A Management Plan For

Caye Bokel Marine Reserve
&
Dog Flea Caye Marine Reserve

World Wildlife Fund & University of Belize

WWF

September 2008

"The inevitable consequences of uncontrolled exploitation of natural resources in British Honduras make a dismal, repetitious picture. Logwood, turtle, manatee, mahogany, cacao, sponge, chicle, pine, spiny lobster, and conch have all been subjected to indiscriminate harvesting to the point where they have failed commercially or show evidence of alarming declines. We may safely predict the same fate for the grouper fishery….

-- Craig, 1968: 263 --

The Executive Summary

Caye Bokel and Dog Flea Caye Marine Reserves are small, protected areas that cover spawning aggregation sites at Turneffe Atoll. Fishermen have exploited these sites heavily. The Government of Belize created these and nine other small reserves in 2003 with S.I. #161 because of precipitous declines in some species that aggregate to spawn. Nassau grouper is the prime example. Both Reserves are Conservation 1 Zones; no extraction is allowed.

The plan's overall goal is to maintain spawning aggregations and other biodiversity within Dog Flea Caye and Caye Bokel Marine Reserves while still providing benefits to fishermen. Accordingly, patrols and surveillance have high priority, but alternative livelihoods for fishermen are emphasized also. In addition, Fisheries will issue special licenses to traditional fishermen during spawning events in April, May, and June on recommendation of Reserve staff.

The University of Belize through its field station on Calabash Caye will manage the Reserves. UB will promote research opportunities within academia especially those studying marine connectivity. UB will also develop courses -- both theoretical and practical – around marine protected areas management. Fisheries will also benefit from its partnership with a research institution. The program outlined here should take approximately 5 years. A budget for the first two years is included.

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Acknowledgements

Many, many fine people contributed to this management plan. The Spags Working Group members took time to share their expertise with me. Ms. Beverly Wade, Fisheries Administrator, and Isaias Majil were helpful and patient. Julio Maas added his energy toward the end of the process. Jan Meerman and George Hanson provided background information along with their conservation wisdom.

One of the great Belizean warriors and excellent friend Eloy Cuevas from Monkey River Village captained us successfully through some rough seas. His passion for the sea is as important as his vast repertoire of technical skills.

Craig Hayes & Turneffe Flats offered a wealth of information as well as luxurious accommodations. And Eddie, Sandy, and Gaz at the Turneffe Island Lodge provided Eloy and I with charming hospitality.

Dr.Geraldo Flowers at University of Belize somehow found time to be perpetually helpful for this project. Will Heyman and Shinichi Kobara sent maps and data. They also created the 3-D maps of Caye Bokel and Dog Flea Caye spawning sites. And Will made some excellent comments on the first draft.

Shalini Cawich and the staff at World Wildlife Fund in Belize provided unending support, and Kenneth Gale took up the banner at the end. Oak Foundation provided the funds for the project.

I thank you all.

1.0 Introduction

1.1: Background and Context:

Most of the Meso-American Barrier Reef lies off the coast of Belize; it is a hotbed of marine biology. Some of the most spectacular biological events are spawning aggregations where many large and commercially important reef fishes (especially families Serranidae and Lutjanidae) gather together at recognizable sites – often windward reef promontories with steep drop-offs – to spawn. These aggregations also take place at predictable times – within 10 days of the full moon in certain months of the year. Often several species use the same site. At Gladden Spit, for example, 38 species spawn over the course of each year's lunar cycles.

This predictability has not been lost on local fishermen. The aggregations have been heavily exploited, and many of the sites have simply disappeared. In 2003, after frantic lobbying by reef scientists, the government passed two regulations SI 161 of 2003 which creates small marine reserves at 11 spawning aggregation (spag) sites along the reef, and S.I.162 of 2003 which prohibits fishing of Nassau grouper, a fish that aggregates to spawn and whose numbers had dwindled alarmingly.

