we fully support those recommendations.

Training programmes should be conducted for reef tour operators, marine park wardens and SCUBA instructors, allowing local communities to benefit from livelihoods created through sustainable tourism. This can be achieved through programmes initiated through collaborative efforts between the THA and environmental NGOs such as CCC and the BRT as well as exchange programmes with other Caribbean island states. Training programmes must also strive to 'arm' stakeholders with the knowledge, technical capacity and will to manage their coastal resources in a sustainable manner. Finally, an extensive public education and awareness campaign is needed to build on existing efforts and ensure that all users appreciate and understand the value of these precious coastal resources.

References

- Bak, R. P. M., Nieuwland, G., and Meesters, E. H. 2005. Coral reef crisis in deep and shallow reefs: 30 years of constancy and change in reefs of Curacao and Bonaire. *Coral Reefs* 24: 475 – 479.
- Bellwood, D.R., T.P. Hughes, C. Folke, and M. Nystrom. 2004. Confronting the coral reef crisis. *Nature* 429: 827-833.
- Bellwood, D.R., T.P. Hughes, and A.S. Hoey. 2006. Sleeping functional group drives coral-reef recovery. *Current Biology* 16: 2434-2439.
- van Bochove, J-W, Harding, S, Head, K, Gibson, K and Raines, P 2008. Tobago Coastal Ecosystems Mapping Project. Results of Community and Scientific Work, March – December 2007. CCC report for IWCAM. Coral Cay Conservation, London, UK 52 pp.
- Bruno, J. et al. 2007. Thermal Stress and Coral Cover as Drivers of Coral Disease Outbreaks. *PLoS Biology* 6: 1220-1227
- Buddemeier, R., Kleypas, J., Aronson, R. 2004. Coral Reefs and Global Climate Change – Potential Contributions of Climate Change to Stresses on Coral Reef Ecosystems. Pew Center on Global Climate Change, Arlington USA.
- Burke, L. and Maidens, J. 2004. Reefs at risk in the Caribbean. World Resources Institute, Washington D.C. USA.
- Burke, L., Greenhalgh, S., Prager, D. and Cooper, E. 2008. Coastal Capital – Economic Valuation of Coral Reefs in Tobago and St. Lucia. World Resources Institute, Washington D.C. USA.
- Cervino, J.M., Hayes, R.L., Polson, S.W., Polson, S.C., Goreau, T.J., Martinez R.J. and Smith. G.W. Relationship of *Vibrio* Species Infection and Elevated Temperatures to Yellow Blotch/Band Disease in Caribbean Corals. *Applied and Environmental Microbiology*, Nov. 2004, p. 6855–6864
- Gardner, T., Côté, I., Gill, J., Grant, A. and Watkinson, A. 2003. Long-term region wide declines in Caribbean Coral Reefs. *Science* 301: 958-960.
- Glynn, P. 1993. Coral reef bleaching ecological perspectives. *Coral Reefs* 12: 1-17.
- Harding S., Comley, J., Dawson, C., Tamblin, A. and Raines, P. 2006. Fiji Coral Reef Conservation Project – Kaduva Islands, March-September 2006. Coral Cay Conservation, London, UK 93 pp.
- Harding S., van Bochove, J., Gibson, K.. and Raines, P. 2008. Continued degradation of Tobago's coral reefs linked to the prevalence of coral disease following the 2005 mass coral bleaching event. *Proc. 11th International Coral Reef Symposium*.

Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, and D. Xiaosu (eds.) 2001. IPCC Third Assessment Report: Climate Change 2001: The Scientific Basis. Cambridge University Press, Cambridge, UK, 944 pp.

Hughes, T.P. 1994. Catastrophes, phase shifts, and large-scale degradation of a Caribbean coral reef. *Science* 265: 1547-1551.

Hughes, T. et al. 2003. Climate change, human impacts, and the resilience of coral reefs. *Science* 301: 929-933.

Hughes, T. et al. 2007. Phase Shifts, Herbivory, and the Resilience of Coral Reefs to Climate Change *Current Biology* 17: 360-365

IPCC 2007. The Physical Science Basis. Summary for Policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. 18 pp.

