A Rapid Ecological Assessment (REA) of Coral Reefs and Reef Fishes of Barrier Islands within Central Belize Barrier Reef Complex utilizing the Mesoamerican Barrier Reef Systems (MBRS) Protocol

by

Gianna M. Gómez

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Corvallis, Oregon 97331

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ABSTRACT

Rapid assessments are essential to establish baseline information of ecosystems that can be used to design management plans such as marine protected areas. A rapid ecological assessment was conducted to determine the conditions of coral reefs and reef fish around barrier islands that occur within the central Belize Barrier Reef Complex. The reefs adjacent to these barrier islands are very important for commercial and artisinal fishing. Both cruise-ship tourism and the export of marine products from these areas are increasing rapidly.

Utilizing the Mesoamerican Barrier Reef Systems Protocol for assessing coral and reef fish assemblages, underwater surveys were conducted within the shallow, back-reef region of these barrier islands during the summer of 2003. These surveys revealed reefs with an overall low mean percent coral cover (<20%), mainly composed of the most robust coral species: *M. annularis*, and *P. astreoides*. The reefs at three cays displayed recent incidence of coral mortality. Coral bleaching was substantial at all reefs except at Rendezvous Cay, and diseases affected corals at Goff's Cay and Sergeant Cay. Adult reef fish populations were of a low density (<60/100m^2), composed mainly of herbivores (*Scaridae* & *Acanthuridae*) than carnivores. Goff's Cay and Rendezvous Cay were identified as priority sites for preserving coral health and productivity. Cay Chapel and Gallow's Point were identified as critical areas that have been degraded due to observed anthropogenic impacts, which have altered their ecosystems. Management incentives need to focus on protecting the valuable and vulnerable ecosystems of these impacted islands to promote the protection, restoration and sustainable use of barrier island resources and enhance their significance to the fishing and tourism industries.

Keywords: Mesoamerican Barrier Reef Systems Protocol, species richness, reef fish populations, coral bleaching, coral mortality, diversity, barrier islands.

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INTRODUCTION

The Mesoamerican Barrier Reef Systems (MBRS) span approximately 1,000 km of marine ecosystems including coral reefs, seagrass beds, mangroves, coastal lagoons and rivers within Mexico, Belize, Guatemala and Honduras. It includes the largest barrier reef in the Western Hemisphere, the Belize Barrier Reef Complex, which spans approximately 250 km parallel to the coast of Belize. To enhance the protection of these unique and vulnerable marine ecosystems, the MBRS Project was designed to promote the sustainable use of resources within the MBRS.

A protocol was designed to support the objective of the MBRS Project, which is to enhance the protection of marine ecosystems within Mesoamerica. It was used to establish the conditions of coral reefs and reef fish populations of barrier islands within the central Belize Barrier Reef Complex. Five islands were chosen to be included in a rapid ecological assessment (REA) to address resource managers and stakeholders' concerns about ecosystem degradation. These islands included: Cay Chapel, Gallow's Point, Sergeant Cay, Goff's Cay and Rendezvous Cay. Each island is not within any protected areas management system and is subject to varying degrees of use and anthropogenic impacts.

The protocol allowed for biological measures that were then used to assess the ecosystem structure and composition of coral reefs around these barrier islands. This ensured that a REA was practicable within the scope of the MBRS protocol. The assessment of coral health was based on the status of coral bleaching, coral mortality and incidence of diseases. A profile of benthic cover was assessed to help describe coral reef community structure. Assessments of reef fish populations and the long-spined sea urchin (*Diadema antillarum*) was important to establish the composition and productivity of the coral reefs of these barrier islands.

Therefore, the REA was used to estimate conditions of coral reefs with immediate anthropogenic impacts, where direct observations were used to classify potential anthropogenic impacts to each island. This was linked to the assessed conditions and productivity of coral reefs to identify priority and critical areas at which to focus management incentives.

A commitment to utilizing the MBRS protocol for monitoring will enhance data-sharing and establish ecological trends within the Belize Barrier Reef Complex, a major component of the MBRS Project. It will facilitate the process of assessing the benefits and effectiveness to our MPA system. It will also provide a vital tool with which to conduct REAs of ecosystems subject to impacts from anthropogenic and natural disturbances. In all, it will help determine if management strategies are conserving and sustaining the resources provided by our marine and coastal ecosystems.

Studies have shown that the Belize Barrier Reef Complex supports the majority of species within the MBRS in terms of reef fish (80%) and corals (>90%) (Almada-Villela, 2002; Kramer & Kramer, 2002; Gibson & Carter, 2003). The Belize Coastal Zone Management Program and the Government of Belize promote the sustainability of the barrier reef by protecting about 13.4% of its coastal waters, of which 1.3% is under full protection as 11 grouper spawning aggregation sites (Appendix A).

Back-reef sites are defined as obvious shallow zones which lie between the reef crest and a lagoon or cay (Mumby and Harborne, 1999). These sites are easily accessible due to their close proximity to barrier islands and the commercial capitol of Belize. With the shipping channel in front of English Cay and developments of marinas to support the cruise ship industry, these islands are being targeted as tourist destinations, especially Goff's Cay and Rendezvous Cay. As a corollary, tourism is currently the largest foreign exchange earner in Belize. A projected one million cruise ship passengers are expected by the end of 2004 (Salas, 2003). Cruise ship arrivals in February 2004 constituted an 81.7% increase over that of February 2003 (BZ Tourism Board, 2004).

The majority of Belize's foreign exchange earnings thus rely heavily on the health and productivity of the barrier reef. The fishing industry is the third largest foreign exchange earner in Belize (BZ Fisheries Department, 2002), earning US$35 Million in foreign exchange for the year 2000 (Almada-Villela, 2002). Fishing zones associated with reef formations have also been defined under the Belize Fisheries Department to facilitate monitoring and enforcement of fishing regulations (Appendix B). Coral reefs are very important to support artisinal fishing and the commercial fishing industry, functioning as very productive grounds for numerous species of lobster, conch and finfish (CZMAI, 1999). However, enforcement of fishing regulations is done only on an ad hoc basis, unless within a MPA, where regulations are enforced daily.

The five barrier islands within the REA occur within the Fishery Area 5, an area of approximately 662 km^2, supporting about 300 fishermen (Appendix B). It is a very productive region, especially for the Caribbean spiny lobster (*Panularis argus*), finfish (*Lutjanidae* and *Serranidae*), and the Queen conch (*Strombus gigas*). This area contributed 30% of the annual conch fishery of Belize in 2002, but catch was reduced by 28% from the previous year. In 2002, Area 5 contributed 38.78% of the lobster and 32.25% of the conch fisheries of Belize (BZ Fisheries Department, 2003). Besides tourism and fishing, the use of the English Channel has increased shipping activities and the potential for oil spills and oil contamination associated with oil storage and tankers that utilize these navigable waters. Other anthropogenic threats to this region include: wastewater discharge and industrial effluent, agricultural runoff, ship groundings, dredging of channels and beaches, and habitat destruction from expanding urbanization (Kramer and Kramer, 2002). These threats can alter marine benthic habitats that are found within the shallow-waters of Belize (Appendix C). Increased levels of turbidity as influenced from coastal runoffs, sedimentation and dredging can smother corals resulting in coral bleaching or even mortality.

There are natural impacts to these systems as well, in the form of hurricanes and coral bleaching events. Aronson et al. (2000) reported that high sea surface temperatures (SST) during the 1997-1998 *El Niño* induced mass mortality of scleractinian corals on lagoonal reefs in Belize. Hurricanes and bleaching events have initiated recognized coral mortality, coral bleaching and the incidence of diseases upon corals (McField, 1999; Mumby, 1999, Aronson 2002).

Shallow-water back-reef systems have supported high biodiversity and species richness, especially in terms of reef fish populations (Kramer et al., 2000). Therefore, in order to establish baseline information on the conditions of these systems, a REA was conducted to assess the current status of these barrier island reefs. This information will be used to support management decisions that will contribute to the sustainable use and conservation of these barrier islands for Belize, Mesoamerica and the World.

BACKGROUND

CORAL REEF DISTRIBUTION

Shallow living coral reefs currently comprise over 600,000 km^2 of our oceans (Smith, 1978). The limitations on the distribution of coral reefs restrict them to clear, shallow, tropical and subtropical waters, giving them unique characteristics in community structure (McField et al., 2001) and high value in biodiversity and productivity (DeVantier et al., 1998; Done, 1995). Many factors limit the distribution of these natural systems. Hermatypic or reef building corals tolerate a narrow range of environmental conditions, and are limited to oligotrophic tropical waters between 30°N and 30°S. Corals are most predominant within a temperature range of 25°–29°C (Salm, 2000), but have a tolerance limit between 18°C and 36°C. Even a slight increase in SST may have a drastic impact on coral vitality and distribution because the majority of corals live at temperatures that approach the upper thermal limits of viability (Hubbard, 1997). Increased water temperature is associated with episodes when the photosynthetic, symbiotic algae, zooxanthellae that live within the coral polyp, are expelled from the coral polyp causing the discoloration of coral pigmentation or 'bleaching'. Mass coral bleaching events have been correlated to high SST as during *El Niño* events (Liu et al., 2003; Aronson et al. 2002; Reaser et al. 2000).

A second factor that determines hermatypic coral distribution is light availability. Although corals occur in nutrient-poor waters, they are some of the most productive ecosystems in the world (Bryant et al., 1998). This is a corollary of the highly efficient internal nutrient cycling and recycling that occurs within the coral polyp's tissue. Zooxanthellae translocate carbon to the host polyp in the form of amino acids, sugars, complex carbohydrates and small peptides in exchange for protection and a source of essential limiting plant nutrients such as ammonia and phosphorus that are excreted by the coral polyp via waste metabolism (Trench, 1979). The coral uses the translocated carbon in light-enhanced calcification of reef structure (Muller-Parker & D'Elia, 1997). Because of light dependency, hermatypic corals are restricted to clear, shallow waters with depths of no more than 100 meters (Viles and Spencer, 1995). For these reasons, fore-reef coral species that are in deeper waters are distinct from shallow back-reef corals because of their adaptation and tolerance to light attenuation. Salinity also limits the distribution and vitality of corals. Reefs are restricted to a salinity range of 33 to 36 parts per thousand (ppt).

Finally, the characteristics of reef building corals have been linked to their exposure to wave energy. Reef zonation patterns result in part from the interaction of currents and wave intensity (Adey & Burke, 1977 and Geister, 1977). According to McField (2001), atoll reefs located in the open ocean are characterized by the physically robust *Montastraea annularis* and *Porifera* coral species; while back reefs have the more fragile *Agaricia tenuifolia*.

CORAL REEF ECOLOGY & COMMUNITY STRUCTURE

Coral reefs are some of the most productive ecosystems based on high marine biodiversity and species richness (Bryant et al. 1998). Most corals live in immense colonies, harvesting nourishment and energy from their symbiotic algae. Corals grow by generating limestone skeletons. Over hundreds of years, the limestone accumulates to form the framework and support the structure of a coral reef. Other marine animals and plants settle, attach and burrow into the structure, creating a diverse and dynamic ecological community.

Coral reefs provide habitats for a large variety of organisms. The organisms that use corals through mutualism, commensalism and parasitism come from a variety of taxonomic groups, including *Porifera*, *Polychaeta*, *Gastropoda*, *Crustacea*, *Echinodermata* and *Pisces*. Sponges (*Porifera*) inhabit crevices in the reef where they seek refuge from predators. Boring sponges, such as *Cliona*, remove small chips of calcium carbonate from corals as they establish themselves and cause bioerosion of the coral. Polychaetes such as *Hermodice carunculata* and *Gastropods* in the family *Trochidae* depend on corals for food. They feed on corals such as *Porites* and *Agaricia*. *Decapod* crustaceans such as shrimps and crabs depend on corals for shelter. *Xantid* crabs form cavities in the coral *Acropora palmata*. Fish such as the squirrelfish (*Holocentridae*) depend on corals for protection against predators. *Echinoderms* such as *Acanthaster planci* feed on corals. There are many other species of fungi, sponges, polychaetes, crustaceans and mollusks that bore into coral skeletons. Other organisms that inhabit coral reefs include sea urchins, jellyfish, oysters, clams, sea anemones and sea turtles.

Community dynamics within coral reefs depend on reef species and habitat types. Coral reefs support plant forms such as algae. More than half of the plant growth on coral reefs is of macroalgae such as *Dictyota, Lobophora,* and *Sargassum*. A keystone species, the long-spined sea urchin (*Diadema antillarum*) grazes on the macroalgae promoting the continued recruitment of corals and keeps the macroalgae growth in check from smothering corals. With limited urchin densities, fast-growing macroalgae can proliferate to support huge and diverse populations of herbivorous reef fish families *Acanthuridae* (Surgeonfish), *Scaridae* (Parrotfish), *Pomacanthidae* (Angelfish), *Chaetodontidae* (Butterflyfish), and *Pomacentrids* (Damselfishes). The presence of these herbivores attracts other carnivorous reef fish species such as *Serranidae* (Groupers), *Lutjanidae* (Snappers) and *Haemulidae* (Grunts) to the coral reef community.

The coral reef ecosystem has demonstrated shifts in equilibrium states (Jennings et al., 2001; McClanahan, 1995). Figure 1 shows some of the processes that can cause these shifts. Changes in the community structure and composition of coral reefs may be reflected by the feeding behaviour of herbivores (McClanahan et al., 2000) and other interspecific species interactions. The interactions of these species through predation and competition combined with fishing may produce complex responses to ecological changes in structure and function. For instance, the increase in late successional macroalgae may increase the structural refuge for small invertebrates, which could increase invertebrate-feeding fishes if the fishing pressure is mild.

This change may limit the proliferation of benthic types such as turf algae, which are more favorable to herbivores.

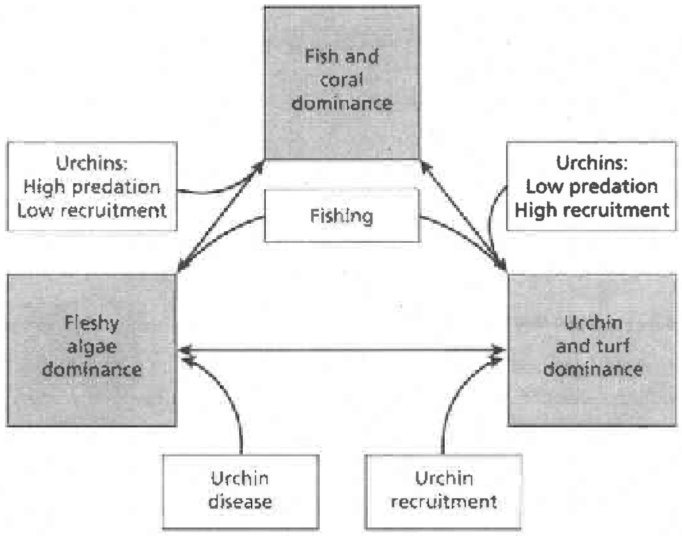

Figure 1. A conceptual model of the coral reef ecosystem. The model indicates those processes that cause shifts between three equilibrium states (shaded) and which have been demonstrated by simulation and empirical studies. After McClanahan (1995).

CORAL REEF ECOSYSTEM SERVICES & FUNCTIONS

On a more regional scale, coral reefs have evolved to form lagoons and calm shorelines where seagrass beds and mangroves can flourish, providing habitats for numerous species at the interface of the land and sea (Bryant et al., 1998). They support and protect these coastal habitats which are also very productive nursery grounds for commercial fish and invertebrate species (Birkleland, 1997; Richmond, 1993). Reef dwellers that are bioeroders provide valuable functional services in sand replenishment. Coral reefs also protect coastlines from erosion and floods during storm events as they dissipate wave actions. Their loss removes protection from ocean waves and storms, exposes shorelines to increased tidal action, and facilitates coastal erosion and degradation.

Worldwide, reefs may contribute goods and services at a value of $375 billion each year (Costanza et al., 1997). Two-thirds of reef systems are in developing countries, with one quarter in developed countries (Whittingham et al. 2003). Although reefs cover less than 0.2% of the ocean's area, they contain 25% of marine fish species (Roberts et al., 1998). Reefs and the flora and fauna they support provide the primary source of dietary protein and livelihood for ten of millions of people in tropical coastal areas of developing nations (Salvat, 1992). The fisheries of coral reefs yield at least 6 million metric tons of fish catches around the world annually, excluding local subsistence fisheries (Munro, 1996). This accounts for one-quarter of the fish catch in developing countries and employment to millions of fishers (Robert et al., 1998).

Nature-based tourism has benefited from the substantial income derived from coral reef ecosystems. People from all over the world travels to reefs to fish, explore and indulge in the wonders of the reef while snorkeling or diving. Within the Caribbean alone, coral reefs provide 60% of the world's scuba-diving tours to about 20 million people every year (Whittingham et al. 2003).

Coral reef resources also have biomedical applications. For instance, the skeleton of *Porites astreoides* has been successfully used since 1995 in orthopedic human surgery as bone replacement material (Bouchon et al., 1995). There is the anti-AIDS drug (AZT) that is based on chemicals from a Caribbean reef sponge. It is now estimated that over half of all new cancer drug research focuses on marine organisms (CBD, 2003). *A. palmata* has important medical properties where initial analysis suggests it could be used as an alternative xenograft for such bone reconstruction (CBD, 2003).

Coral reefs are now considered environmental indicators of global warming due to their vulnerability to high SST on a world-wide scale (IPCC, 1998). Continuous monitoring of impacts to coral reef ecosystems will enhance correlations to global warming. Compounded with the rapid growth in coastal populations and developments, the degradation of reefs is on the increase with many adverse synergistic effects.

IMPACTS TO CORAL REEF ECOSYSTEMS

Factors that affect the health, distribution and biodiversity of coral reef ecosystems are due to natural or anthropogenic disturbances, imposing stress to corals. "Stress" is a physiological response to conditions in the environment that upset the homeostasis of an organism and can be either acute or chronic. Stress can be measured in corals by decreased growth rates, metabolic differences and biochemical changes (Richmond, 1993 and Sebens, 1994). The ability of corals to fight diseases can be compromised by stress. A "disturbance" is a localized ecological phenomenon that includes acute alterations from natural conditions that may result in shifts within the ecosystem. Thus, disturbances can cause stress to corals, altering reef ecosystems. However, most consequences of stress and disturbances have resulted in induced bleaching events, coral mortality and the onset of diseases.

There are many impacts to coral reefs. For instance, storm events can cause natural, physical disturbance. When storm frequency accelerates to every two years, a steady decline in the abundance of coral colonies can occur (Lirman, 2003). Corals can also be stressed by outbreaks of sea urchins, macroalgae or the crown-of-thorns starfish. In the Caribbean, low coral cover has been linked to the die-offs of the long-spined sea urchin (*Diadema antillarum*) during 1983-1984, stimulating the 80-90% dominance of macroalgae (River & Edmunds, 2001; Edmunds & Carpenter, 2001). These systems are characterized as 'impacted' or 'unhealthy' and can contribute to a phase shift in the community structure of coral reefs (McField et al., 2001).