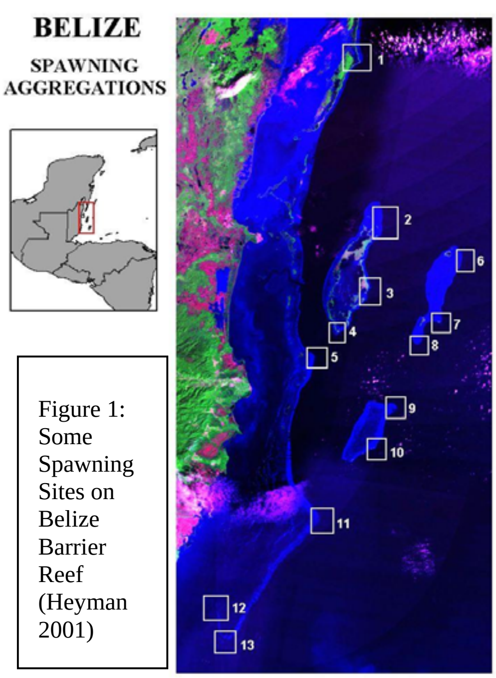

Figure 1: Some Spawning Sites on Belize Barrier Reef (Heyman 2001)

Two of the protected spag sites, Dog Flea Caye (DFCMR) and Caye Bokel (CBMR) Marine Reserves (Numbers 2 & 4 respectively on the map) are located just off the reefs of Turneffe Atoll which sits *ca.* 40 kilometers east-southeast of Belize City. These are Marine Reserves under Belize law which could fall under IUCN Category II or V. They are both expanses of open sea, 575 hectares each. Windward sides are square; leeward sides follow the edge of the fore-reef. The specific spawning aggregation site is located near the center in both reserves. Until recently, these were paper parks with no oversight or management. However, Fisheries Department and the University of Belize have recently agreed to co-manage these Reserves together.

A Project Coordinator working through the Institute of Marine Sciences (IMS) of the University of Belize is the on-ground manager through its field station at Calabash Caye. The field station lies between the two reserves – about ten miles from Caye Bokel and about 15 miles from Dog Flea Caye.

1.2: Purpose and Scope of the Plan:

Of the 11 spawning aggregation (spags) sites reserved in 2003, 8 of them are already within protected areas and are actively managed. University of Belize has recently established the Calabash Caye field station and is now ready to manage these 2 of the last 3 Reserves. This Plan for Dog Flea Caye and Caye Bokel Marine Reserves will guide activities until the end of 2012. The Plan is designed to conserve both multi-species spawning sites while encouraging fishermen to help monitor and protect the stocks.

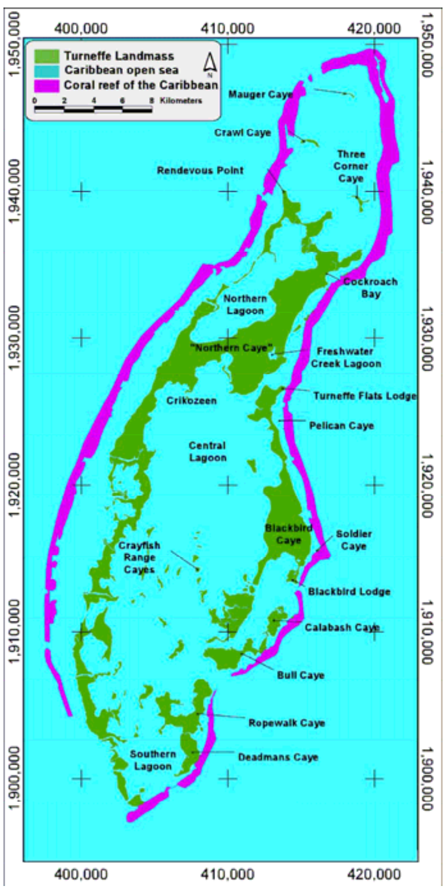

Figure 2: Turneffe Atoll, from Meerman (2006)

However, the management of these two Marine Reserves can only be effective when combined with protection of the extensive mangrove forests of Turneffe and the sea grass beds which carpet the inner lagoons. Both are nursery grounds for most of Belize's commercial species. Indeed, the close association of these ecosystems and their importance as habitats is one of the main reasons that Turneffe Atoll is ranked high on all the eco-regional programs (NPASPS Report 2005).