Jackson, J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, C.B. Lange, H.S. Lenihan, J.S. Pandolfi, C.H. Peterson, R.S. Steneck, M.J. Tegner, and R.R. Warner. 2001. Historical overfishing and the recent collapse of coastal ecosystems. *Science* 293: 629-638.

Kinsey, D.W. 1988. Coral reef system response to some natural and anthropogenic stresses. *Galaxea* 7: 113-128.

Kramer, P. 2003. Synthesis of coral reef health indicators for the western Atlantic: results of the AGRRA program (1997 – 2000). in J.C. Lang (ed.), *Status of Coral Reefs in the western Atlantic: Results of initial Surveys, Atlantic and Gulf Rapid Assessment (AGRRA) Program*. Atoll Research Bull. 496.

Larcombe, P., and Woolfe, K. 1999. Increased sediment supply to the Great Barrier Reef will not increase sediment accumulation at most coral reefs. *Coral Reefs* 18: 163-169.

Mora, C. 2008. A clear human footprint in the coral reefs of the Caribbean. *Proceedings of the Royal Society B*. doi:10.1098/rspb.2007.1472 (published online).

Mumby, P.J., C.P. Dahlgren, A.R. Harborne, C.V. Kappel, F. Micheli, D.R. Brumbaugh, K.E. Holmes, J.M. Mendes, K. Broad, J.N. Sanchirico, K. Buch, S. Box, R.W. Stoffle, and A.B. Gill. 2006. Fishing, trophic cascades, and the process of grazing on coral reefs. *Science* 311: 98-101.

Mumby P. J., Harborne A. R., Williams J, Kappel C. V., Brumbaugh D. R., Micheli F, Holmes K. E., Dahlgren C. P., Paris C. B., Blackwell P. G. (2007) Trophic cascade facilitates coral recruitment in a marine reserve. *Proc Natl Acad Sci USA* 104: 8362-8367

Myers, R., Baum, J., Shepherd, T., Powers, S. and Peterson, C. 2007. Cascading Effects of the Loss of Apex Predatory Sharks from a Coastal Ocean. *Science* 315: 1846-1850.

Orr, J. et al. 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature* 437 (29): 681-686.

- O'Farrell, S., Day, O., 2006. Report on the 2005 mass coral bleaching event in Tobago, Part 1: Results from Phase 1 Survey. Coral Cay Conservation and the Buccoo Reef Trust. 41 pp.
- Riegl, B. and Branch, G. 1995. Effects of sediment on the energy budgets of four scleractinian (Bourne 1900) and five alcyonacean (Lamouroux 1816) corals. *Journal of Experimental Marine Biology and Ecology* 186: 259-275.
- Royal Society. 2005. Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide. The Royal Society, London, UK [<http://www.royalsoc.ac.uk/displaypagedoc.asp?id513539> accessed 19 July, 2008].
- Sheppard, C.R.C., Harris, A. and Sheppard, A.L.S. 2008. Archipelago-wide coral recovery patterns since 1998 in the Chagos Archipelago, central Indian Ocean. *Marine Ecology Progress Series* **362**: 109-117.
- Smith, G., Ives, L., Nagelkerken, I and Ritchie, k. 1996. Aspergilliosis associated with Caribbean sea fan mortalities. *Nature* 382:487
- Steneck, RS, Mumby P, and Arnold S. 2008. A Report on the Status of the Coral Reefs of Bonaire in 2007 with Results from Monitoring 2003 – 2007. Unpublished report to the Bonaire National Marine Park (STINAPA Bonaire). 94 pp.
<http://www.stinapa.org/pdfs/Bonaire-Report-2007-Bob-Steneck-etc.pdf>
- Webster, P., Holland G., Curry, A., Chang, H. 2005. Changes in tropical cyclone number, duration, and intensity in a warming environment. *Science* 309: 1844-1846.
- Wilkinson, C., Souter, D. 2008. Status of Caribbean coral reefs after bleaching and hurricanes in 2005. Global Coral Reef Monitoring Network, and Reef and Rainforest Research Centre, Townsville, 152 p.
- Williams, I. D., and Polunin, N. V. C. 2001. Large-scale associations between macroalgal cover and grazer biomass on mid-depth reefs in the Caribbean. *Coral Reefs* 19: 358 – 366.
- Willis, B., 2006. Surveying Coral Disease. School of Marine Biology and Aquaculture, James Cook University
- Winter, A., Appeldoorn, R., Bruckner, A., Williams, E. and Goenaga, C. 1998. Sea surface temperatures and coral reef bleaching off La Parguera, Puerto Rico. *Coral Reefs* 17: 377-382
- Wolanski, E., Richmond, R., McCook, L. and Sweatman, H. 2003. Mud, marine snow, and coral reefs. *American Scientist* 91: 44-51.
- Voss, J., Richardson, L. 2006. Nutrient enrichment enhances black band disease progression in corals. *Coral Reefs* 25: 569–576