Although *Diadema* seems to be recovering in the Caribbean (Edmunds & Carpenter, 2001), some populations are still well below 1% of their pre-1983 levels (Turgeon et al., 2002). Other shifts in coral composition are actively occurring where more robust species of corals can replace less stress tolerant species (Done, 1999). Aronson (1998) describes this kind of shift within the Belize Barrier Reef Complex.

The most prominent impacts to coral reefs are anthropogenic. Overfishing of commercially important reef fish stocks has altered reef ecosystems (Jennings & Polunin, 1997, Connell & Gillanders, 1997). The loss of large herbivores and predatory fishes due to overfishing has stimulated the proliferation of small herbivorous fish such as the damselfish, thereby multiplying their damaging effect on reefs (Causey et al. 2002, Bruckner, 2002, McClanahan et al., 2001). Declining fish stocks from overfishing can stimulate macroalgae growth that dominates coral reefs and prevents settlement of coral larvae (Scheffer et al. 2001). In the Caribbean, overfishing of the Caribbean spiny lobster (*Panularis argus*) has induced a population explosion of its prey, a coral-eating mollusk that particularly feeds on the *Acropora* species (Causey et al., 2002).

Coral reefs are threatened by pollutants from land runoff, oil spills and sewage that induce eutrophication in shallow, coastal waters. Nutrient overloads allow macroalgal dominance that can suffocate corals (Scheffer et al. 2001), or infect corals with diseases. Some of the most destructive chronic human factors causing significant localized damage to shallow-water coral reefs are induced by groundings and anchor damage (Turgeon et al. 2002). Coral reef damage associated with ship groundings includes the direct loss of corals and other benthic invertebrates when they are dislodged, fractured, and crushed. Additionally, coastal development, boat and diver damage, siltation, and damaging fishing practices affect corals. The continuous dredging of harbors and lagoons for shipping and ports has enhanced sedimentation and turbidity in coastal waters that bury and smother corals. Dredging-related activities have been rated as the highest level of concern by reef managers in every US Atlantic-Caribbean jurisdiction (Turgeon et al. 2002).

Declines in Caribbean coral reefs have been attributed to coral diseases (Aronson et al., 1998) such as white-band disease (WBD)[1], mass coral bleaching (McField, 1999) induced by rising SST (Williams, 2000; Aronson et al., 2000; Liu et al., 2003), *El Niño* events (Aronson et al., 2002) and hurricanes (Mumby, 1999; Lirman, 2003). Corals may have a chance for survival after bleaching if conditions become favorable. However, corals require at least four to five years to fully recover their zooxanthellae, and bleaching episodes are now occurring at least every two to three years. Within this period of recovery, corals can be more susceptible to diseases and mortality (Williams 2000).

On a global scale, climate change is increasing the trends of high SST especially within the tropics and consequently increasing the frequency of warming events such as *El Niño* and storms. Global warming is expected to cause hotspots[2] to become more frequent, more intense and more widespread. Simulation studies have shown that CO_2-induced global warming of about 2°C results in increased surface wind intensities by 3-10%, thus increasing storm intensity by 20% (Knutson et al., 2001; Walsh & Ryan, 2000) with adverse impact on coral reefs. As a result, bleaching mortality is likely to become more severe unless corals are capable of physiological acclimatization to higher temperatures (Goreau et al., 2000). The rising level of atmospheric carbon dioxide (CO_2) has been linked to reduced calcium carbonate ($CaCO_3$)

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[1] White-band disease (WBD) is a type of necrosis (tissue death) of uncertain pathogenic origin causing extensive white bands and patches on corals (Gladfelter, 1982).
[2] Hotspots are defined as regions where sea surface temperatures equal or exceed the annual monthly maximum climatological value by 1 °C (Goreau et al, 2000).

deposition in coralline algae and reef building corals. A predicted doubling in the level of atmospheric CO_2 by the year 2100 may result in a 10-20% reduction in coral reef calcification (Kleypas et al. 1999; Pennisi, 1997). The call to reverse global warming and reduce green-house gases into the atmosphere is important to reduce the potential increase in frequency of natural disturbances to coral reefs.

CORAL REEF MANAGEMENT

The world-wide mass coral bleaching and mortality event of 1998 had measurable effects. The reefs of three oceans were affected by severe bleaching, extending from the Arabian/Persian Gulf through the northern and central Indian Ocean, parts of Southeast Asia, the Great Barrier Reef of Australia, and far west Pacific to throughout the Caribbean Sea and Brazil in the Atlantic Ocean. This event alarmed coral reef scientists and managers about the possible extinction of some corals and the cumulative implications of their loss to coastal populations.

Consequently, current management incentives are urgently trying to improve conservation measures of coral reefs. It is with the growing awareness that the conservation and protection of coral reef ecosystems entails the sustainable use of the resources they provide. With growing coastal populations, the natural resources of barrier islands are overexploited, and human impacts have enhanced the adverse impacts of bleaching, mortality and incidence of diseases on coral reefs. The increasing awareness of the need to mitigate and minimize human impacts on coral reefs has resulted in an effort to determine effective management strategies. The use of public outreach to build awareness and marine protected areas (MPAs) to limit uses has long been successful tools implemented within the broader scope of Integrated Coastal Zone Management (ICZM) strategies.

Public outreach and community involvement play a key role in management strategies to inculcate the public with a sense of stewardship. This involves working with the public and stakeholders to enhance conservation values and sustainable use practices. Activities such as public forums and clean-up campaigns can stimulate public awareness of problems and appropriate behaviour to protect reefs. However, it is important to allow enough resources and time to promote behavioral change and evaluate effectiveness.

MPAs have the potential to preserve biodiversity (Bohnsack, 1996), and enhance biomass and species richness (Jennings et al., 1996; Roberts, 1995), as well as provide an environment to support increased public awareness, research and monitoring. While it is generally accepted that reserving certain areas of the ocean as networks of MPAs is the best management tool to enhance the conservation and sustainable use of marine ecosystems, the effectiveness of a MPA is highly dependent on its purpose and scope. The World Conservation Union (IUCN) has provided a broad classification scheme for applying different types of protected areas to suit management objectives.

MPAs are an essential management tool for marine resources on a small scale as well. To achieve fishery and conservation goals, a network of reserves can be established that would encompass a significant area with diverse habitats (Roberts, 1998). To ensure that these resources support a greater proportion of fishes, MPAs will have to be of an adequate size to protect the viable life history stages of essential reef fishes and there must be connectivity to increase the probability that the progeny of the protected species can recruit to another protected area (Jennings et al., 1996). This essential aspect of knowledge to designing MPAs requires the integration of sound science and effective monitoring and assessment strategies, supported by appropriate management incentives. Approaches to the development of management plans for

MPAs have evolved considerably. Major advances include innovative financing mechanisms, partnerships with the private sector and NGOs, and collaborative management between government and coastal communities (Salm et al., 2000).

Coupled with other global effects, MPAs may not be enough to provide adequate protection to all corals and other reef-associated species (Reaser et al., 2000). Given the increase in SST (Liu et al., 2003), storms (Lirman, 2003) and warming events (Aronson et al., 2002), more stringent management plans are being proposed to combat global warming. Also, there is great concern for the people who depend on coral reefs for their livelihoods and who live on low-lying islands. With these concerns comes the need for remediation strategies such as mechanisms to assist communities likely to be affected by global warming, sea level rise and potentially more damaging tropical storms, as well as global measures to reduce the release of greenhouse gasses.

CORAL REEF ASSESSMENT STRATEGIES

Every management strategy has to be supported by efficient monitoring and assessment programs. Most environmental monitoring programs have a goal to protect the environment, living resources and human health. Likewise, coral reef monitoring programs are most concerned with the detection of long term changes and trends and the documentation of the current status within coral reef ecosystems. This information is valuable to: (1) enhance the knowledge of these ecosystems; (2) provide coastal managers with a basis for setting use standards; (3) support effective management decisions and identify strategies; (4) establish a baseline for future comparisons; and (5) provide an early warning of future threats to be addressed and prevent other problems. Natural variability can limit our ability to assess coral reef ecosystems. Monitoring is limited in time and space, and since impacts occur at multiple spatial and temporal scales and interact with natural processes, characterizing change can be difficult.

Rapid ecological assessments provide a perspective on coral condition. They are most successful when used to address concerns such as the incidence of diseases, premature mortality and geographical extent of decline in health. REAs are used to make regional assessments such as that made for the Caribbean, where rapid declines of coral reefs have been documented with no significant recovery. In Florida, Jamaica, Belize, Curacao, and the US Virgin Islands, greater than 80% loss of coral reefs has occurred (Bruckner, 2002). However, limitations based on random sampling prohibit extrapolation to larger areas of that region or to similar ecosystems in different regions. In addition, trends cannot be established.

Barrier islands and their surrounding marine habitats that are susceptible to great anthropogenic impacts can be monitored and evaluated by a REA, thus providing localized information on changes in coral reef ecosystems. The regional and long-term implementation of the MBRS Project will allow ecological assessments to be made in an efficient manner. Local assessments can then be integrated into developing management plans for the use and conservation of larger areas.

Identifying ecological factors such as the presence/absence of predators, competitors and disease are important to identify damaged sites and their potential in recovery (Done, 1995). Visual assessments have been used to estimate conservative values of ecosystems based on indicators such as: 'habitat type and quality', 'degree of community structure', and 'biodiversity' (DeVantier, 1998). Continued monitoring and assessments can also determine and predict "strategic shifts" where one habitat type can replace another or "phase shifts" where one species can replace another species (Done, 1999).

A healthy coral reef ecosystem is characterized by many factors. Coral cover of 25-30% has been considered "good" for the Caribbean (Almada-Villela et al., 2002). Reefs that are less than 5% diseased and less than 10% bleached corals indicate levels of low threat to coral vitality. A reef with high macroalgae and low coral cover has been considered of 'low quality' and one of high coral cover and the absence of dead or injured corals reflects 'high quality' (DeVantier, 1998). The presence of rich reef fish populations and sea urchins are key indicators that shape the community structure of marine ecosystems. The types of reef fish, presence/abundance of invertebrates and percentage benthic cover can indicate high priority areas and shifts in ecosystem dynamics. Herbivorous reef fish and sea urchins instigate shifts in community structure (Edmunds & Carpenter, 2001) which subsequently alters the services and functions that these systems provide.

There is an urgency to understand the causes of diseases and their consequences on coral populations. Regional and global coral reef monitoring programs [MBRS, Reef Check, Caribbean Coastal Marine Productivity (CARICOMP), Atlantic and Gulf Rapid Reef Assessment (AGRRA)] are providing valuable information from reef assessment protocols to provide for a more global assessment of the status of coral reefs. Databases are being developed that link reef assessments with other oceanographic and climatological information using Geographic Information Systems (GIS) in order to improve our understanding of the correlation between global climate change and changes in reef structure.

The MBRS project is funded by the Global Environment Facility (GEF), of the World Bank, and the governments of participating countries (Mexico, Belize, Guatemala and

Honduras). It was declared effective since Nov. 2001. It is executed by the four countries and the Comisión Centro Americana de Ambiente y Desarrollo (CCAD) of the System for Central America Integration (SICA) with a Project Coordinating Unit (PCU) headquartered in Belize. The World Wildlife Fund (WWF) Mesoamerican Caribbean Reef Ecoregional Conservation Program has a significant complementary program. Other international non-governmental organizations (NGOs) involved include the Nature Conservancy (TNC), Wildlife Conservation Society (WCS), and the World Conservation Union (IUCN) as well as many local NGOs.

A significant component of the MBRS Project is the establishment of a regional environmental monitoring and information system. To ensure this, a web-based Regional Environmental Information System (REIS) is currently being implemented by the PCU to facilitate the dissemination of information throughout the region. With the establishment of the MBRS Synoptic Monitoring Program (SMP), the MBRS Protocol was designed to standardize data management for ecosystem monitoring. The protocol calls for the monitoring of changes in ecosystem health of priority protected areas, which are permanent monitoring locations. These sites are included with a marine protected area, which includes any area reserved or protected by a system of management as defined by participating countries. Additional sites include strategic sites within the MBRS, chosen by Technical Working Groups.

The SMP, through the design and implementation of the MBRS protocol, hopes to measure the effects of management actions taken in response to detected changes in 'health' or taken in an effort to mitigate or eliminate anticipated impacts. The MBRS protocol will allow for the establishment of the much needed, comparable baseline information on the condition of marine ecosystems, and detect the extent and patterns of decline in ecosystem through the continuous monitoring of marine and coastal ecosystems, marine pollution and water quality.

This information will provide basic knowledge to link land-use practices and other anthropogenic activities to reef ecosystem health and productivity. These efforts will support sound decision-making processes, such as in the formulation of policies and management strategies for the sustainable use of marine ecosystems. As the SMP is linked with the REIS, regional changes in the coral reef ecosystem will be facilitated to enhance greater conservation efforts.

STUDY AREA

BELIZE BARRIER REEF COMPLEX

The Belize Barrier Reef Complex encompasses an area of 22,800 km^2 (Kramer & Kramer, 2000), and is the largest continuous reef system (250 km) in the western Atlantic. Between the coastline of Belize and the barrier reef lies a 20-40 km wide lagoon. This barrier reef platform supports about 1000 mangrove and barrier islands, patch reefs, faros, and seagrass beds. The barrier reef is comprised of a reef crest several meters wide and a series of spur and groove formations extending seaward for about 100 meters along the fore-reef. This system has been classified by provinces, characteristic of unique coral reef formations. Appendix A shows a detailed map of the MPA systems in Belize. Appendix B outlines the fishing area of territorial waters within Belize.

The Northern Province extends for 46 km of shallow-water reefs to the northern tip of Gallow's Point. It forms mostly discontinuous "ribbon reefs", except along the largest barrier island, Ambergris Cay. The most unusual formation is that of a double reef crest at the Bacalar Chico region, far north, along the border with Mexico. At Rocky Point, the reef actually creeps onto the shore (McField et al., 1996). The breaks along the reef are wide and shallow (Gibson & Carter, 2003).

The Central Province spans 91 km from Gallow's Point to Gladden Spit. Its reefs are the best developed due to its elevation and moderate wave action. The reefs in this area are wide and continuous, with a high-relief fore-reef. A unique high spur and groove system extends for 16 km (Gibson & Carter, 2003).

The Southern Province extends for only 10 km from Gladden Spit to the Sapodilla Cays. The reefs in this area are discontinuous and less developed due to deeper depths and greater open exposure. The channels in the reef are narrow and deep (Gibson & Carter, 2003). Each province can also be characterized according to the distribution of coral species within the reef zonation. However, this is changing with natural and anthropogenic impacts over the years.

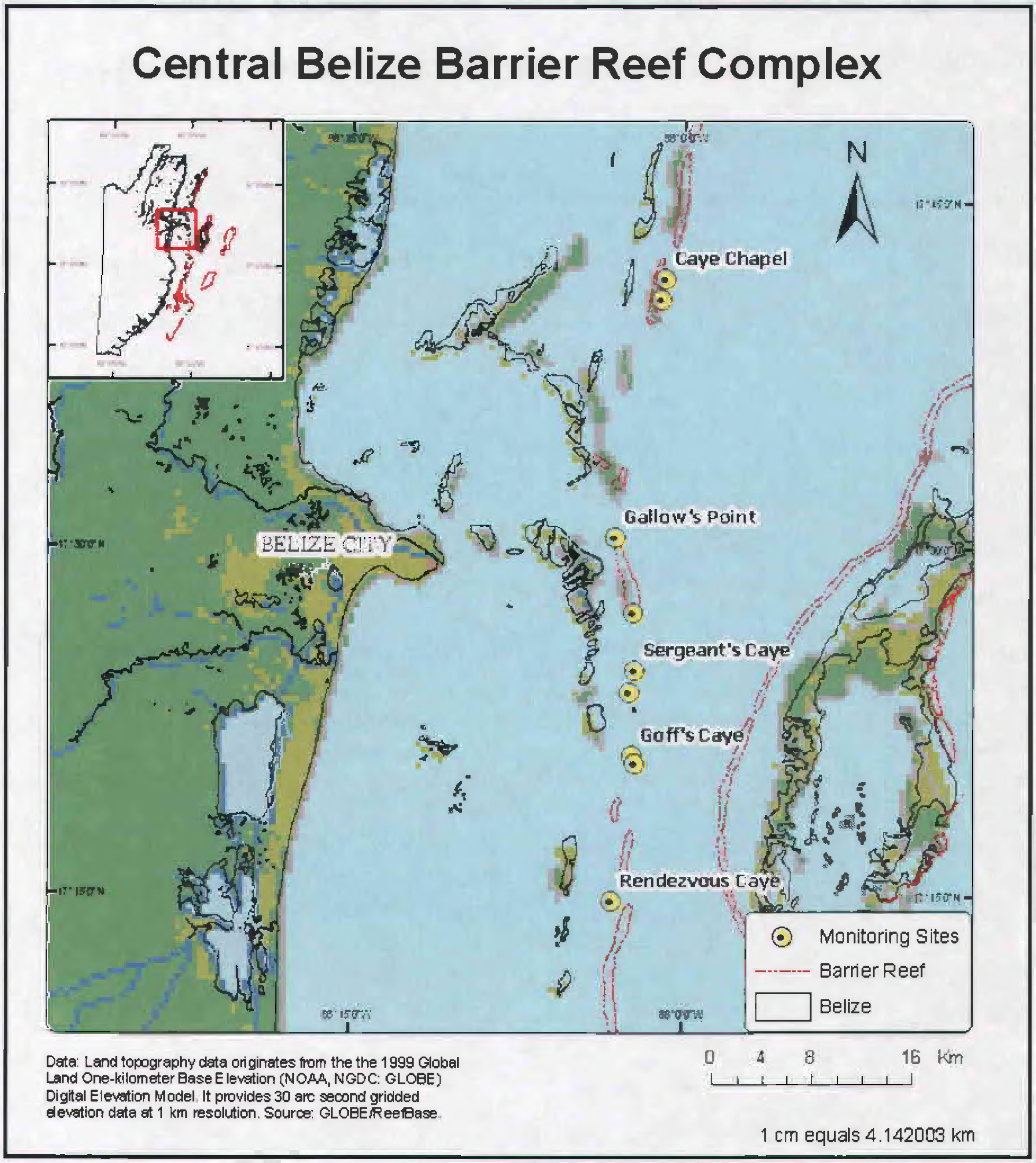
Belize lies in the northern subtropical belt. The annual average temperature is 26°C. The temperature usually never exceeds 36 °C or falls below 16 °C. The mean annual humidity on the mainland is 83%, controlled by the east southeast (ESE) ocean currents from the Caribbean Sea. The ESE tradewinds measure within 10-13 knots. The tidal influence is diurnal with 2 high and 2 low tidal periods per day, ranging from -1 to 2 feet. The amount of rainfall varies both seasonally and regionally. The rainy season is recognized as June to December with the dry season being January to May. The rainy season is characteristic of tropical storms, hurricanes and cold northern fronts that alter mean oceanic conditions.