In 2006, Meerman and Sabido assessed the conservation value of the northern mangrove forests of Turneffe Atoll and found them of unusually high value. As a nursery ground, larvae first find shelter among sea grass blades then migrate to protective mangrove roots. Many species shelter in mangroves all the way to adulthood. Some species like gray snapper return to the sea grasses as juveniles to grow out. In addition the northern part of the Atoll has the threatened American crocodile (*Crocodylus acutus*) the white-crowned pigeon, etc. In short the entire Turneffe Atoll should be managed. This plan can act as a stepping-stone to broader protection for the Atoll even though it focuses on only two small areas.

2.0 Current Status

2.1 Location (All UTM Coordinates use WGS 84 datum)

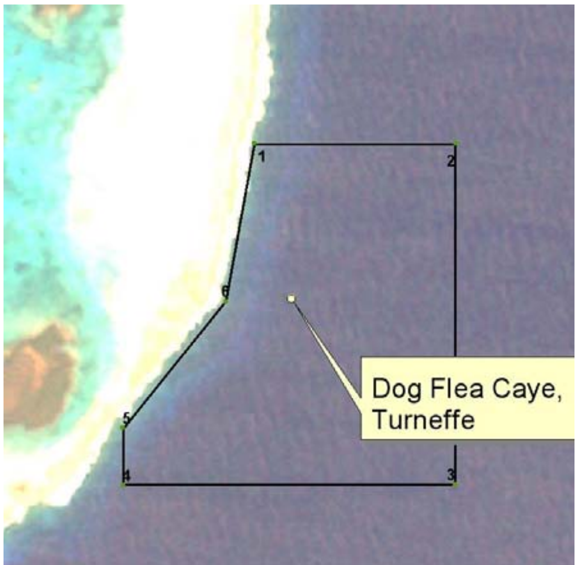

Figure 3: Coordinates of Dog Flea Caye

Dog Flea Caye, Turneffe Atoll – Commencing on the fore reef at a point 1, and having scaled UTM Coordinates 420 656 East 1 937 720 North; thence proceeding 1.02 miles in a bearing of 90 (true bearing) to a point 2, having the scaled UTM Coordinates 422 281 East 1 937 717 North; thence proceeding 1.72 miles south to a point 3, having scaled UTM Coordinates 422 277 1 934 965 North; thence proceeding 1.67 miles west to a point 4, having scaled UTM Coordinates 419 605 East 1 934 958 North; thence proceeding 0.29 miles north to a point 5, on the fore reef, having scaled UTM Coordinates 419 597 East 1 935 420 North; thence proceeding 0.82 miles on a bearing 39 (true bearing) to a point 6, on the fore reef, having scaled UTM Coordinates 420 427 East 1 936 444 North; thence proceeding 0.81 miles on a bearing of 10 (true bearing) to the point of origin, and encompassing 2.20 square miles (SI 162 of 2003).

Caye Bokel, Turneffe Atoll – Commencing at a point 1, at the steep reef drop-off in southwestern Turneffe Atoll, having scaled UTM Coordinates 401 894 East 1 897 817 North; thence proceeding 0.84 miles southeasterly on a bearing of 120 (true bearing) to a point 2, having scaled UTM Coordinates 403 049 East 1 897 140 North; thence proceeding northeasterly 1.00 miles on a bearing of 62 (true bearing) to a point 3, having scaled UTM Coordinates 404 458