Appendix: TCEMP target species

BENTHIC CATEGORIES

19-Jun-07

		Lifeform	Species			Lifeform	Species			Lifeform	Species
SUBSTRATES				SESSILE INVERTEBRATES				HARD CORALS cont.			
Rock	>15cm diameter	1		<i>Porifera</i> (Sponges)				Smooth Star	<i>S bournoni</i>	28	67
Sand	<0.5cm diameter	2		Encrusting		14	30	Knobby Star	<i>S hyades</i>	28	68
Silt/Clay	clouds when wafted	3		Barrel		14	31				
Rubble	0.5 to 15cm diameter	5		Vase		14	32	Elliptical Star	<i>D stokesi</i>	42	69
Recently Killed Coral		4		Tube		14	33	Golfball	<i>F fragum</i>	42	70
Other Animal *		6		Branching		14	34				
				Ball		14	35	Mustard Hill	<i>P pastreoides</i>	29	71
				Rope		14	36				
MICRO-ALGAE				Lumpy		14	37	Lesser Starlet	<i>S radians</i>	30	72
Cyano-Bacteria: Blue-Green		7		Red Boring Sponge		14	38	Massive Starlet	<i>S siderea</i>	30	73
				Coral Encrusting Sponge		14	39				
MACRO-ALGAE								Knobby Brain	<i>D clivosa</i>	31	74
<i>Chlorophyta</i> : Green								Symmetrical Brain	<i>D strigosa</i>	31	75
Green Filamentous		8	1	<i>Cnidarians</i>				Grooved Brain	<i>D labyrinthiformis</i>	31	76
<i>Acetabularia</i>		8	2	Zoanthid		15	40	Maze	<i>M meandrites</i>	31	77
<i>Avrainvillea</i> spp.		8	3	Hydroid		15	41	Rose	<i>M areolata</i>	31	78
<i>Caulerpa</i> spp.		8	4	Corallimorph		15	42	Boulder Brain	<i>C natans</i>	31	79
<i>Halimeda</i> spp.		8	5	Encrusting Gorgonian		15	43				
<i>Codium</i> spp.		8	6					Sunray Lettuce	<i>H cucullata</i>	32	80
<i>Neomeris</i> spp.		8	7	<i>Tunicates</i>		16					
<i>Udotea</i> spp.		8	8					Lettuce	<i>A agaricites</i>	33	81
<i>Ulva</i> spp.		8	9	<i>Bryozoans</i>		17		Thin Leaf Lettuce	<i>A tenuifolia</i>	33	82
								Low Relief Lettuce	<i>A humilis</i>	33	91
<i>Phaeophyta</i> : Brown				HARD CORALS				Other Lettuce	<i>Agaricia</i> spp.	33	83
<i>Dictyota</i> sp.		9	11	Lace	<i>S roseus</i>	18					
<i>Padina</i> sp.		9	12					Ridged Cactus	<i>M lamarckiana</i>	34	84
<i>Lobophora</i> sp.		9	13	Fire spp.	<i>Millepora</i> spp.	19		Knobby Cactus	<i>M aliciae</i>	34	85
<i>Stypopodium zonale</i>		9	14					Rough Cactus	<i>M ferox</i>	34	86
<i>Turbinaria</i> sp.		9	15	Staghorn	<i>A cervicornis</i>	20	50				
<i>Sargassum</i> sp.		9	17	Fused Staghorn	<i>A prolifera</i>	20	51				
				Elkhorn	<i>A palmata</i>	20	52	Rough Star	<i>I rigida</i>	41	93
<i>Rhodophyta</i> : Red											
Encrusting Coralline Algae		10	18	Thin Finger	<i>P divaricata</i>	21	53	Spiny Flower	<i>M angulosa</i>	35	87
<i>Galaxaura</i> sp.		10	19	Branched Finger	<i>P furcata</i>	21	54				
<i>Amphiroa</i> sp.		10	20	Clubtip Finger	<i>P porites</i>	21	55	Smooth Flower	<i>E fastigiata</i>	36	88
<i>Jania</i> sp.		10	21					Orange Cup	<i>T coccinea</i>	37	89
Red Filamentous		10	22	Pillar	<i>D cylindrus</i>	22					
Sheet		10	23					Misc Cup Corals		40	92
<i>Wrangelia penicillata</i>		10	24	Diffuse Ivory Bush	<i>O diffusa</i>	23					
<i>Laurencia</i> spp.		10	25					Scolymia spp.		38	90
<i>Liagora</i> spp.		10	26	Yellow Pencil	<i>M mirabilis</i>	24	58				
				Eight-Ray Finger	<i>M formosa</i>	24	59				
Other Macro Algae *		11		Ten-Ray Star	<i>M decactis</i>	24	60	Other Live Hard Coral *		39	
MARINE PLANTS				Blushing Star	<i>S intersepta</i>	25					
Seagrass											
Turtle		12	28	Boulder Star Complex		26	62				
Manatee		12	29	Lobed Star	<i>M annularis</i>	26	63				
Halophila		12	30	Mountainous Star	<i>M faveolata</i>	26	64				
				Boulder Star	<i>M franksi</i>	26	65				
Mangroves		13									
				Great Star	<i>M cavernosa</i>	27					