Some of the first reported disturbances to corals in Belize were due to severe storms and hurricanes, such as Hurricane Hattie in 1961 which reduced living coral cover by 80% (Kramer et al. 2000). *Acropora cervicornis* was the dominant reef-builder until populations were devastated by disease in the mid-1980s. These losses were followed by increases in macroalgal cover (up to 60%) that prevented settlement of coral larvae (Kramer et al. 2000). Another coral species, *Agaricia tenuifolia* colonized dead *A. cervicornis* rubble and replaced it as the dominant coral species (Aronson et al. 1998). The algal competition coupled with *Agaricia* recruitment combined to prevent the *Acropora* species from successfully recolonizing the reefs. The transition between coral and algal communities were particularly obvious on patch reefs of the remote Glovers Reef where there has been a 75% loss of coral cover over the last 25 years, including a 99% loss of *A. palmata* and *A. cervicornis*, and an over 300% increase in macroalgae (McClanahan et al. 1998, Kramer et al. 2000).

BARRIER ISLANDS

Barrier islands are well developed coral reef formations adjacent to the reef crest and surrounded by shallow waters, seagrass beds and sandy bottoms. These coral reefs and barrier islands are within the shallow-water barrier lagoon (Appendix C), the back-reef zone of the barrier reef platform. The shallow waters of the Belize Coastal Zone range within a depth profile from 1-5 m (Appendix C). Below, are brief descriptions to the barrier islands within the REA. Figure 2 provides a map of the location of these islands and the monitoring sites where the MBRS protocol was implemented.

Figure 2. The Central Belize Barrier Reef Complex within the Western Tropical Atlantic and monitoring sites amongst barrier islands included in the Rapid Ecological Assessment.



1. Cay Chapel:

Cay Chapel occurs in the northern province of the barrier reef. Its reefs are patchy, surrounded by turbid waters, with obvious smothering of corals by sediments. This was the northern-most location in the local study area. It is under continuous development and dredging to maintain a privately owned golf resort (Kramer et al., 2000). It has been monitored under the Coastal Zone Management Reef Monitoring Program since 1998 for sedimentation impacts.

2. Gallow's Point:

The reefs of Gallow's Point are unique with a well-developed spur and groove framework. It marks the start of the central province of the barrier reef system. The reefs support a popular fishing ground for conch. This high elevated barrier island supports many residents that are dependent on the conch fishery. Development is increasing with the construction of tourist resorts. In a study by McField et al. (2001), Gallow's Point showed similarity to another impacted barrier island reef ecosystem at 'Tackle Box' from fishing.

3. Sergeant Cay:

Sergeant Cay is a very small isolated sand island. Activities on the small stretch of land are very limited. Some years the exposed land can be completely inundated due to the dynamics of tides, waves and currents. Its surrounding reefs are also used for diving and fishing.

4. Goff's Cay:

The reefs of Goff's Cay support a diverse and healthy coral cover (Kramer & Kramer, 2002), and a high fish density. Its reefs have supported the highest species richness in the entire

MBRS (Almada-Villela, 2002). South of Goff's Cay is the English Channel, and it provides the principal route for navigation by barges, oil tankers, and cruise ships. Traffic along this route is increasing rapidly with the growth in the cruise ship industry, making Goff's Cay a popular destination to go diving, snorkeling and sunbathing. It is a small island of approximately 1 acre in coverage. Tourists have been observed standing on corals and tour operators have been throwing boat anchor on corals. Solid waste pollution is an increasing problem on this island.

5. Rendezvous Cay:

Rendezvous Cay is another isolated barrier island popularly used by fishermen as a camping ground when on their long-lining expeditions for finfish, and free-diving for conch and lobster. It is now becoming a popular tourist site for camping, diving, snorkeling, sunbathing and kayaking.

Cay Chapel, Gallow's Point and Goff's Cay have already been listed as potential strategic sites to be included in the Synoptic Monitoring Program of the MBRS Project (Almada-Villela et al., 2003). The location of monitoring sites for all assessed islands is found on Map 1. Pictures of some of these islands are found on Appendix K. Observed disturbances to coral reefs and potential sources of disturbances were summarized in Table 1.

Table 1. Summary of observed disturbances to coral reefs and proposed potential sources of disturbances to assessed barrier islands.

Barrier Islands	Observed Disturbances	Potential Sources causing stress
1. Cay Chapel	Sedimentation, increased levels of turbidity.	Dredging or sediment run-off
2. Gallow's Point	Fishing: free-diving & long-lining.	Fishing (commercial)
3. Sergeant Cay	Fishing: trolling.	Fishing (artisinal)
4. Goff's Cay	Boat anchor on coral, tourist standing on corals, other interactions during diving & snorkeling.	Tourism and/or Shipping
5. Rendezvous Cay	Fishing: long-lining; Tourist: interactions during diving & snorkeling.	Tourism and / or Fishing

MBRS MONITORING PROTOCOL

The MBRS protocol includes specific techniques for monitoring corals, reef fish, seagrass, mangroves, and general oceanographic parameters (Almada-Villela et al., 2003). These techniques were selected and modified from other protocols (e.g. AGRRA and CARICOMP) to suit assessments of the MBRS. The following techniques were used to assess corals and reef fishes as per the MBRS protocol.

A. AREAL ASSESSMENT

1. Manta Tow Technique:

Surveys were done within the shallow (1-5 m depth), back-reef region of the barrier reef around barrier islands. This is a surface tow at about 4 km/hr at two minutes intervals using basic snorkeling gears as illustrated in figure 2. This technique was used to identify adequate survey sites, where areas are representative of reefs (50% reef cover) around the islands to support the implementation of the MBRS monitoring protocol. The location of survey sites was recorded using a global positioning system (GPS). The manta tow survey provided a general description and percent cover of habitat types. This ensured that areas were chosen that reflected adequate habitat coverage to support the survey techniques of the assessment design. Additional descriptions per site included: wind strength, cloud cover, tide and sea state, visibility, and topology (reef zone and degree of slope). The datasheet used to make this assessment is found at Appendix D. Two sites per barrier islands were identified for adequate implementation of the protocol for the monitoring of coral reefs and reef fishes. However, only one site was found at Rendezvous Cay (Map1).

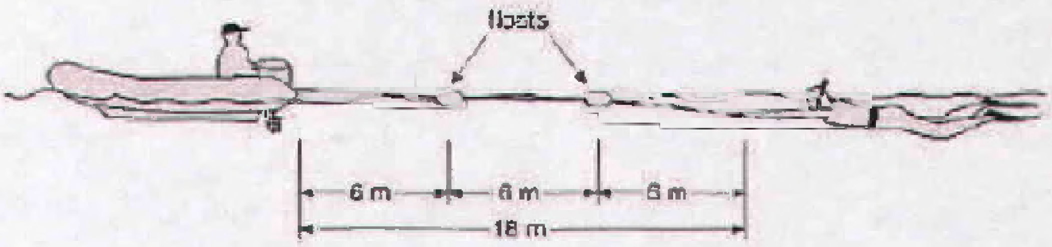


Figure 3. The manta tow technique (from Bass and Miller, 1998).

B. CORAL REEFS, ALGAE AND OTHER SESSILE ORGANISMS: (AGRRA, 2000)

(1.) Transects were deployed haphazardly; that is, in a quasi-random manner, using SCUBA or snorkeling gear. A 30 m transect line was laid just above the reef surface in a direction that is perpendicular to the reef slope (parallel to the reef crest). Five transects per site were sampled haphazardly. Also recorded with each transect was depth, time, and date. The first technique to this assessment included the Linear Point Intercept (LPI) Method. Water depth was recorded at the beginning and end of each transect. The percent cover of benthic types was based on counts by swimming along the line transect, recording the nature of the benthic cover directly below every 25 cm point along the line transect. Classifications included: coralline algae, turf algae, macroalgae, sponges, gorgonians, bare rock, sand, dead coral, specific genera of stony corals. Recording every 25 cm covered 120 records per transect to compute the percentage cover of each substratum type as: (# records/120) x 100%. The datasheet used for this assessment is found at Appendix E.

(2.) The second technique involved the characterization of coral community under the line transects. After completing the point-intercept survey, the same transect line was used again to measure coral heads, clusters or portions that were located directly beneath the transect line. Only those, which were at least 10 cm in diameter and in original growth position, were recorded. A target minimum of 50 coral colonies were assessed for each site. The datasheet used is found at Appendix F. The diameter of the coral was measured perpendicular to the axis of growth and the height was measured parallel to the axis of growth. Percent recent dead and old dead were estimated as viewed from an angle that is parallel to the axis of growth. "Recent" dead is defined as any non-living parts of the coral in which the corallite structures are white and either still intact or covered over by a layer of fine mud or algae. "Old" dead is defined as any non-living parts of the coral in which the corallite structures are either gone or covered over by organisms that are not easily removed such as certain algae and invertebrates (AGRRA, 2003). The source of recent mortality was also recorded if it could be identified (sediment smothering, parrotfish and damselfish bites, storm damage, predation by snails or bristle worm, or overgrowth by algae). Coral bleaching was characterized according to different levels of severity (CARICOMP, 2001):

P = Pale (discoloration of coral tissue)

PB = Partly Bleached (patches of fully bleached or white tissue)

BL = Completely Bleached (tissue is totally white, no zooxanthellae visible).

Diseases identified on coral colonies included: Black Band Disease (BBD), White Band Disease (WBD), White Plague (WP), Yellow Blotch Disease (YBD), Red Band Disease (RBD), Dark Spots Disease I (DS-I), Dark Spots II (DS-II), Aspergillosis (ASP) and others.

C. CORAL REEF FISH AND *DIADEMA* URCHINS:

(1.) This assessment included the use of belt transects as illustrated in figure 3 (Rogers et al., 2001). A minimum of eight transects were conducted at each site at approximately 5 m intervals across the reef front. For each transect depth, time, and date were recorded. Transect lines were

30 m long and were laid haphazardly across the reef face in the same general area as the coral assessment transects. The 1 m T-bar was calibrated at 5 cm intervals to measure fish size while swimming in a straight line and releasing the measuring tape from the reel.

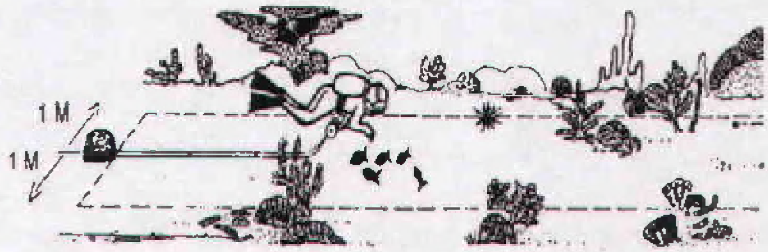


Figure 4. Diagrammatic representation of a diver conducting a belt transect (from Rogers *et al.* 2001). This method will be utilized to set up the transects for benthic organisms. A variation of this method will be used for the belt transects for fish censuses, in which the diver will have a T-bar.

Size estimates were categorized in a standard format and juveniles of less than 5 cm in total length were not counted - to avoid counting recruits. The datasheet was used to record classifications of fish species by size (Appendix G). Species within the fish families included *Acanthuridae* (surgeonfish), *Scaridae* (parrotfish), *Haemulidae* (grunts), *Lutjanidae* (snappers), *Serranidae* (groupers), *Pomacanthidae* (angelfish), *Chaetodontidae* (butterflyfish), *Monacanthidae* (leatherjacket), *Pomacentridae* (damselfish) and others. It is important to swim in a slow, uniform manner to minimize diver influences to fish behaviour. At the end of the transect line, two minutes were allowed for acclimatization of fishes to reef before the line was swum again (in reverse) to count for fish recruits (<5 cm) within a 1 m width. The datasheet used for this assessment of fish recruitment is found at Appendix H. At the end of this assessment, the same transect line was swum again for the third time to count for the presence of lone-spined sea urchin (*Diadema antillarum*) that were found amongst corals and substratum.

Survey area was limited to a 1 m width. Counts were not based on size. The datasheet used to record counts is found at Appendix H.

(2.) Another technique used was the Rover Diver survey (Schmitt et al, 1998). This was done in the same general area as the belt transects. One survey was done per surveyor in each site, where surveys ranged from 2-5 at some sites (Table 2). This was done for 30 minutes and was limited to a 200 m radius search as measured by a fiber tape. Surveyors swam around and recorded all fish species observed. A species list with logarithmic categories (S-single, F-few, M-many, A-abundant) was used that approximated the relative abundance of each species. The datasheet used is found at Appendix I.

DATA ANALYSIS

Benthic habitat and fish data were entered into a custom Excel spreadsheet. The percent coral cover, percent coral mortality, mean coral colony size, and incidence of coral disease and level of coral bleaching were calculated for each location. Data provide by the LPI method was used to provide percent cover of common genera of corals and marine benthic cover. Hard coral cover included species of the genera *Agaricia, Porities, Diploria, Montastraea, Millepora, Leptoseris, Siderastrea, Mycetophyllia, Madracis, Acropora* (*A. palmate* and *A. cervicornis*). A relative abundance score, the Coral Abundance Index (CAI), was assigned to percent hard coral cover (DeVantier et al., 1998). Macroalgae cover was represented by species of *Dictyota*, *Lobophora* and *Halimeda*. Benthic habitat assessments were used to estimate structural diversity by using the Shannon-Weiner Index (0-4 scale): $H' = - \sum P_i \ln(P_i)$ where P_i is the proportion of individuals found in the *i*th species. The coral health assessment of individual coral colonies provided assessments of percent coral mortality, percent coral bleaching, and identified types of diseases for specific coral species.

For fish, the average density (#/200m^3) and the average size (cm) of key fish species and families were calculated per island. This data was used to estimate the size-frequency distribution and mean density of herbivorous and carnivorous fish guilds. The Shannon-Weiner Index (H′) was used to estimate a measure of biodiversity. Data from belt transects were used to calculate the densities of reef fish recruits and that of *Diadema* urchins.

The Rover Diver Technique provided a species list, percent sighting frequency and relative abundance of most common reef fishes in this local region. Percent sighting frequency (%SF) for key species was calculated as the percentage of dives on which the species was recorded. An abundance index was calculated as:

Abundance = $((n_s x1) + (n_f x2) + (n_m x3) + (n_a x4)) / (n_s+n_f+n_m+n_a)$, where n_s, n_f, n_m, and n_a represent the number of times each abundance category (single, few, many, and abundant) was assigned to a given species on observation. Species richness per island was determined as a count of species encountered during Rover Diver surveys.

Biological indices were used to qualify the status of corals, reef fish and benthic habitats from assessments. For corals, the indices included: a Coral Abundance Index (CAI), a coral cover standard (25-30%), a standard for recent (1%) and old mortality (20%), a standard for coral bleaching (10%) and diseases (5%). The indices for assessing benthic habitats are based on data describing the structure and composition of coral reefs. The indices included: Shannon-Weiner index that was based on benthic classifications, habitat dominance, hard coral dominance by genera, and standard for *Diadema* urchin density (15/100m^2). For assessing reef fish, the indices used were: Shannon-Weiner Index of diversity, the herbivore to carnivore ratio, standards for adult fish density and fish recruit density ($60/100m^2$). These indices were used to clearly emphasize priority areas and critical areas; whereby priority areas are considered important to ecosystems and natural resource use, and critical areas are considered areas of excessive habitat degradation or declining species populations. If standards for each index were highly met by a reef system, it was considered a priority area. If standards were poorly met by reef systems, it was considered a critical area.

RESULTS

OVERALL ASSESSMENT:

All sites showed a coral cover of less than 23% (Table 2). The mean diameter of individual coral colonies was ~51 cm (range 35-70 cm) (Table 3). Massive colonies included those of *Montastraea annularis*, *Acropora palmata* and *Agaricia tenuifolia*, which ranged from 200-400 cm in diameter. Most coral colonies assessed had over 70% live tissue, free of any disease, bleaching or coral mortality (Tables 3), except some at Gallow's Point.

The highest mean total mortality (39.88%) was observed at the southern site of Gallow's Point (Table 3). These reefs recorded the highest incidence of recent dead (4.78%) and old dead (35%) corals in comparison to other reefs (Table 3). However, the northern site recorded the lowest mean total coral mortality (11.98%), in comparison to other sites. Reefs within Gallow's Point, Sergeant Cay and Goff Cay experienced recent coral mortality, ranging from 1.38 - 4.78% (Table 3). Some sites had >10% coral bleaching, except the northern site of Sergeant Cay, the southern site of Goff Cay, and Rendezvous Cay (Table 2). The southern site of Gallow's Point had as much as 30% coral bleaching. The incidence of coral bleaching was greater than the presence of coral diseases at almost all sites. Only the southern sites of Sergeant Cay and Goff Cay experienced >5% infection of diseases (Table 3). At Sergeant Cay, the Black Band Disease (BBD) infected *M. annularis* (lobed star coral) and *Diploria strigosa* (symmetrical brain coral). At Goff's Cay, the White Band Disease (WBD) infected *A. palmata*. In terms of sea urchins, most sites measured low *Diadema* densities (<15/100m^2), except at Rendezvous Cay (52/100m^2) and the southern sites of both Sergeant Cay (79/100m^2) and Goff's Cay (21/100m^2) (Table 2).

For reef fishes, most sites showed a Shannon-Weiner index of above 2.5 (Table 2). Gallow's Point showed the highest species diversity and richness in terms of fish (Table 2). A standard used by the AGRRA protocol (Peckol et al., 2003), showed low adult fish density (<30/200m^3) at most sites, except at Goff's Cay and the southern site at Gallow's Point (Table 2), where the reefs are important to reef fish populations. The foureye butterflyfish (*Chaetodon capistratus*) was observed in every Rover Diver survey. This reef fish feeds on zoantharians, polychaete worms, gorgonians and tunicates. The bicolor damselfish (*Stegastes partitus*) recorded a high abundance index of 3.0 on a 4.0 scale (Table 4). This species is a territorial herbivore, making permanent residence on patch reefs preferably containing *M. annularis* (Sorokin, 1993). Table 4 lists the abundance of the *Labridae*, *Pomacentrida*, *Chaetodontidae*, *Haemulidae*, *Lutjanidae*, *Acanthuridae*, *Scaridae*, and *Serranidae*.

Table 2. Site information and transect survey effort (S-W = Shannon-Weiner Index derived from belt transect data, * = data based on the Rover Diver Technique).