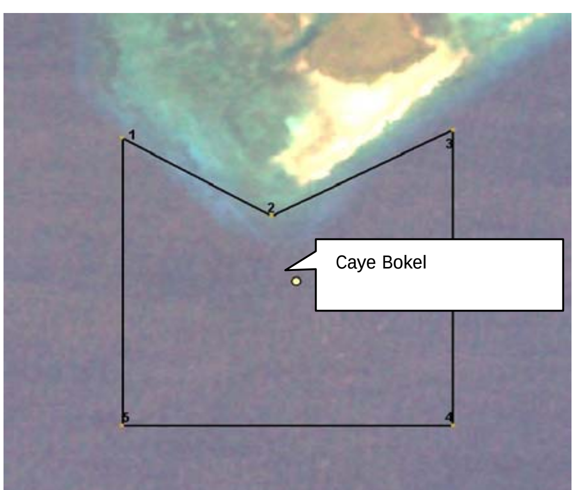

Figure 4: Coordinates of Caye Bokel

East 1 897 890 North; thence proceeding south 1.60 miles to a point 4, having scaled UTM Coordinates 404 461 East 1 895 326 North; thence proceeding west 1.60 miles to a point 5 having scaled UTM Coordinates 401 494 East 1 895 322 North; thence proceeding north 1.56 miles to the point of origin, and encompassing 2.15 square miles (SI 162 of 2003).

No village or town exists on Turneffe Atoll. UB maintains its Field Station on Calabash Caye and manages the Reserves from there. The rangers from the Reserves have a station on Calabash as does the Belize Coast Guard and several fishing camps. Little other development has occurred on Turneffe so far. Only four up-scale resorts cater to fly fishermen and SCUBA divers. However, several leases have been issued (most, illegally) during the last 8 years, and tourism development could suddenly skyrocket. About 15 active fishing camps line the east coast of Turneffe Atoll. About 50 regular and 50 part time fishermen -- mostly from Belize City, Sarteneja, and San Pedro – fish a variety of species including fish that aggregate at these two sites. Lobstermen have traditionally worked the central lagoon and back reef areas.

In addition, the Atoll is one of the finest scuba diving areas in the entire Caribbean. Dive shops from Belize City, Caye Caulker, and San Pedro have about 30 named dive sites at Turneffe mostly in the south, but some shops even dive the wall in Vincent's Lagoon. About 4,000 divers visit Turneffe every year, many of them at the Elbow (Caye Bokel). The two live-aboard dive boats based in Belize – the *Belize Aggressor* and the *SunDancer* – both visit the Elbow weekly.

2.2 Regional Context

The country of Belize is signatory to several international treaties that bear on this plan:

The Convention on Biological Diversity, Rio de Janeiro, 1995 (CBD):

CBD is a legally binding agreement opened for signature at the Earth Summit. Over 145 countries are parties. The Convention's objectives are: the conservation of biological diversity; the sustainable use of biodiversity's components; and the equitable sharing of benefits derived from genetic resources. The Convention establishes a framework of general obligations that the parties are to elaborate in more detail at the national level. Parties must create national plans and programs for conservation and sustainable use, inventory and monitor the biodiversity within their own territories, and identify and regulate destructive activities. This plan helps fulfill Belize's obligations because it is a program for conservation, establishes routine monitoring, and protects spawning sites from destruction while offering a program of sustainable use.

The Jakarta Mandate:

In Jakarta also in 1995, the Parties to the CBD agree on a program of action for implementing the Convention with respect to marine coastal biodiversity. The Mandate recognizes the utility of local technological knowledge. Indeed, fishermen have been key informants in identification of and protection of the spawning sites on the Belize Barrier Reef.

Agenda 21:

Agenda 21 is an action program for sustainable development. Chapter 17 covers protection of the oceans, and it provides support for sustainable use which is what management of the snapper spawning aggregations will allow.

United Nations Convention on the Laws of the Sea. Montego Bay, 1982 (UNCLOS):

UNCLOS establishes the legal basis by which to pursue protection and sustainable development of coastal resources, including the rights of Belize to establish Marine Reserves.

United Nations Agreement on Straddling and Highly Migratory Fish Stocks. New York 1995.