* If substrate, algae or coral falls into 'other' category please justify with a description or an identification in notes.

Demersal Fish Species				18-Jun-07			
<u>BUTTERFLY</u>	1	<u>HAMLETS</u>	25	<u>SQUIRRELFISH</u>	50	<u>BOXFISH</u>	75
Spotfin	2	Barred	26	<u>BIG EYES</u>	51	Cowfish	76
Foureye	3	Indigo	27	<u>CARDINALFISH</u>	52	Trunkfish	77
Banded	4	Yellowbelly	28	<u>GOBIES</u>	53		
Reef	5	Shy	29	<u>BLENNIES</u>	54	<u>TRIGGERFISH</u>	78
Longsnout	6	Black	30	<u>JAWFISH</u>	55	Queen	79
		Butter	31	<u>FLOUNDER</u>	56	Black Durgon	80
<u>ANGEL</u>	7	Yellowtail	32	<u>BATFISH</u>	57		
Rock Beauty	8	Golden	216	<u>TOADFISH</u>	58	<u>FILEFISH</u>	81
Queen	9			<u>SCORPIONFISH</u>	59	Scrawled	82
French	10	<u>BASS</u>	33	<u>FROGFISH</u>	60	Orangespotted	83
Gray	11	Harlequin	34	<u>FLYING GURNARD</u>	61	Whitespotted	84
Cherubfish	12	Tobacco	35	<u>LIZARDFISH</u>	62		
		Fairy Basslet	36	<u>SEAHORSE</u>	65	<u>GOATFISH</u>	85
<u>SURGEON</u>	13	Blackcap	37	<u>PIPEFISH</u>	66	Spotted	86
Ocean	14	Greater Soapfish	38	<u>HAWKFISH</u>	67	Yellow	87
Doctor	15	Creolefish	39	<u>TRUMPETFISH</u>	68		
Blue Tang	16			<u>CORNETFISH</u>	69	<u>DRUM</u>	88
		<u>WRASSE (TP only)</u>	40	<u>TILEFISH</u>	70	Spotted	89
<u>DAMSELFISH</u>	17	Spanish Hogfish	41			Highhat	90
Yellowtail	18	Puddingwife (also IP)	42	<u>PUFFER</u>	71		
Bicolour	19	Creole (also IP)	43	Bandtail	72	<u>SWEEPERS</u>	91
Sergeant Major	20	Yellowhead	44	Sharpnose	73		
Night Sergeant	21	Slippery Dick	45			<u>EELS</u>	92
Blue Chromis	22	Blue Head	46	<u>PORCUPINEFISH</u>	74	Moray	93
Brown Chromis	23	Clown	47			Conger	94
Sunshine Fish	24	Blackear	48			Garden	95
		Rosy Razorfish	49			Snake	96