Site Name	Latitude (° N)	Longitude (° W)	Benthic Coral Transect	Coral Cover (%)	# Fish Belt Transect	Adult Fish Density (#/200m^3)	Fish S-W Index	*Diadema* Density (#/100m^2)	Rover Diver Surveys	*Fish Species Richness
CChap1	17°41′44.8″	-88°00′49.3″	5	16.69	8	23.33	2.93	5.42	3	55
CChap2	17°40′50.2″	-88°01′01.2″	5	12.27	8	28.75	2.83	1.67	5	53
GalPt1	17°30′31.9″	-88°03′02.7″	5	18.09	8	25.42	2.67	4.58	4	53
GalPt2	17°27′17.1″	-88°02′15.6″	5	20.36	8	33.96	3.01	2.08	5	69
SergC1	17°24′46.6″	-88°02′11.4″	5	8.12	8	26.46	2.43	4.17	5	61
SergC2	17°23′48.9″	-88°02′23.9″	5	20.94	8	25.42	2.82	79.58	5	67
GoffC1	17°21′06.8″	-88°02′16.5″	5	8.79	8	34.17	2.69	1.67	2	49
GoffC2	17°20′45.7″	-88°02′08.9″	5	14.76	8	57.71	2.51	21.25	3	51
RendC	17°14′46.9″	-88°03′09.9″	5	22.41	8	20.00	2.45	52.08	3	63

Table 3. Summary of Coral Data (* includes any level and amount of bleaching).

Site	Counts of Coral Colonies	Mean Diameter (cm)	Mean Height (cm)	Mean Live Coral (%)	Mean Recent Mortality (%)	Mean Old Mortality (%)	Mean Total Mortality	Bleached (%)*	Diseased (%)
CChap1	42	64.24	34.95	71.90	0.43	27.67	28.10	19.05	4.76
CChap2	46	69.29	35.35	72.24	0.59	27.17	27.76	15.22	2.17
GalPt1	57	35.21	18.79	88.02	1.88	10.10	11.98	24.56	3.51
GalPt2	50	61.68	36.30	60.12	4.78	35.10	39.88	30.00	4.00
SergC1	43	46.42	25.81	78.42	0.74	20.84	21.58	9.30	4.65
SergC2	56	43.38	25.98	76.16	4.02	19.82	23.84	28.57	8.93
GoffC1	50	41.12	24.18	71.38	2.22	26.40	28.62	20.00	4.00
GoffC2	52	55.39	35.00	74.90	1.39	23.71	25.10	3.85	7.69
RendC	61	50.92	27.37	86.59	0.39	13.02	13.41	1.64	4.92

Table 4. The twenty-five most common reef fish species. Data are calculated from the Rover Diver Technique surveys.

#	Common Names	Scientific Names	Percent Sighting Frequency	Abundance Index (0-4)
1	Foureye Butterflyfish	*Chaetodon capistratus*	100.	2.1
2	French Grunt	*Haemulon flavolineatum*	94.3	2.4
3	Yellowtail Snapper	*Ocyurus chrysurus*	94.3	2.2
4	Ocean Surgeonfish	*Acanthurus bahianus*	94.3	2.6
5	Blue Tang	*Acanthurus coeruleus*	88.6	2.4
6	Yellowtail Damselfish	*Microspathodon chrysurus*	85.7	2.6
7	Bluehead Wrasse	*Thalassoma bifasciatum*	82.9	2.7
8	Stoplight Parrotfish	*Sparisoma viride*	80.0	2.4
9	Schoolmaster	*Lutjanus apodus*	77.1	2.2
10	Redband Parrotfish	*Sparisoma aurofrenatum*	74.3	2.3
11	Banded Butterflyfish	*Chaetodon striatus*	71.4	2.0
12	White Grunt	*Haemulon plumieri*	68.6	2.0
13	Squirrelfish	*Holocentrus rufus*	65.7	1.7
14	Bicolor Damselfish	*Stegastes partitus*	65.7	3.0
15	Yellowhead Wrasse	*Halichoeres garnoti*	62.9	2.6
16	Princess Parrotfish	*Scarus taeniopterus*	60.0	2.7
17	Bar Jack	*Caranx rubber*	60.0	2.0
18	Porkfish	*Anisotremus virginicus*	60.0	1.9
19	Graysby	*Epinephelus cruentatus*	60.0	1.7
20	Cocoa Damselfish	*Stegastes variabilis*	57.1	2.7
21	Sergeant Major	*Abudefduf saxatilis*	57.1	2.6
22	Slippery Dick	*Halichoeres bivittatus*	54.3	2.7
23	Blue Chromis	*Chromis cyanea*	51.4	2.1
24	Dusky Damselfish	*Stegastes fuscus*	51.4	2.6
25	Threespot Damselfish	*Stegastes planifrons*	51.4	2.3

BENTHIC COMPOSITION

At least 10% of a marine benthic habitat is needed to contribute to the community structure of coral reef ecosystems (McClanahan, 2001). Benthic composition was determined from data collected during surveys using the LPI method. Data was pooled from all sites associated with a particular island. Therefore, each island had 16 transects, except for Rendezvous Cay (1 site = 8 transects). The benthos around Cay Chapel is dominated by macroalgae (41%), with 14.4% hard coral cover. Gallow's Point also showed a predominance of macroalgal cover (32%), over hard corals (19%). Sergeant Cay portrayed almost equal representation between macroalgae (24%) and turf algae (25%), with 14.4% hard coral cover. Goff's Cay was dominated by turf algae (36.24%), with just over 11.7% hard corals. Rendezvous Cay was the only site dominated by hard corals (22.4%), with 14.84% soft corals and an almost equal distribution of macroalgae (18.3%) and turf algae (17%) (Figure 5).

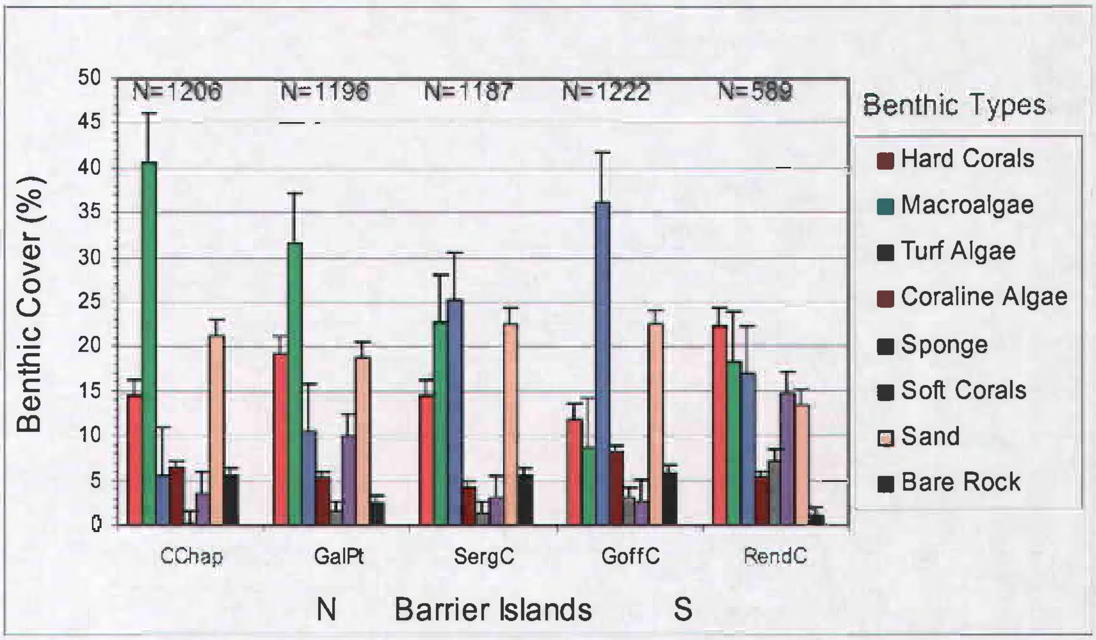


Figure 5. Average percent benthic coverage per surveyed location based on Point Intercept Method (N = # of point intercepts; bars = 1 SE).

HARD CORAL COMPOSITION

Using the LPI, hard coral cover was mostly represented at islands by the genera *Montastraea*, *Diploria* and *Porites* (Figures 6). Both Cay Chapel and Gallow's Point had hard corals of the *Montastraea* genera, specifically *M. annularis*. Corals at Sergeant Cay were representative of the *Montastraea* genera and *P. astreoides*. Hard corals at Goff's Cay had almost equal representation between *Acropora palmata* and species of the *Millepora* genera (Figure 6). Rendezvous Cay had mostly *Agaricia* and *Porites* corals (Figure 6), especially those of *P. astreoides*.

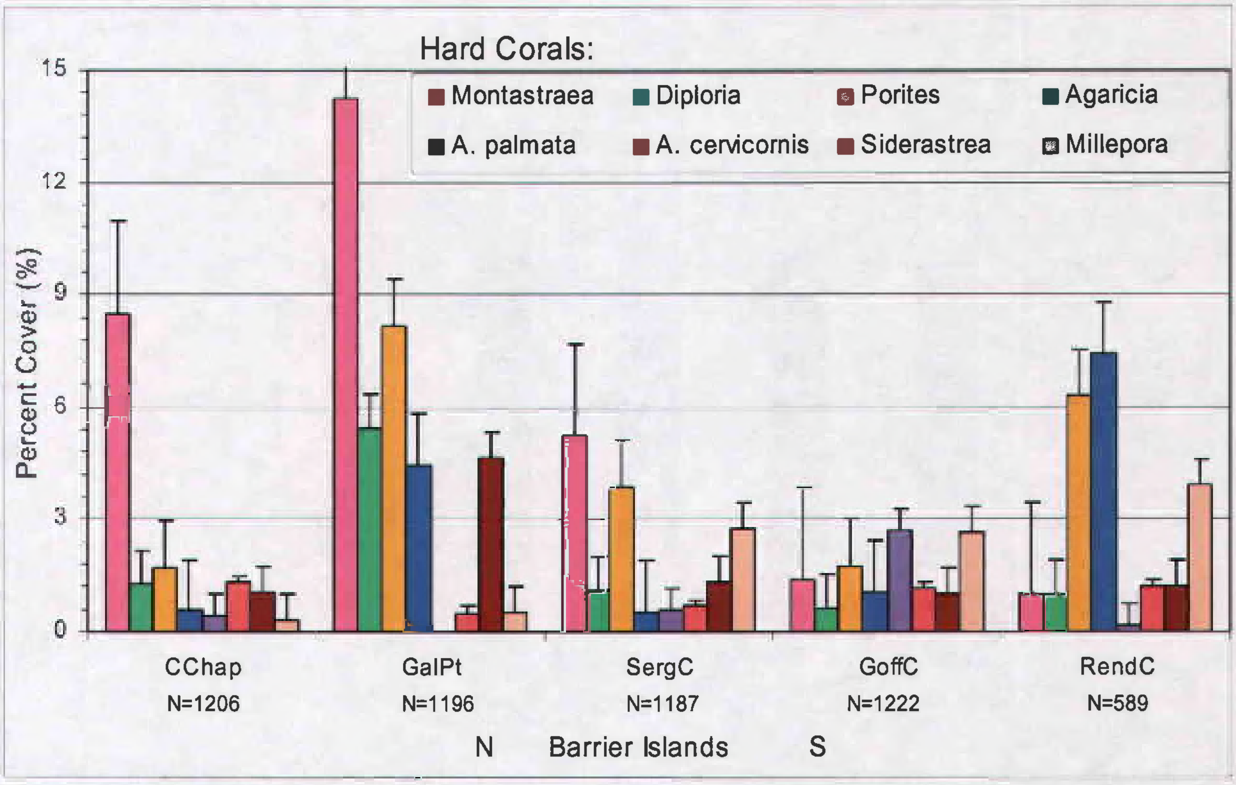


Figure 6. Mean percent cover of the most common hard coral genera per barrier island (N= # of point intercepts, bars = 1 SE). Data based on LPI method.

CORAL MORTALITY

Coral mortality and bleaching indicate stressed corals. Recent coral mortality reflects impacts to corals within a time frame from a month to 2 years; while old dead corals reflect impacts after this time period. Estimates of bleached coral tissue are not included in the quantification of recent coral mortality. However, estimates of completely bleached coral tissue does account for estimates of recent coral mortality. Individual assessments of coral colonies showed evidence of recent coral mortality at Gallow's Point (3.3%), Sergeant Cay (2.4%) and

Goff's Cay (1.8%), due to impacts within the past 2 years (Figure 7). Cay Chapel had the greatest amount of long-standing dead corals (27.4%), depicting years of impacts and stress. The reefs at Rendezvous Cay had the lowest coral mortality with 86.75% live corals, showing a healthy coral reef ecosystem (Figure 7).

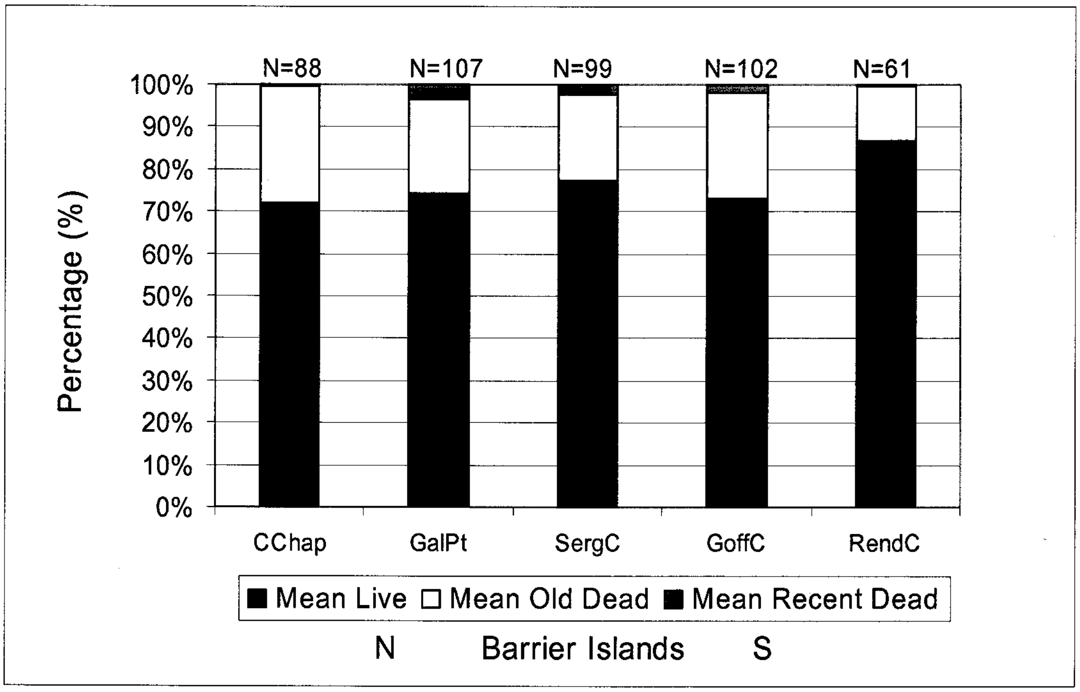


Figure 7. Percent live and dead (recent and old) corals per barrier island (N = # of coral colonies).

CORAL BLEACHING & DISEASES

All cays experienced >10% coral bleaching, except Rendezvous Cay (Figure 8). Gallow's Point experienced the most coral bleaching (27.38%). These levels do not indicate an incidence of Mass Coral Bleaching because all cays did not experiencing >25% coral bleaching (Glynn, 1993). Disease occurs in corals that are under stress, where conditions become unfavorable for the coral polyp's symbiotic algae but favorable for other forms of pathogens. An incidence of 5% disease indicates a level of stress and potential threat to coral reef vitality. Only the reefs at Sergeant Cay and Goff's Cay displayed greater than 5% disease (Figure 8). Colonies of *M. annularis* and *D. strigosa* were infected with black-band disease at Sergeant Cay, and colonies of *A. palmate* were infected with white-band disease at Goff's Cay.

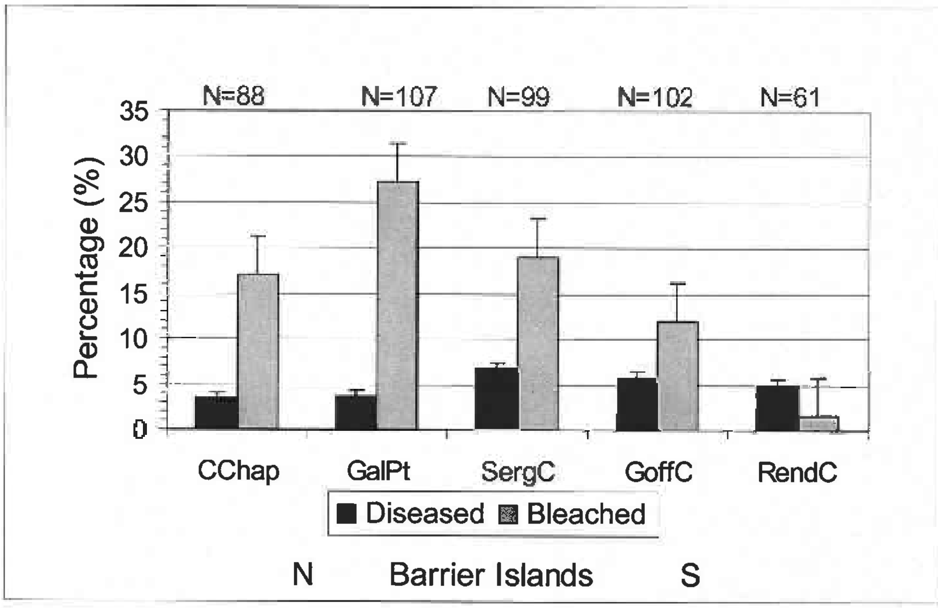


Figure 8. Mean percent diseased and bleached corals per island (N = coral colonies, bars = 1 SE).

The highest incidence of pale coral bleaching was experienced at Sergeant Cay (Figure 9), indicating a high potential for coral recovery. Partial coral bleaching is characterized by patches of fully bleached or white tissue. The reefs at Rendezvous Cay only experienced partial coral bleaching (Figure 9), also reflecting a high potential for complete recovery of corals from bleaching, if conditions become favorable for corals. Completely bleached corals show no visible coloration (tissue is completely white). Gallow's Point had the highest levels of complete coral bleaching (Figure 9), reflecting years of impacts upon the reefs. All reefs except those at Rendezvous Cay experienced between 20 and 25% completely bleached corals. This suggests that these barrier islands have been exposed to impacts over the past years, such as from the 1998 Mass Coral Bleaching Event (McField, 1999). Both Cay Chapel and Goff's Cay experienced mostly partial coral bleaching.

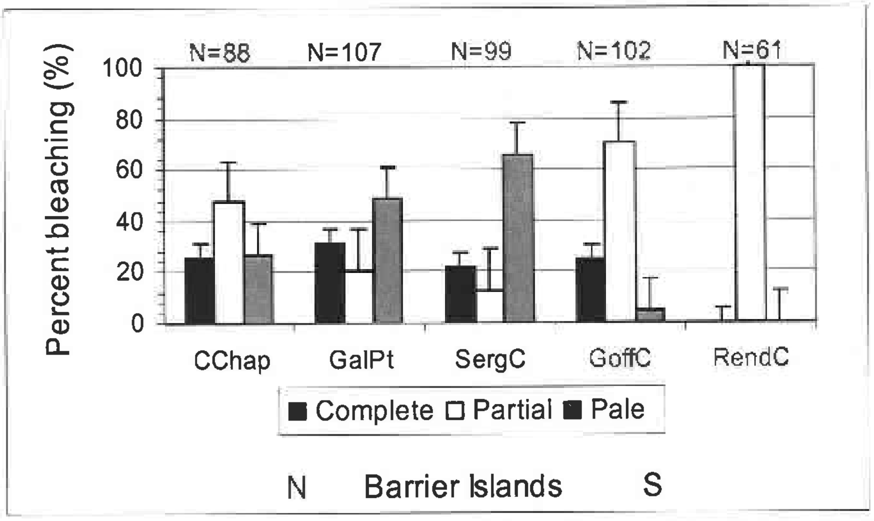


Figure 9. Mean percent level of coral bleaching per island (N = # of coral colonies; bars = 1 SE).

COMPOSITION OF REEF FISH POPULATIONS

The two most dominant reef fish families were the *Acanthuridae* and the *Scaridae*, while the least dominant was of the *Pomacanthidae* (Figure 10). This shows that the community structure of the coral reef ecosystems around these islands were mostly defined by herbivorous fishes (*Acanthuridae* and *Scaridae*). The average body size of the *Acanthuridae* ranged from 15-18 cm and the *Scaridae* body size ranged from 17-25 cm (Figure 11). Most grunts, groupers, snappers and angelfishes were >25 cm in body size (Figure 11). The *Chaetodontidae* were the smallest, with sizes ranging from 7-15 cm (Figure 11). There was a distinct class size distribution within the *Pomacanthidae* between islands. Angelfishes at Cay Chapel and Gallow's Point had an average size of about 15 cm; Sergeant Cay had angelfishes of 25 cm; while angelfishes at both Goff's Cay and Rendezvous Cay averaged 30 cm (Figure 11). This spatial difference may be due to the different habitat types that these islands supported.

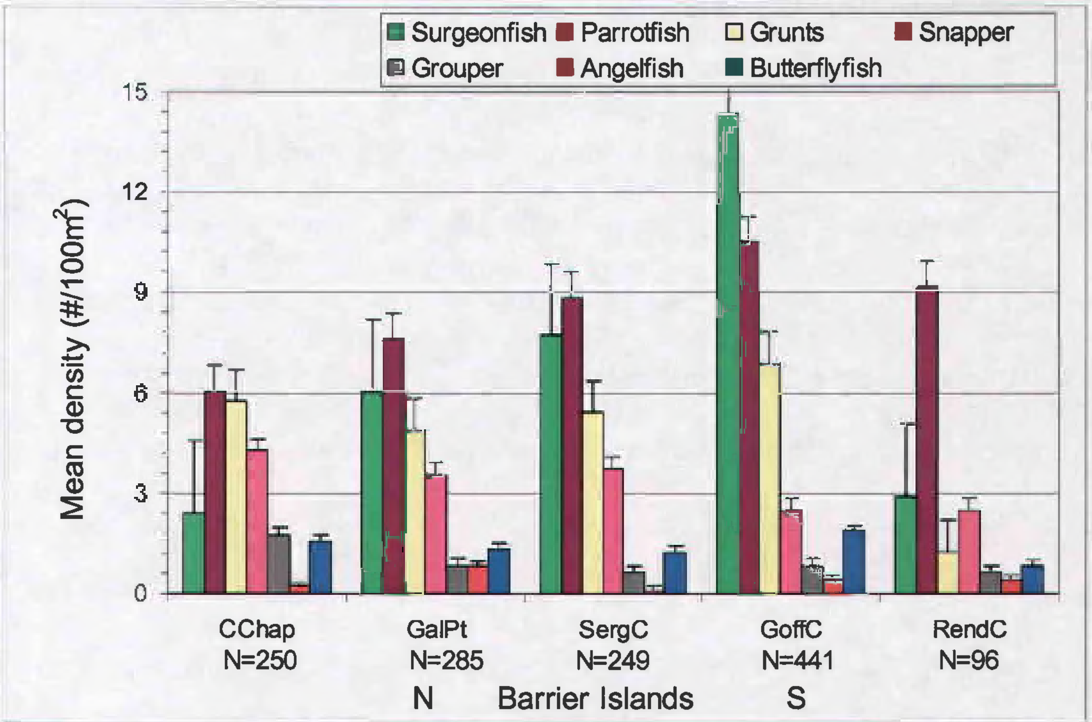


Figure 10. Mean density of common adult reef fish families per barrier island (N = # of fish, bars = 1 SE). Data based on belt transect sureveys.

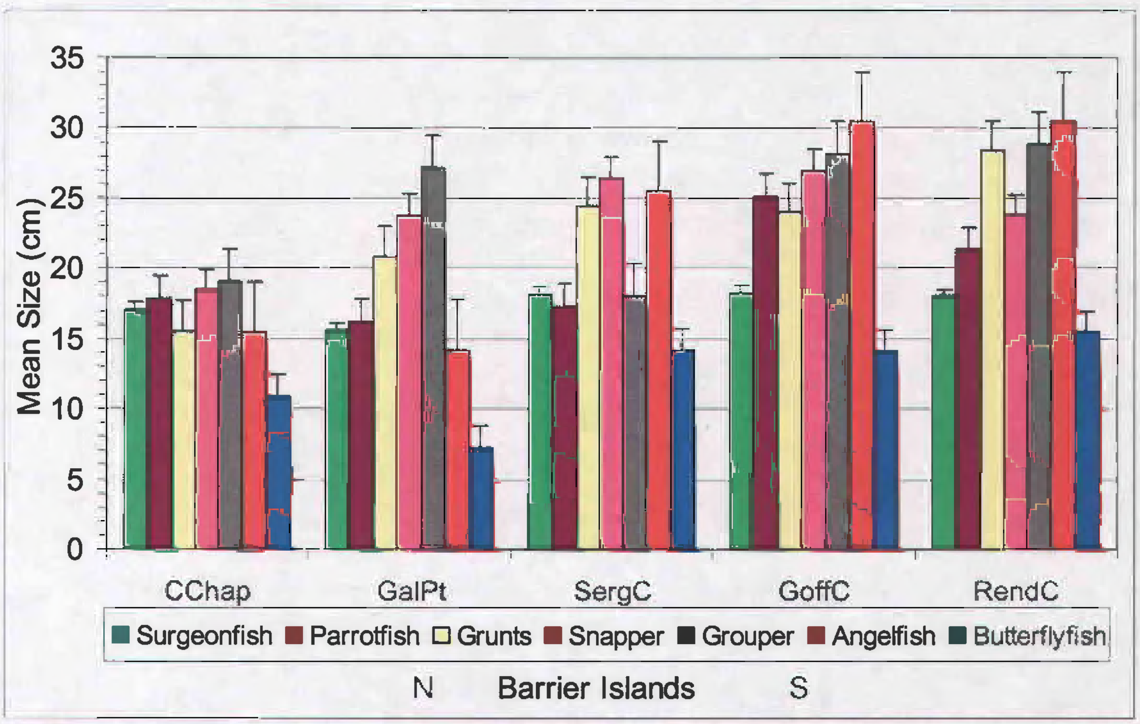


Figure 11. Mean size of common adult reef fish families per barrier island (bars = 1 SE).

STRUCTURE OF REEF FISH POPULATIONS

Populations of reef fish were further classified into carnivorous (*Haemulidae, Serranidae* and *Lutjanidae*) and herbivorous guilds (*Scaridae* and *Acanthuridae).* Carnivorous fishes were larger than herbivorous fishes. Most carnivores ranged from 21-30 cm; while most herbivores ranged from 11-20 cm (Figure 12). Cay Chapel showed an almost equal distribution of both herbivores and carnivores (Figure 13). Most herbivores in the size class (11-20 cm) were supported by the reefs at Sergeant Cay (Figure 14). Herbivores from every island were within two class ranges: the 6-10 cm and the 11-20 cm (Figure 14). Most carnivores were at Cay Chapel, falling into the 11-20 cm size class (Figure 15), which may have limited the amount of herbivores within this size class at Cay Chapel (Figure14). The majority of carnivores, within the 21-30 cm class range, were at Gallow's Point (Figure 15). These larger carnivores also limited the amount of herbivores of this size class at Gallow's Point (Figure 14 & 15).

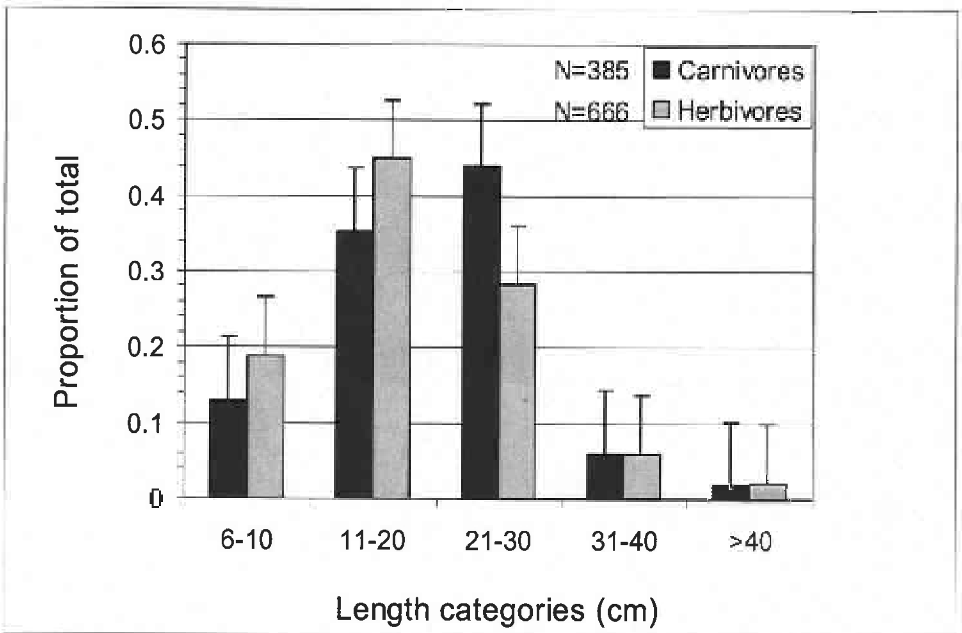


Figure 12. Size-frequency distribution of herbivorous (*Scaridae & Acanthuridae*) and carnivorous (*Haemulidae, Serranidae & Lutjanidae*) reef fish families pooled from all islands (N = # of fish, T = total # of fish, bars = 1 SE).

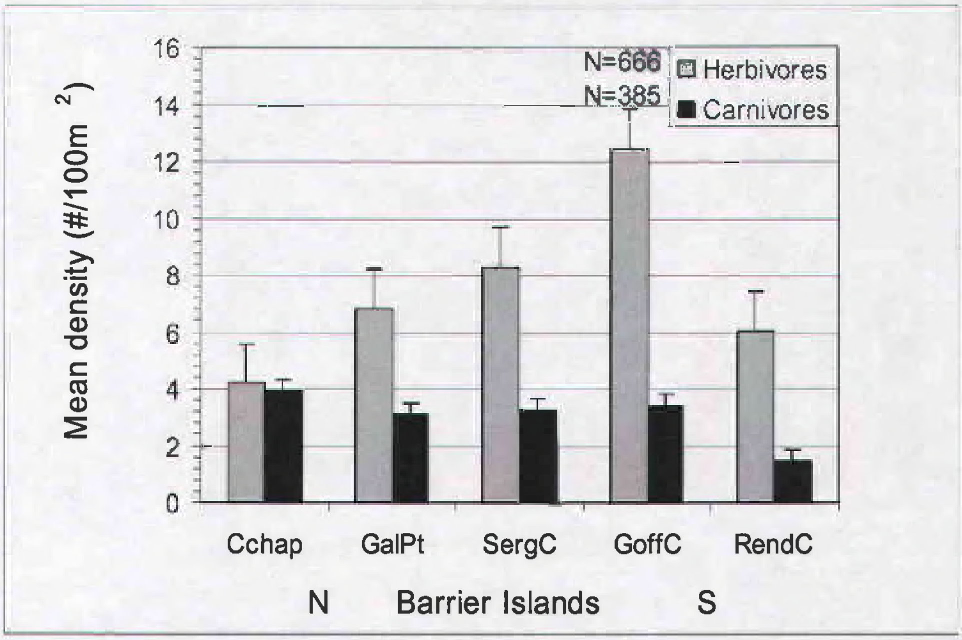


Figure 13. Mean density of herbivorous (*Scaridae* & *Acanthuridae*) and carnivorous (*Haemulidae*, *Serranidae* & *Lutjanidae*) reef fish families per island (N = # of fish; bars = 1 SE).

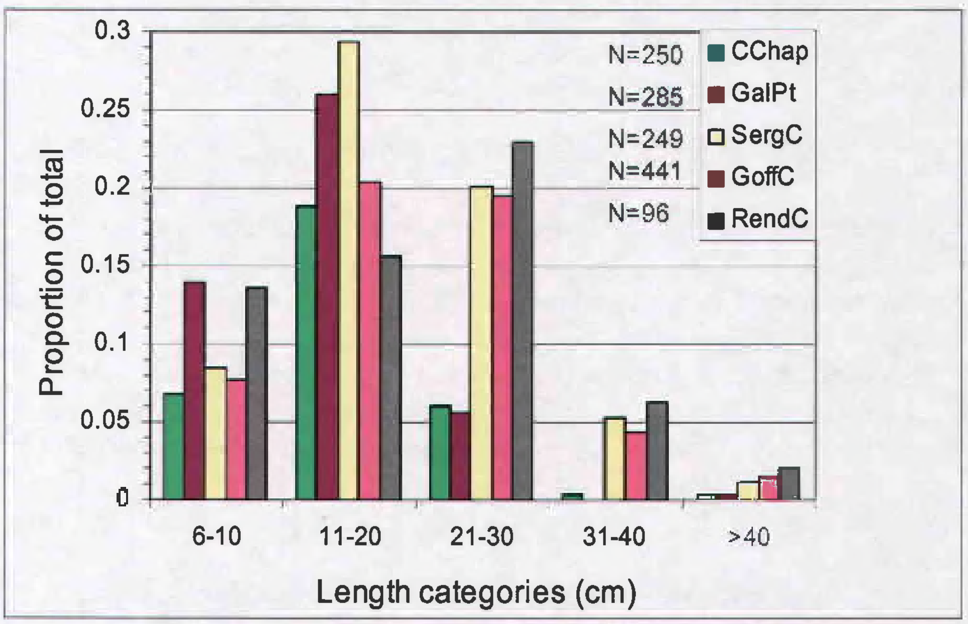


Figure 14. Size-frequency distribution of herbivorous reef fish families (*Scaridae* & *Acanthuridae*) per island (N = # of fish, T = total # of fish).

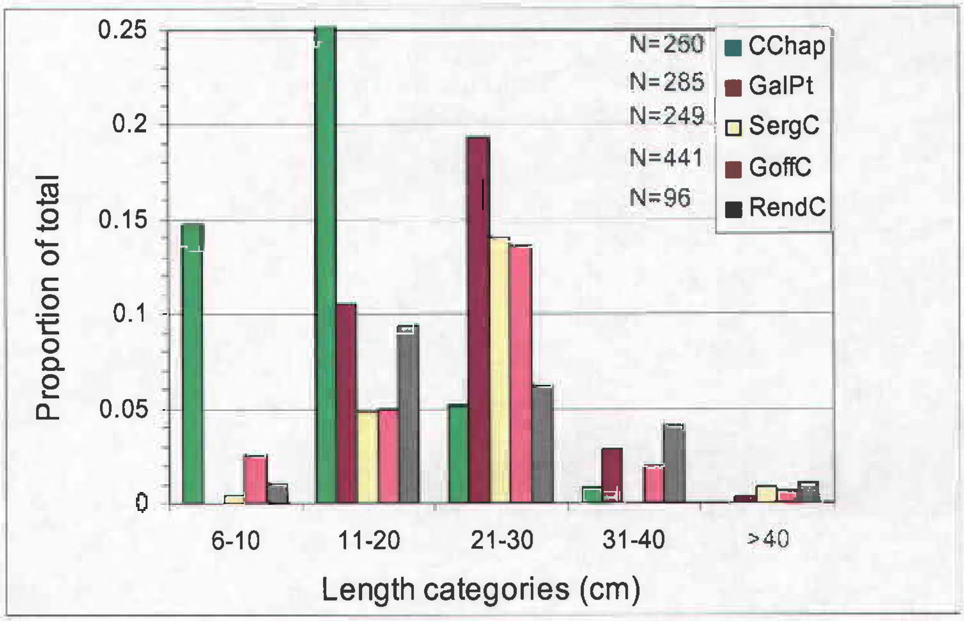


Figure 15. Size-frequency distribution of carnivorous reef fish families (*Haemulidae*, *Serranidae* & *Lutjanidae*) per island (N = # of fish).

CORAL REEF COMMUNITY STRUCTURE

All islands had almost twice as many recruits as adult fishes in terms of density, except at Goff's Cay (Figure 16). The majority of adult fishes at Goff's Cay were of the family *Acanthuridae*. The presence of *Diadema* and *Acanthuridae* at Goff's Cay may have contributed to the proliferation of turf algae. The adult fishes at both Cay Chapel and Gallow's Point were mainly of the family *Scaridae* (Figure 10), but of an intermediate size class (Figure 12). Coupled with the low density of *Diadema* and herbivores (Figure 17), the reefs at these islands were dominated by macroalgae (Figure 5) and carnivores (Figure 15). The adult fishes at Sergeant Cay and Rendezvous Cay were also mainly of the family *Scaridae* (Figure 10). Their reefs had low densities of herbivores and high densities of *Diadema* (Figure 17). However, the benthos at Sergeant Cay displayed a mix between turf algae and macroalgae (Figure 5). This may be due to the high proportion of an intermediate class size of herbivores (Figure 14) and a high *Diadema* density (Figure 17). While, the benthos at Rendezvous Cay was dominated by hard corals

(Figure 5), which may be due to the larger size class of the herbivorous fishes (Figure 14) and the high *Diadema* density (Figure 17).