Commercial and Pelagic Fish				Target Invertebrates		18-Jun-07	
<u>MISC SILVERY</u>		97	<u>GROUPE</u>	141	<u>ANNELIDS</u>		<u>ECHINODERMS</u>
Needlefish	105	Goliath / Jewfish	142	Lugworm	169	Feather Star	194
Barracuda spp.	106	Nassau	143	Xmas Tree Worm	170	Sea Star	195
Boga	107	Comb	144	Feather Duster Worm	171	Brittle Star	196
Bonefish	108	Black	145	Spaghetti Worm	172	West Indian Sea Egg	197
White Mullet	109	Yellowfin	146	Fireworm	173	Long Spined Urchin	
Saucereye Porgy	110	Yellowmouth	147			Adult	199
Mojarra spp.	111	Tiger	148	<u>ARTHROPODS</u>		Juvenile	200
Tarpon	112	Marbled	149	Spiny Lobster	175	Pencil Urchin	201
Chub	113	Red Hind	150	Slipper Lobster	176	Sea Cucumber	202
Spadefish	114	Rock Hind	151	Banded Coral Shrimp	230		
		Graysby	152	True Shrimp	177	<u>FLATWORMS</u> 203	
		Coney	153	Mantis Shrimp	178		
<u>MACKERELS</u>				Hermit Crab	184	<u>CNIDARIANS</u>	
Cero	101	<u>WRASSE</u>		Porcelain Crab	180	Jellyfish	204
Spanish Mackerel	102	Hogfish (all phases)	154	Spider Crab	179	Anemone (Sea)	214
King Mackerel	103			Batwing Coral Crab	182	Anemone (Tube)	215
Little Tunny	104	<u>JACKS</u>	155	Yellowline Arrow Crab	183		
		Bar	156	Other Crab	181	<u>OCTOCORALS</u>	
<u>GRUNTS (adults)</u>	116	Horse-eye	157			Common Seafan	205
Bluestriped	117	Yellow	158	<u>MOLLUSCS</u>		Deepwater Seafan	206
Spanish	118	Permit	98	Queen Conch	185	Rod	207
Smallmouth	119	Palometa	99	Triton Trumpet	186	Plume	208
Striped	120	Scad spp.	100	Bivalve	187	Red Sea Whip	209
White	121	Blue Runner	115	Cowrie	188	Flat Sea Whip	210
Ceasar	122			Seahare	189	Corky Sea Finger	211
Cottonwick	123	<u>PARROT (TP + IP)</u>	159	Nudibranch	190		
French	124	Queen TP	160	Sea Slug	228	<u>BLACK CORALS</u>	
Tomtate	125	Rainbow TP	161	Flamingo Tongue	191	Black Coral Bushy	212
Margate	126	Princess TP	162	Octopus	192	Black Coral Wire	213
Black Margate	127	Blue TP	163	Squid	193		
Porkfish	128	Striped TP	164	Other Snail	229		
Latin	129	Midnight TP	165				
Black	130	Stoplight TP	166				
Corocoro	131	Redband TP	167				
		Yellowtail TP	168				
<u>SNAPPER</u>		132	Redtail TP	169			
Schoolmaster	133	Queen IP	218				
Mahogany	134	Rainbow IP	219				
Dog	135	Princess IP	220				
Gray	136	Blue IP	221				
Mutton	137	Striped IP	222				
Lane	138	Midnight IP	223				
Yellowtail	139	Stoplight IP	224				
Cubera	140	Redband IP	225				
		Yellowtail IP	226				
		Redtail IP	227				