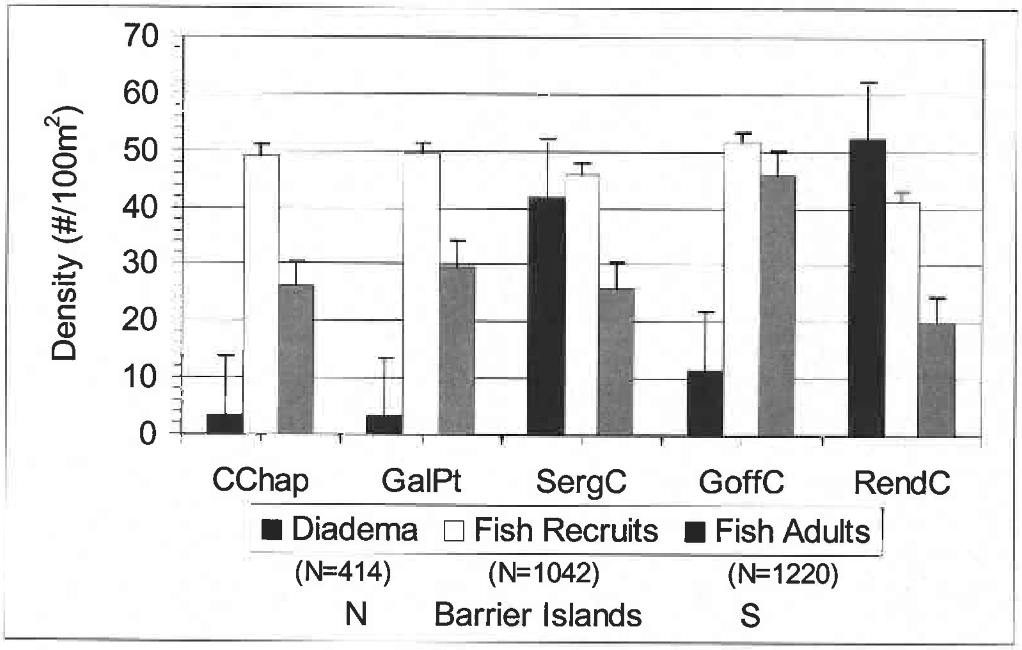


Figure 16. Mean density of reef fish adults, recruits and *Diadema* urchins per barrier island (N = total # of species pooled from all islands, bars = 1 SE).

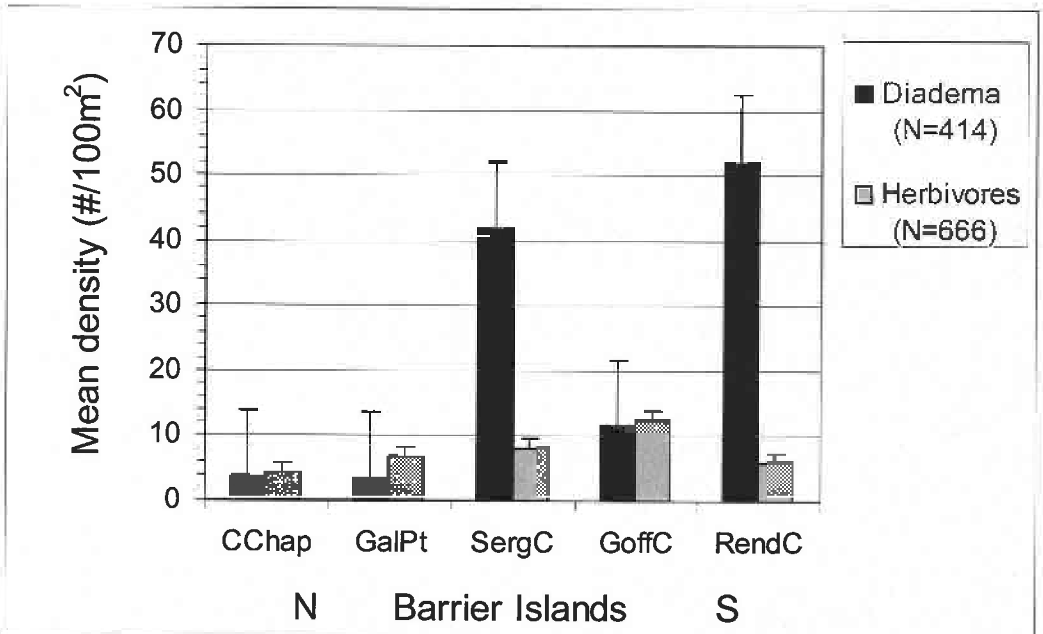


Figure 17. Mean density of *Diadema* urchin and herbivorous (*Scaridae* and *Acanthuridae*) reef fishes per barrier island (N = total # of species, bars = 1 SE).

CRITERIA ASSESSMENTS

The corals at all islands showed a low coral cover with respect to a regional scale, having <20% coral cover (Table 5). According to the Coral Abundance index (CAI), the local relative abundance of corals was common (score = 3) with at least 5-30% cover (Table 5). Rendezvous Cay had the healthiest corals, with high coral cover and minimal coral bleaching, disease and mortality (Table 5). The Shannon-Weiner Index ranged from 2.0 - 2.5 (Table 6). Cay Chapel and Gallow's Point had the poorest systems in terms of benthic cover. The reefs at these particular islands were dominated by macroalgae. They had low urchin densities and low coral cover composed mostly of the most robust coral species (Table 6). In regards to reef fish, the reefs at Goff's Cay supported the highest adult and recruit fish densities. In terms of biodiversity, Cay Chapel and Gallow's Point displayed the highest fish diversity, based on the Shannon-Weiner Index and species richness (Table 7).

Sergeant Cay has a diverse ecosystem in terms of community structure and species composition. Its benthic cover of macroalgae and turf algae, as well as high *Diadema*, has allowed for the proliferation of the robust *Montastraea* and *Porites astreoides* (Table 6). Corals are 77% healthy with mild incidences of pale coral bleaching and diseases (Table 5). The reefs also support diverse fish populations, contributing to both the carnivore and herbivore guilds, and a high fish recruit density (Table 7).

Table 5. Criteria Assessment of Status of Corals of Barrier Islands (CChap: Cay Chapel; GalPt: Gallow's Point; SergC: Sergeant Cay; GoffC: Goff's Cay; RendC: Rendezvous Cay; YB: Yellow Band Disease; BB: Black Band Disease; WB: White Band Disease; RB: Red Band Disease; PB: Purple Blotch; WP: White Plague; WPox: White Pox; DS 1/2: Dark Spots I/II; * = multiple incidence; shaded areas indicate conditions that are "not good").

Criteria	**N**		**Barrier Islands**		**S**
	CChap	**GalPt**	**SergC**	**GoffC**	**RendC**
Area Surveyed	300 m^2	300 m^2	300 m^2	300 m^2	150 m^2
1. Coral Abundance Index (5-30%)	3 (common)	3 (common)	3 (common)	3 (common)	3 (common)
2. Coral Standard (25-30%)	<15 (low)	<20 (low)	<15 (low)	<15 (low)	<25 (low)
3. Healthy (% live coral)	>70 (good)	>70 (good)	>70 (good)	>70 (good)	>80 (great)
4. Recent Dead Mortality (1%)	<1 (good)	3	<3	<2	<1 (good)
5. Old Dead Mortality (20%)	>20	>20	20	>20	<20 (good)
6. Total Coral Mortality (20%)	>20	>20	>20	>20	<20 (good)
7. Diseased (5%)	<5 (YB, DS1,BB)	<5 (YB, BB*, WP)	>5 (WB, PB, BB*, RB, WP, YB)	>5 (DS1*, WP,WPox BB, WB*)	5 (DS2, WP, PB, WB)
8. Bleached (10%)	>10 (partial)	>10 (pale)	>10 (pale)	>10 (partial)	2 (partial)

Table 6. Criteria Assessment of Status of Coral Reefs of Barrier Islands (* = Shannon-Weiner Biodiversity Index; shaded areas indicate conditions that are "not good").

Criteria	N		Barrier Islands		S
	CChap	GalPt	SergC	GoffC	RendC
1. Dominant Habitat	Macroalgae	Macroalgae	Macroalgae, Turf algae	Turf algae	Hard Corals
2. Benthic* Biodiversity	2.26	2.37	2.30	2.10	2.42
3. Dominant Coral Genera	*Montastraea*	*Montastraea*	*Montastraea*	*Millepora, Acropora*	*Agaricia*
4. Dominant Coral Spp.	*M. annularis*	*M. annularis*	*P. astreoides*	*P. astreoides*	*P. astreoides*
5. Urchin Density ($15/100m^2$)	<15 (low)	<15 (low)	>15 (high)	>15 (intermediate)	>15 (high)

Table 7. Criteria Assessment of Status of Reef Fish Populations of Barrier Islands (* = Shannon-Weiner Biodiversity Index, shaded areas indicate conditions that are "not good").

Criteria	N		Barrier Islands		S
	CChap	GalPt	SergC	GoffC	RendC
Area Surveyed	3840 m^2	3840 m^2	3840 m^2	3840 m^2	1920 m^2
1. Fish Biodiversity (S-W Index*)	2.88	2.84	2.65	2.60	2.45
2. Herbivore: Carnivore Ratio	1.075	2.21	2.54	3.64	4.14
3. Adult Fish Density ($40/100m^2$)	<40	<40	<40	>40	<40
4. Fish Recruit Density ($60/100m^2$)	<60	<60	<60	<60	<60

DISCUSSION

The reefs of the five assessed islands have always contributed significantly to the fish production of Fishery Area 5 (Appendix B). With the degradation of reefs at the northern cays due to dredging activities and coastal development, fishing effort has moved to more central and southern fishing grounds. With tourism now the primary industry in Belize, the additive impacts that this industry may pose to natural resources has become a most important issue to resource managers.

Each island has adequate representation of corals to contribute to the community structure and biodiversity of coral reefs. This central region supports low coral cover (<20%) in comparison to the Caribbean as a whole (Almada-Villela et al., 2002), but on a local scale low coral cover is common (DeVantier et al., 1998). Most corals had >70% live coral tissue on individual assessment.

Coral bleaching has been attributed to exposure to increased solar ultraviolet radiation, temperature or salinity extremes, high turbidity, sedimentation and other factors (Glynn 1993). It appears to be a generalized stress response of the coral, with some species more susceptible to bleaching than others under the same conditions. Bleaching is characterized on various levels depending on the severity of the incidence. Pale coral bleaching is merely a loss of pigmentation but tissue is still intact. This is the lowest level of severity and corals can recover their symbiotic relationship with their zooxanthellae. Less than 5% of corals were diseased, while coral bleaching ranged from 12-27%. All reefs except for Rendezvous Cay were above the coral bleaching threshold (Figure 8), suggesting that if conditions do not become favorable soon, corals will be completely bleached, initiating their partial mortality. Large coral colonies were comprised primarily of *M. annularis*, *P. astreoides* and *D. strigosa* (Figure 6). There were spatial differences in habitat dominance amongst the islands. Major habitats that were represented included those of macroalgae, turf algae and hard corals. These habitats may have contributed to the differences in composition and abundance of fish species. Most sites had very low densities of *Diadema* urchin, but two sites (Sergeant Cay & Rendezvous Cay) had higher urchin densities, indicating that a *Diadema* recovery may be occurring in these areas. Sea urchins may be influential in structuring coral communities.

All reefs had fish populations representative of biodiversity (>2.5), according to the Shannon-Weiner Index (Table 2). Foureye butterflyfish (*Chaetodon capistratus*), and the bicolor damselfish (*Stegastes partitus*), a territorial herbivore with preferences for *M. annularis* were permanent residents on all reefs (Table 3). The densities of reef fishes were low ($<30/200m^3$) at most sites (Table 2), except Goff's Cay. All reefs supported populations of herbivorous fishes, mostly *Scarids* that were greater in density to carnivores. The majority of fishes were <30 cm in body length, showing that islands are not supporting large target species. All reefs supported twice as many fish recruits than adults, except at Goff's Cay.

No site surveyed was "best" in all criteria measured, indicating a need for multiple assessment measures. Reefs were stressed in one form or another (diseases, bleaching) or below standards (e.g. low D*iadema* density). These influences are probably because of their close proximity to population centers and are thus impacted in some way as observed during surveys (Table 1).

A. PRIORITY AREAS

Priority areas are those that include healthy ecosystems worthy of preserving and conserving with sustainable use. The reefs at Rendezvous Cay are worthy of designation as a coral priority site for preserving coral diversity, maintaining coral health and cover, and potentially enhancing coral recruitment. These reefs represent the highest coral cover (22.4%) as the dominant marine benthic habitat. Corals showed the highest percent live tissue, an average of about 86.75%, on individual assessments. This percent cover of hard corals represented the highest diversity among the reefs studied. The majority of the hard corals were of *Agaricia* and *Porites* (especially that of *P. astreoides*). *Agaricia* species are highly susceptible to mortality and *Porites* are more robust to ensure some resilience in the event of impacts and stress (Goreau, 2000). *Agaricia* species are also fast-growing and fast-recruiting (McField, 1999), representing high potential for continued coral growth and recruitment. This mix in *Agaricia* and *Porites* can represent a dynamic community, where corals may have recruited on dead A. cervicornis (Aronson et al., 1998) or competed with *Acropora* for space (Curran et al., 2002). These reefs were only about 2% partially bleached and 5% diseased. Therefore, the corals can easily recover to enhance ecosystem health and eventually support viable fishery if management strategies mitigate further impacts and stress to coral reefs.

The community was composed mainly of the largest *Scarids* (21 cm) but at a very low density, probably an influence of the surrounding fishing pressure. Its herbivore to carnivore ratio shows that there is four times as much herbivores than carnivores at these reefs. This also suggests that the target carnivorous fish species may have been overfished and the herbivore guild maintaining the hard coral dominance at these reefs. The *Diadema* density was the highest at this site, suggesting very strong potential for recovery of this population to keep macroalgae dominance at a balance and enhance availability of substratum for greater coral recruitment.

A study by McField (1999) classified "affected reefs" as those affected by pale, partial and complete coral bleaching including partial coral mortality. She found that in 1995, back-reefs at Goff's Cay were "affected" by 48%, which was suggested to be fishing related. In 1996, they recovered to having only 3% (McField, 1999). In 1997, the fore-reefs at Goff's Cay were considered "non-impacted" as it reflected similar characteristics to protected coral reefs within the Hol Chan Marine Reserve (McField et al., 2001). Now, Goff's Cay has a 27% total mortality incidence (Figure 5), where recent impacts (within the past 2 years) are degrading this system. Kramer et al. (2000) wrote of the high fish density and diversity at Goff's Cay from a 2000 assessment of Mesoamerica. Therefore, the reefs at Goff's Cay can be considered a fish priority site representative of the highest adult fish density (46/100m^2) (Figure 16), with the highest herbivore density (Figure 13) and the highest fish recruit density (52/100m^2) (Figure 16). The dominant marine benthic habitat was composed of turf algae, allowing the *Acanthurids* to proliferate, which may have contributed to its large size class (21-30 cm) and a high supply of fish recruits (Figure 16). A secondary habitat was of hard corals mainly of *A. palmata*, *P. astreoides* and *Millepora* species, showing some coral diversity. Most of the 5.8% diseased corals were due to white-band disease on *A. palmata*. *Millepora* species have a high rate of recovery and *Acropora* species are usually the last coral species to be affected by impacts and stress (McField, 1999). The *Diadema* population may also be recovering (12/100m^2) (Table 2) and may potentially enhance coral recruitment and maintain macroalgae at this balance in the community structure.

Therefore, the reefs at Rendezvous Cay should be protected to maintain healthy reefs and limit fishing activities that may have depleted fish stocks. Goff's Cay should be protected to maintain its diverse and productive ecosystem, which will be important to sustain the tourism and fishing industries.

B. CRITICAL AREAS

Critical areas are those whose ecosystems are degrading and require restoration. The reefs at Cay Chapel should be protected to ensure their recovery from coral bleaching and prevent further mortality and degradation. This is essential to restore the ecosystem structure and function of these reefs. The reefs have a high incidence of long dead corals (27.4%) and 17% coral bleaching, probably due to the observed smothering of corals by sediments from surrounded turbid waters. Hard corals are mostly representative of the more robust *M. annularis*, which is a slow-growing and slow-recruiting species. It is also dominated by macroalgae with a low *Diadema* population. The fish population at Cay Chapel is low but represents an almost equal amount of herbivores and carnivores (Figure 13), where if stocks are allowed to build-up, these reefs can contribute to both fishery guilds. The herbivores are mostly *Scarids*, (Figure 10) and the carnivores are mostly *Haemulids* (Figure 13). The fish recruit density was ~50/100m^2 (Figure 16), showing some contribution to future recruitment and replenishment of stocks.

Gallow's Point is another critical area for protection due to coral degradation and impaired ecosystem structure and function. Its hard corals had the highest incidence of coral bleaching (27%), mostly in the form of complete coral bleaching (Figure 9). They also have the highest recent coral mortality at 3% (Figure 7). These impacts may be a consequence of sedimentation as Gallow's Point, which is consequently no longer a popular fishing ground. Its hard corals represent the greatest percent of the robust *M. annularis* in the region (Figure 6). This species may represent an indication of a shift in the community composition, where after long-standing impacts only robust species can recruit and colonize these reefs. Its reefs are dominated by macroalgae and its urchin density is low. Nonetheless, it supports the second highest adult fish density (30/100m^2) and high fish recruits (Figure 16). The greatest proportion of 21-30 cm carnivores observed in this study occurred at these reefs (Figure 15). However, it supports more herbivores (*Scarids*) than carnivores, which may be potentially contributing to the large size class of carnivores. These reefs may be critical to supporting viable fish populations. Management incentives such as the adaptive fishery management plan can safeguard these areas from further impacts and ensure their recovery to potentially support viable the fisheries.

RECOMMENDATIONS

A. BARRIER ISLAND MANAGEMENT

Barrier islands are geological features comprised of unconsolidated sand, arising and subsiding from the natural processes of storms, currents, winds and tides. They are mobile and ill-defined, constantly being reshaped by processes of sediment erosion and deposition (Salm, 2000). Because of their remoteness and isolation from human habitation, they are known to provide unique ecological niches. However, coastal development activities such as dredging, clearcutting of mangroves and forest, storm-water runoff and overfishing are posing threats to the natural resources of barrier islands. The central barrier islands of Belize are subject to these influences of natural and anthropogenic changes. They are surrounded by coral reefs that provide vital niches for reef fish populations. This assessment has identified levels of degradation and impacts to these barrier reef ecosystems. Management incentives to protect and conserve these systems must be designed to sustain both the natural resources and the industries that have grown to rely on these systems, mainly fishing and tourism.

With the long-term implementation of the MBRS project, regular monitoring of barrier islands can be ensured once adopted into the project as priority monitoring sites. Since the MBRS protocol was derived from other protocols used world-wide, its techniques for assessment are good to measure the conditions of ecosystems. However, careful interpretation of assessments is necessary to address the observer biases from collected data. The standardized monitoring protocol will allow for regional comparison with protected areas. The protocol allows the conditions of coral reefs to be measured, where a minimum level of assessment is ensured at small scales. It can be adjusted to meet the scale of sampling designs by increasing the number of transects. For the small scale assessment of barrier islands, the protocol did allow for assessments to be made on the conditions of coral reefs and reef fish populations.

This assessment supports other inventories of this central region of Belize. The World Wildlife Fund (WWF) Mesoamerican Caribbean Reef Ecoregional Conservation Program characterized this region as the Belize City Complex. It was determined to be a high priority site at high risk of threats to biodiversity from shipping and development. However, it also displayed a high persistence value which only requires a slight reduction of human pressure to preserve habitat quality, biota and ecosystem function (Kramer and Kramer, 2002). It is recommended that at least 20-50% of high priority sites be afforded complete protection in this area. To adhere to this recommendation, management plans should be developed for priority and critical areas identified in this REA. This will provide for some level of protection of barrier island ecosystems within the Belize City Complex. Since most reefs supported high fish recruits ($\sim 50/100m^2$) (Figure 13), management strategies will reduce impacts to these habitats and rebuild fish populations that can contribute to the fishing industry outside of protected areas. With protective measures in place, corals can also recover and enhance ecosystem health and biodiversity.

B. MONITORING PROTOCOL

1. Sampling Design

It is recommended that satellite images and GIS software be used to design strategic sampling of areas of concern for REAs. It would save time and resources from surveying the entire region solely by the manta tow survey. A stratified sampling design can be used to expand the spatial scale to include other habitats and further implementation of the MBRS protocol. After designing a strategic sampling method, the manta tow can be used to verify these sites and ensure their appropriateness for sampling techniques. Hopefully, through the MBRS Project and similar projects like that at WWF, a relationship can be established with organizations that can provide these images to be used when needed. The resolution, spatial extent and accuracy of these images will have to be verified to ensure their suitability in representing marine benthic habitats. If areas are already designated strategic sites (Cay Chapel, Gallow's Point and Goff's Cay) under the MBRS project, it would be wise to establish permanent transects at these sites where future assessments can be conducted. Baseline data then could be used to establish trends over time and space.

Since an REA is basically to establish baseline information of conditions of an ecosystem, it would be wise to ensure an equal amount of sampling for all methods. That is, if eight transects are done to assess fish populations, then eight transects to assess corals should be done over the same spatial cover. This will allow for correlations to be made between habitat quality and fish abundance. It would also be best to identify key areas in close proximity to a particular region of concern to create more of a strategic sampling design. Continuous monitoring should be based on a stratified sampling strategy, or the establishment of permanent transects so as to support future trend analysis. The sites used in this REA can be established as the permanent sites. This will offer the greatest amount of consistency and reliability with current baseline data. Sites that are randomly selected each time are considered inherently less biased; however, sampling at different sites each time may not be sensitive enough to measure change because of the patchiness of fish and habitat distribution. Thus, in establishing permanent transects, changes can be attributed to a particular patchiness or habitat distribution within transects. The use of temporary sites will require more samples to give the same level of statistical confidence as provided by repeated sampling at permanent sites (Rogers, 1995).

2. Coral Reef Assessment

To make further assessments of the reef profile, it will be necessary to extend sampling to other reef zones (shallow and deep fore-reef) to evaluate the condition of the entire system. It is important to encourage the use of the new method of estimating recent coral mortality, as stated by the MBRS Protocol. This will ensure that more detailed temporal patterns can be estimated to better understand the dynamics of coral reefs. A monitoring plan should be established to standardize frequency (annual or biannual) and time period of monitoring (preferably after August when corals spawn to monitor coral recruitment). It is important to encourage a full monitoring plan; that is, to incorporate all aspects of monitoring including coral recruitment which was not considered in this assessment due to time and resource constraints.

Visibility and water temperature at depth are always important parameters to record when monitoring. These parameters are very important to measure turbidity levels, and depth and temperature profiles which can be potential stress factors to coral reefs. Turbidity levels are reflective of surrounding dredging activities. If possible on-board CTDs can be carried that are small and efficient enough to establish profiles of conductivity, depth and temperature. These may be more appropriate for sampling deeper reef zones such as out on the fore-reef. A secchi disc may be more practicable for the shallow back-reef zone. Additional parameters may include the daily wind direction and speed, and wave heights to establish better daily conditions of days of sampling. These parameters will estimate the oceanographic influences that can be linked to fish and coral recruitment potentials. This is important to establish biological connectivity patterns amongst islands, which is essential for MPA design.

3. Reef Fish Assessment

It is always necessary to have a good "practice day" to test and standardize visual assessment strategies with field team members. This practice will improve estimates for collecting data when out in the field. The use of paperboard cutouts representing the silhouettes of common reef fish in the study area can be used in practice sessions. By varying the size to confirm accurate estimates of fish lengths. Team members can compare data after the first couple of surveys to establish some quality assurance estimates in data collection. However, continual comparing can introduce some bias against looking for rare, cryptic or unusual species. Data can also be compared with a model that standardizes real measurements of fish lengths for specific reef fishes. Also, to test observer accuracy in fish identification, enumeration and size estimation is to perform a visual census followed by complete destructive sampling of the community surveyed, in order to have a standard against which to judge the observed data. It is important to only sample at a precise time during the day to eliminate temporal variability that may affect inferences to populations. Again, permanent fish transects should be established at these sites for future assessments where trends can be based on particular patchiness and habitat distribution.

Other fisheries assessments are needed to determine fishing pressure as these islands are not with marine protected areas that would allow strict enforcement of fishing regulations. Fisheries-dependent surveys on catch and effort are required to judge the productivity of these areas on local fisheries for which the data should be specific to island areas. Social and economic data on the local fishing communities should be collected to determine the value and use of these resources to specific communities.

4. Criteria Assessment

It will also be important to follow up with the protocol and incorporate this data into the regional environmental information system (REIS) and support its further use to establish spatial and temporal trends within Mesoamerica. Figure 18 provides a guide to further assessments that will address the use and threats to these islands that need to be estimates. These data can then be presented to managers, stakeholders, policy-makers and the public to develop sound management strategies for particular areas of concern. For instance, the data from the REA can be used to determine conservation and biodiversity values of coral reefs and reef fish for which to determine critical areas to be conserved.

Eventually, as more data are compiled, scientists can use data to refine assessments of coral reef health and conditions, community structure and value to biodiversity. This can be done by incorporating the data to determine factors to qualify and quantify these values. For instance, in Indonesia, indices such as the Coral Fish Diversity Index (CFDI) and Reef Condition Index (RCI) have been established that incorporate data from monitoring techniques to qualify conditions of reefs and fish populations (McKenna et al., 2002). Assessments can also be used to determine resilience and resistance factors (West & Salm, 2003) of coral reefs as well as

Indexes of Biological Integrity (IBI) through use of reference sites (Jameson et al., 2001). With the implementation of the Mesoamerican REIS, regional assessments will be possible whereby indices will have to be established to standardize and facilitate these assessments.

MANAGEMENT IMPLICATIONS

MANAGEMENT GUIDELINES OF BARRIER ISLANDS AND THEIR REEFS

1. Long-term Monitoring Plan

To mitigate against coral reef degradation, an increase in the frequency of monitoring and assessment of coral condition, mortality, and recovery is essential to understanding the resistance and resilience factors of these systems. This can determine ecological shifts or adaptation to environmental changes from anthropogenic impacts. Continuous assessments are important to ensure regional trend analysis.

An action analysis approach was developed to provide a structural framework that can be used to further assess and evaluate the value and uses of these island resources (Figure 18). By integrating the information from this REA with the proposed general principles and guidelines as outlined in this document, management agencies can ensure that management plans or restoration plans as well as policies or zoning schemes will preserve and enhance the ecological value of these systems and ensure their sustainable use.

2. Public Awareness Campaign

It is with great urgency that the public must be informed of the importance and value of marine conservation and biodiversity of these coral reefs to coastal populations. This can be encouraged through the design of an environmental awareness campaign to address the public and stakeholders. Community participation must be encouraged in the conservation planning and management of these island resources. Promoting community outreach programs can provide extra incentives in the participation of conservation practices and stewardship. REA can prove useful to inform these interest groups about the conditions of marine and coastal ecosystems.

3. Mooring Buoy System

It is necessary to establish mooring buoy systems at sites that are most frequently used such as at Goff's Cay and Rendezvous Cay to mitigate against impacts to marine benthic habitats. These systems can be established on safe grounds (no impact to marine benthic habitats) and meet user needs. Effective and regular enforcement of regulations will ensure resources are not being overexploited and minimize induced direct impacts.

4. An Adaptive Management Strategy

This can be established with fishermen to monitor fishing pressure and trends in fish population from their catch. They must be made aware of the value of data sharing to monitoring and conservation efforts. Alternate fishing areas can be identified for the interim or until further monitoring can verify recovery of these reefs. Fishermen that use these fishing grounds can play a more active role in encouraging marine conservation and promoting biodiversity awareness to the public (tourist & other fisher) through their direct use and interactions with the users. The Fisheries Department will have to review their strategies of estimating fishing pressure and viability of fishing areas. A better reporting strategy on catch data and value of the fishing areas will have to be done per fish population, especially for areas that lack much enforcement of fishing regulations.

5. Island Development Plan

CZMAI contributed to the drafting of guidelines and polices for the development of cays. Cay Chapel, Gallow's Point and Goff's cay can be subjected to this plan if this legal document in formally accepted by the Government of Belize. These islands can also be designated as Special Development Areas under the Housing and Town Planning Act of Belize to regulate and control development, population density and waste management.

Figure 18. ACTION ANALYSIS APPROACH OF BARRIER ISLAND MANAGEMENT PLANNING

Phase I	**Phase II**	**Phase III**	**Phase IV**
Data Collection	**Data Analysis**	**Issue Analysis**	**Management Strategies**
	1. VALUES		
1. Conservation/Biodiversity: (Coral Reefs, Reef Fish, Seagrass, Mangroves) 2. Existence Values: (Cultural/Heritage, Aesthetics, Bequest)	1. Critical Habitats 2. Viable Species Populations 3. Standing Stocks 4. Social/Economic Assessments	1. Stakeholder Interests 2. Conflicts w/ Values & Uses	→ Management Plan
	2. USES		
1. Fishery: conch, lobster, finfish 2. Tourism: Diving, Snorkeling 3. Recreation: Sailing, Camping, Fishing.	1. General Use Areas 2. Priority Use Areas	1. Potential Supports (Policy/Legislative/Administrative) 2. Public Awareness 3. Community Participation	→ Protection & Restoration Plans → Draft Policies/Legislations
	3. THREATS		
1. Natural: Storms, Hurricanes, Global Warming 2. Biological: Herbivorous Fish/Inverts, Macroalgae 3. Chemical: Oil Spills, Sewage, Agricultural run-offs 4. Direct: Boat Anchors 5. Indirect: Overfishing, Coastal Development.	1. Priority Threats 2. Severe Threats	1. Rapid Assessments	→ Disaster Preparedness Plan

CONCLUSION

This Rapid Ecological Assessment of barrier islands within the Belize Barrier Reef Complex has identified coral reef priority areas and critical areas. Further regular monitoring will be necessary to confirm and track the status of these reefs to ensure the recovery of degraded reefs and depleted fish populations. These reefs have potential for recovery to a healthy status that can contribute to better community structures and enhance the biodiversity and productivity that they now represent.

Priority areas for protection (Rendezvous Cay & Goff's Cay) support adequate coral cover at healthy levels. These reefs can potentially contribute to coral reef diversity. Their coral reef ecosystems provided a good community structure molded by indicator species (*Diadema*) that can support the recovery of reef fish populations. However, these two islands are most heavily used, especially by the cruise-ship tourism industry. Management strategies will have to focus on ensuring that the carrying-capacity on these reefs is not exceeded at any one time. Public education and awareness is needed to address the value of these reefs to coastal populations for the encouragement of better conservation practices. Fishing will also have to be regulated more frequently to ensure the recovery of reef fish populations.

Critical areas for recovery include the reefs at Cay Chapel and Gallow's Point. Long-term impacts have degraded the reefs and altered the community structure, affecting the ecosystem services and functions they can provide. The reefs support vital reef fish populations that can contribute to the species richness and biodiversity of this area. Strict management strategies against dredging activities and overfishing may help restore these ecosystems and improve their conditions and functions. An adaptive strategy involving fishermen will have to be design to ensure the conservative take of fishery from these reefs and promote there high existence value, which can eventually play a key role in restoring habitats and better community structures within these coral reef ecosystems.

The recommendations made for the MBRS protocol will improve the application and implications of REAs within Mesoamerica. The refinements and complete implementation of the REA will support more assessments from which better indices can be established that can support greater management implications.

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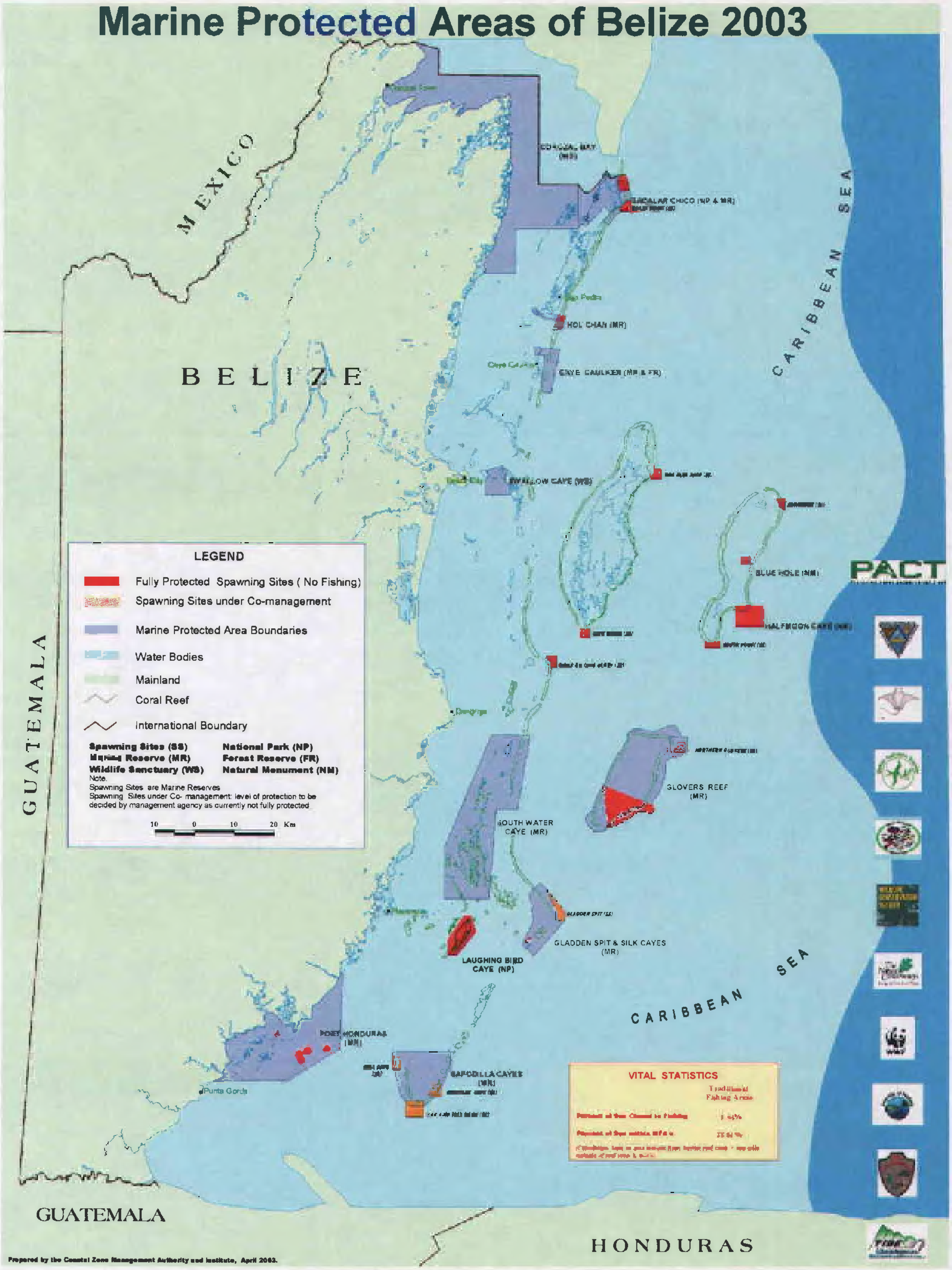
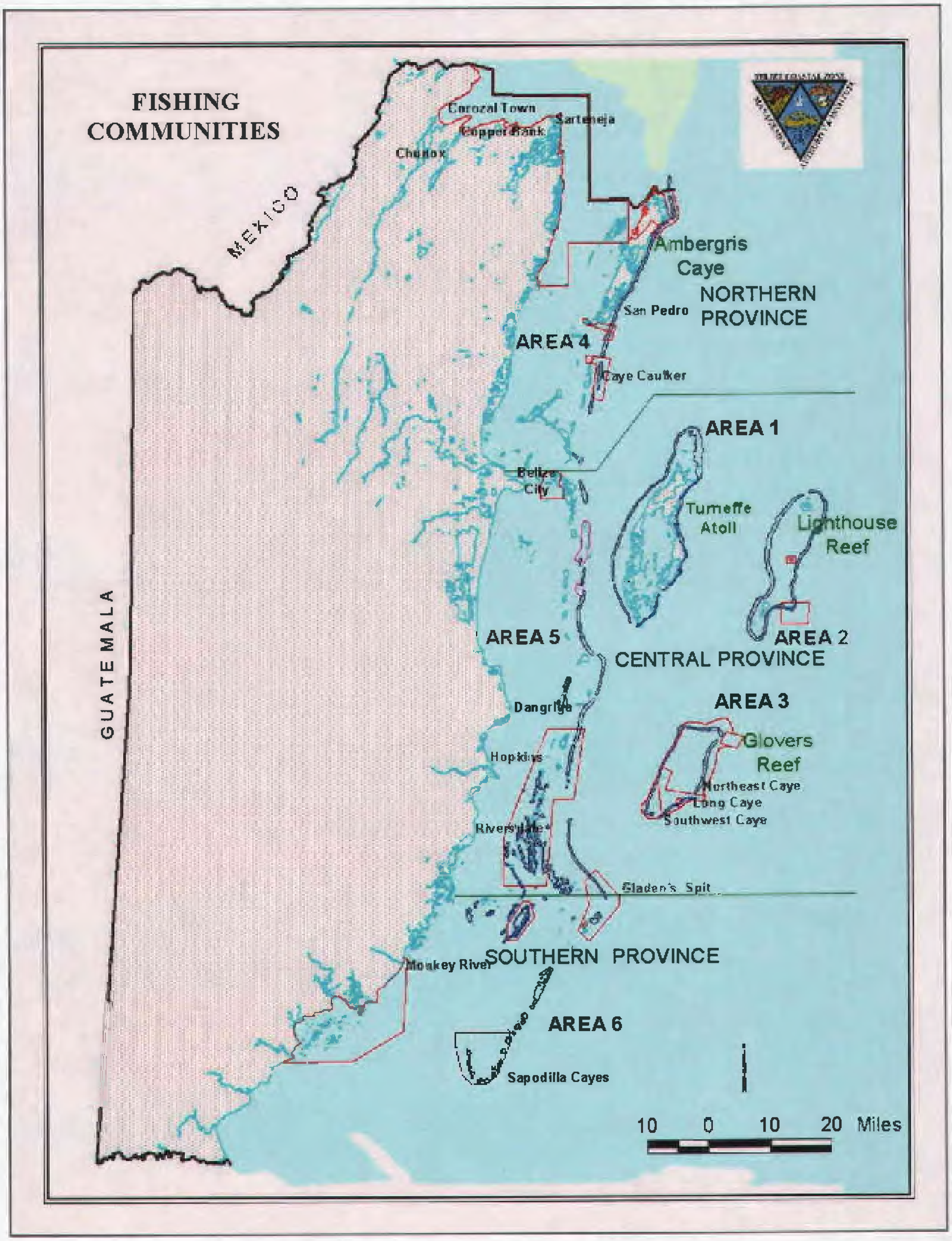
Appendix A. Map of the Marine Protected Areas Systems of Belize.

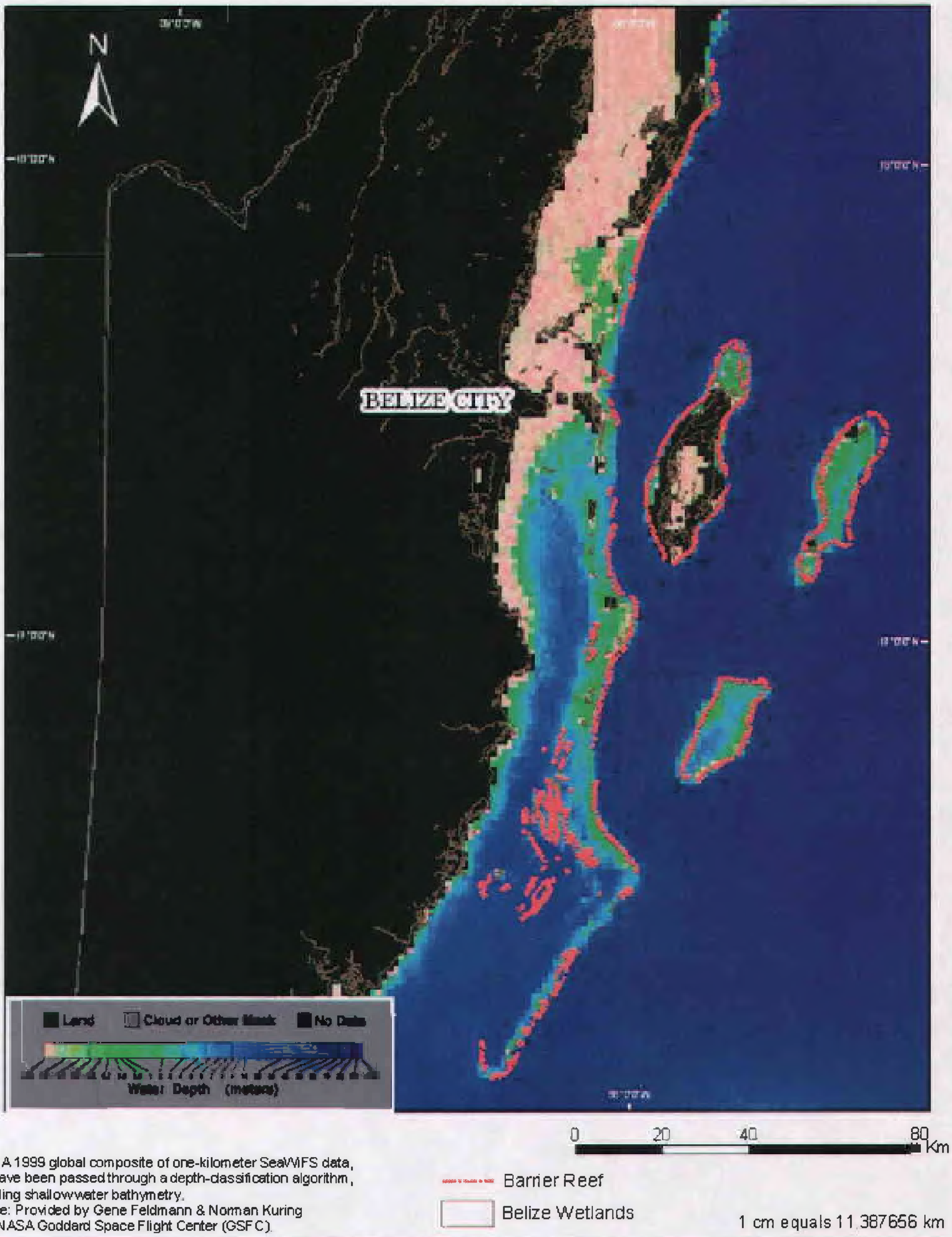


Appendix B. Map of the provinces of the Belize Barrier Reef Complex and associated fishing areas (6). MPAs are outlined in red.



Appendix C. Shallow-Water Bathymetry of Belize.

SeaWiFS Bathymetry of Belize



Data: A 1999 global composite of one-kilometer SeaWiFS data, that have been passed through a depth-classification algorithm, revealing shallow water bathymetry.
Source: Provided by Gene Feldmann & Norman Kuring from NASA Goddard Space Flight Center (GSFC).

1 cm equals 11.387656 km

Appendix D. Data sheet used to conduct Manta Tow surveys.

MBRS MANTA TOW DATA ENTRY FORM

MSMP_A1

Location:	Latitude:	Date:	Wind:
Site ID:	Longitude:	Time:	Cloud:
Recorder:	Sea:	Tide:	

Tow No.	Coral Cover		Cover	Algae	Other Features
1	Live	Dead	SC		
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
N					

Appendix E. Data sheet used in conducting Linear Point Intercept (LPI) surveys of marine benthic cover.

MBRS POINT INTERCEPT TRANSECT DATA ENTRY FORM *MSMP_1B*

Location:		Recorder:		Time:	Latitude:	
Site ID:		Date:			Longitude:	
	Points per Transect					
Benthic Components	Trans 1	Trans 2	Trans 3	Trans 4	Trans 5	Comments
Bare rock						
Sand						
Coralline Algae						
Turf Algae Macroalgae						
Dictyota (Brown algae)						
Lobophora (Brown algae) *Halimeda* (Green algae)						
Blue-green Algae						
Sponges						
Gorgonians						
Coral Genera						
Montastrea spp.						
Diploria spp.						
Porites spp.						
Agaricia spp.						
Acropora palmata						
Acropora cervicornis						
Madracis spp.						
Mycetophyllia						
Siderastrea						
Colpophyllia						
Leptoseris						
Millepora						
Other sessile fauna						

Appendix F. Data sheet used to assess health and mortality of coral colonies from linear transect surveys.

MBRS BENTHIC DATA ENTRY FORM *MSMP_1A*

Loc:	Recorder:	Water depth (start):		Time:		Latitude:	Longitude:
Site ID:	Date:	Water depth (end):		% Dead		Condition	
Tran #	Coral Species	Max Diameter (cm)	Max Height (cm)	% Old	% Recent	Disease: BB, WB, WP-II, YB, DS-I, DS-II, RB, ASP	Bleached P, PB, BL
Comments:							

Appendix G. Data sheet used to assess adult reef fishes from belt transects.

MBRS ADULT FISH DATA ENTRY FORM *MSMP_2A*

Location:		Latitude:			Date:		
Site ID:		Longitude:			Time:		
Recorder:		Transect # _______ of _______					
Families	**Scientific Name**	0-5 cm	6-10 cm	11-20 cm	21-30 cm	31-40 cm	>40 cm
ALL SPP in the following families							
Surgeonfishes	*Acanthurus bahianus*						
Acanthuridae	*A. chirurgus*						
	A. coeruleus						
Butterflyfishes	*Chaet. capistratus*						
Chaetodontidae							
Grunts	*Haemulon plumieri*						
Haemulidae	*H. chrysargyreum*						
	H. flavolineatum						
Snappers	*Lutjanus apodus*						
Lutjanidae	*Lutjanus mahogoni*						
	Ocyurus chrysurus						
Angelfishes	*Pomacant. paru*						
Pomacanthidae	*P. arcuatus*						
Parrotfish	*Sparisoma viride*						
Scaridae	*S. taeniopterus*						
ALL SPP in these genera of Serranidae							
Mycteroperca	*M. bonaci*						
Epinephelus	*E. guttatus*						
	E. fulvus						
	E. striatus						
Balistidae	*Balistes vetula*						
only these SPP	*B. capriscus*						
	Melichthys niger						
	Aluterus scriptus						
	Canther. pullus						
	C. macrocerus						
Five misc. SPP	*Bodianus rufus*						
	Caranx ruber						
	Lachnol. maximus						
	Microsp. chrysurus						
	Sphyr. barracuda						

Appendix H. Data sheet used to assess recruits of reef fishes and sea urchins from belt transects.

MBRS FISH RECRUITMENT DATA ENTRY FORM

MSMP 2B

Location:	Site ID:	Recorder:		Date:	Time:	Latitude:		Longitude:	
Species	**Common name**	**Max. TL cm**	**Trans 1**	**Trans 2**	**Trans 3**	**Trans 4**	**Trans 5**	**Trans 6**	**Trans 7**
Acanthurus bahianus	Ocean surgeon	5							
A. coeruleus	Blue Tang	5							
Chaetodon striatus	Banded butterfly.	2							
C. capistratus	Four-eye butterfly.	2							
Gramma loreto	Fairy basslet	3							
Bodianus rufus	Spanish hogfish	3.5							
Halichoeres bivittatus	Slippery dick	3							
Halic. garnoti	Yellowhead wras.	3							
Halic. maculipina	Clown wrasse	3							
Halic. pictus	Rainbow wrasse	3							
Thalassoma bifasciatus	Bluehead wrasse	3							
Chromis cyanea	Blue chromis	3.5							
Stegastes diencaeus	Longfin damsel.	2.5							
Steg. dorsopun.	Dusky damselfish	2.5							
Steg. leucost.	Beaugregory	2.5							
Steg. partitus	Bicolor damselfish	2.5							
Steg. planifrons	Threespot damsel.	2.5							
Steg. variabilis	Cocoa damselfish	2.5							
Scarus iserti	Striped parrotfish	3.5							
Sc. taeniopterus	Princess parrot.	3.5							
Spararisoma atomarium	Greenblotch parrot.	3.5							
Spar. aurofren.	Redband parrotfish	3.5							
Spar. viride	Stoplight parrotfish	3.5							
Diadema antillarum	Long-spined urchin								

Appendix I. Data sheet used to conduct Rover Diver Technique surveys of reef fish abundance.

MBRS ROVER DIVER ENTRY FORM (PART 1)

IMPORTANT: Only record species if you are certain. Use a tick √ on the left side of the column (√ S F M A) *AND* circle the relevant code. Abundance Codes: S = Single; F = Few, 2-10; M = Many, 11-100; A = Abundant, >100

MSMP_2C

Angelfish	**Eels**
_ S F M A French *Pomacanthus paru*	_ S F M A Brown Garden *Heteroconger halis*
_ S F M A Grey *P. arcuatus*	_ S F M A Goldentail Moray *Gymothorax miliaris*
_ S F M A Queen *Holacanthus ciliaris*	_ S F M A Green Moray *G. funebris*
_ S F M A Rock Beauty *H. tricolor*	_ S F M A Spotted Moray *G. moringa*
Basslets	**Filefish**
_ S F M A Blackcap *Gramma melacara*	_ S F M A Orangespotted *Cantherhines pullus*
_ S F M A Fairy *G. loreto*	_ S F M A Scrawled *Aluterus scriptus*
Blennies	_ S F M A Whitespotted *C. macrocerus*
_ S F M A Redlip *Ophioblennius atlanticus*	**Goatfish**
_ S F M A Saddled *Malacoctenus triangulatus*	_ S F M A Spotted *Pseudopeneus maculates*
Boxfish	_ S F M A Yellow *Mulloidichthys martinicus*
_ S F M A Honeycomb Cowfish *Lactoprys polygonia*	**Gobies**
_ S F M A Scrawled Cowfish *L. quadricornis*	_ S F M A Bridled *Coryphopterus glaucofraenum*
_ S F M A Smooth Trunkfish *L. trinqueter*	_ S F M A Colon *C. dicrus*
_ S F M A Spotted Trunkfish *L. bicaudalis*	_ S F M A Goldspot *Ginatholepis thompsoni*
Butterflyfish	_ S F M A Masked *C. personatus*
_ S F M A Banded *Chaetodon striatus*	_ S F M A Neon *Gobiosoma oceanops*
_ S F M A Foureye *C. capistratus*	_ S F M A Pallid *C. eidolon*
_ S F M A Longsnout C. aculeatus	_ S F M A Peppermint *C. lipernes*
_ S F M A Reef *C. sedentarius*	**Groupers/Seabasses**
_ S F M A Spotfin *C. ocellatus*	_ S F M A Black *Mycteroperca bonaci*
Chromis/Damselfish	_ S F M A Coney *Epinephelus fulvus*
_ S F M A Blue *Chromis cyanea*	_ S F M A Graysby *E. cruentatus*
_ S F M A Brown *C. multilineata*	_ S F M A Nassau *E. striatus*
_ S F M A Sunshinefish *C. insolata*	_ S F M A Red Hind *E. guttatus*
Damselfish	_ S F M A Rock Hind *E. adscension.*
_ S F M A Beaugregory *Stegastes leucostictus*	_ S F M A Tiger *M. tigris*
_ S F M A Bicolor *S. partitus*	**Grunts**
_ S F M A Cocoa *S. variabilis*	_ S F M A Bluestrip. *Haemulon sciurus*
_ S F M A Dusky *S. fuscus*	_ S F M A Caesar *H. carbonarium*
_ S F M A Longfin *S. diencaeus*	_ S F M A French *H. flavolineatum*
_ S F M A Sergeant Major *Abudefduf saxatilis*	_ S F M A Black Margate *Anisotremus surinamensis*
_ S F M A Threespot *S. planifrons*	_ S F M A White Margate *H. album*
_ S F M A Yellowtail *Microspathodon chrysurus*	_ S F M A Porkfis *A. virginicus*
Drums	_ S F M A Sailors Choice *H. parra*
_ S F M A Highhat *Equetus acuminatus*	_ S F M A Smallmouth *H. chrysargyreum*
_ S F M A Jackknife *E. lanceolatus*	_ S F M A Spanish *H. macrostomum*
_ S F M A Spotted *E. punctatus*	_ S F M A Tomtate *H. aurolineatum*
	_ S F M A White *H. plumieri*

MBRS ROVER DIVER ENTRY FORM (PART 2)

IMPORTANT: Only record species if you are certain. Use a tick √ on the left side of the column (√ S F M A) *AND* circle the relevant code. Abundance Codes: S = Single; F = Few, 2-10; M = Many, 11-100; A = Abundant, >100

MSMP_2C

Hamlet/Seabass	**Squirrelfish**
_ S F M A Barred *Hypoplectrus puella*	_ S F M A Blackbar Soldier *Myripristis jacobus.*
_ S F M A Butter *H. unicolor*	_ S F M A Dusky *Holocentrus vexillarius*
_ S F M A Black *H. migricans*	_ S F M A Longjaw *H. marianus*
_ S F M A Blue *H. gemma*	_ S F M A Longspine *H. rufus*
_ S F M A Indigo *H. indigo*	_ S F M A Reef *H. coruscum*
Hogfish/Wrasse	_ S F M A Squirrel *H. adscensionis*
_ S F M A Hogfish *Lachnolaimus maximums*	**Surgeonfish**
_ S F M A Spanish *Bodianus rufus*	_ S F M A Blue Tang *Acanthurus coeruleus*
Jacks	_ S F M A Doctorfish *A. chirurgus*
_ S F M A Bar *Caranx rubber*	_ S F M A Ocean *A. bahianus*
_ S F M A Horse-eye *C. latus*	**Triggerfish**
Parrotfish	_ S F M A Black Durgon *Melichthys niger*
_ S F M A Blue *Scarus coeruleus*	_ S F M A Ocean *Canthidermis sufflamen*
_ S F M A Greenblotch *Sparisoma atomarium*	_ S F M A Queen *Balistes vetula*
_ S F M A Midnight *Scarus coelestinus*	**Wrasses**
_ S F M A Princess *Sc. taeniopterus*	_ S F M A Bluehead *Thalassoma bifasciatum*
_ S F M A Queen *Sc. vetula*	_ S F M A Clown *Halichoeres maculpinna*
_ S F M A Rainbow *Sc. guacamaia*	_ S F M A Creole *Clepticus parrae*
_ S F M A Redband *Sp. aurofrenatum*	_ S F M A Puddingwife *H. radiatus*
_ S F M A Redfin *Sp. rubripinne*	_ S F M A Slippery Dick *H. bivittatus*
_ S F M A Redtail *Sp. chrysopterum*	_ S F M A Yellowhead *H. garnoti*
_ S F M A Stoplight *Sp. viride*	**Others**
_ S F M A Striped *Sc. croicensis*	_ S F M A Great Barracuda *Sphyraena barracuda*
Puffers	_ S F M A Chub, Ber/Yel *Kyphosus sectatrix./incisor*
_ S F M A Ballonfish *Diodon holocan.*	_ S F M A Glasseye Snap. *Heteropriacanthus cruentatus*
_ S F M A Porcupinefish *D. hystrix*	_ S F M A Redspotted Hawkfish *Amblycirrhitus pinos*
_ S F M A Sharpnose *Canthigaster rostrata*	_ S F M A Yellowhead Jawfish *Opistognathus aurifrons*
Rays	_ S F M A Saucereye Porgy *Calamus calamus*
_ S F M A Southern Sting *Dasyatis Americana*	_ S F M A Cero *Scomberomorus regalis*
_ S F M A Spotted Eagle *Aetobatus narinari*	_ S F M A Yellowfin Mojarra *Gerres cinereus*
_ S F M A Yellow Sting *Urolophus jamaicensis*	_ S F M A Sand Diver *Synodus intermedius*
Seabass	_ S F M A Sharksucker *Echeneis naucrates*
_ S F M A Creole Fish *Paranthias furcifer*	_ S F M A Silversides
_ S F M A Harlequin Bass *Serranus tigrinus*	_ S F M A Greater Soapfish *Rypticus saponaceus*
_ S F M A Tobaccofish *Serranus tabacarius*	_ S F M A Glassy Sweeper *Pempheris schomburgki*
Snappers	_ S F M A Tarpon *Megalops atlanticus*
_ S F M A Dog *Lutjanus jocu*	_ S F M A Sand Tilefish *Malacanthus plumieri*
_ S F M A Gray *L. griseus*	_ S F M A Trumpetfish *Aulostomus maculatus*
_ S F M A Lane *L. synagris*	
_ S F M A Mahogany *L. mahogoni*	
_ S F M A Mutton *L. analis*	
_ S F M A Schoolmaster *L. apodus*	
_ S F M A Yellowtail *Ocyurus chrysurus*	

Appendix J. Barrier Islands within the Central Belize Barrier Reef Complex.

Cay Chapel – a private golf resort.

Goff's Cay

Rendezvous Cay