This agreement strengthens UNCLOS and calls for protection of biodiversity in marine environments and sustainable use of fisheries resources, both of which are covered in this management plan.

Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region. Cartagena (Cartagena Convention):

Protects fragile ecosystems as well as habitats of depleted, threatened or endangered species in specially protected areas. Spawning sites are unique and special habitats.

International Convention for the Protection and Conservation of Sea Turtles for the Western Hemisphere:

Promotes the protection, conservation and recovery of sea turtle populations and the habitats they depend on.

2.3 National Context

2.3.1 Legal and Policy Framework

Fisheries Department has traditionally overseen marine reserves. In 2005 a National Protected Areas System was established, its Commission and Secretariat were activated in late 2007.

S.I. 161 of 2003 establishes 11 small reserves along the Belize Barrier Reef as Marine Reserves. It goes on to say that the Reserves shall be Conservation I Zones (No Extraction), but that they "may be used for limited fishing by traditional users who are designated by…the co-managers of the respective marine reserve. Fishermen and the type and quantity of fishing so designated shall be approved by the Fisheries Administrator, who shall grant Special Licenses accordingly." The SI also states "Details of all catches made in these areas shall be submitted to the Fisheries Administrator." Finally, the Law calls for annual review of the special licenses which "shall be cancelled for non-compliance or if monitoring results determine that no fishing shall be allowed."

S.I. 162 of 2003 is the Nassau Grouper Protection Regulation. It states that " No person shall take in the waters of Belize or buy, sell or have in his possession any Nassau grouper (*Epinephelus striatus*) between the 1st December and 31st March of the following year…" S.I. 162 also makes allowance for traditional fishermen, stating that special licenses may be issued to fish Nassau grouper at two sites – Maugre Caye at Turneffe and Northern Two Caye at Lighthouse Reef. "Every catch of Nassau grouper taken from the sites … during the closed season shall be verified by a Fisheries Officer."

The Turneffe Islands Coastal Advisory Committee (TICAC), facilitated by Coastal Zone Management Authority and Institute (CZMAI), established a thorough and elaborate set of development guidelines for the entire Turneffe Atoll. The Spawning Aggregation Reserves are an integral part of that development plan.

UB & Fisheries Department have drafted a co-management agreement (see Appendix 2) to guide their relationship. The agreement also includes consultation with TICAC at every stage. The agreement outlines the joint duties of the three parties and gives authority for day-to-day management to staff of UB in consultation with TICAC.

2.3.2 Land Tenure

No land has been leased or sold within the two Marine Reserves.

2.3.3 Evaluation of Protected Area

The Belize Barrier Reef and its components figure strongly in global eco-regional plans for large international NGOs. World Wildlife Fund's Global Ecoregion #235, for example, includes the Reef and all its components notably snappers and groupers that spawn in the Reserves. The Nature Conservancy also includes Turneffe in its portfolio.

About 15 major spawning sites have been identified on the Belize Barrier Reef -- although many small aggregations may also take place. Spawning fish may only arrive in numbers once for the entire year, and that spawning session may represent its entire annual reproductive output.

The following species are listed on the IUCN Red List as of May 2005:

Critically Endangered
Epinephelus itajara (Goliath grouper)
Endangered
Epinephelus striatus (Nassau grouper)
Vulnerable
Lutjanus analis (Mutton snapper)
Lutjanus cyanoptera (Cubera snapper)
Mycteroperca venonosa (Yellowfin grouper)
Scarus guacamaia (Rainbow parrotfish)

And the following species are found on the Critical List for Belize:

Corals
Anthozoa spp.
Hydozoa spp.
Fish (in addition to above)
*Epinephelus morio (*Red Grouper)
*Epinephelus nigritus (*Warsaw Grouper)
*Epinephelus niveatus (*Snowy Grouper)

All the above species reproduce within the Reserves; in some cases the spawn represents a significant percentage of the reproductive output of local populations. Notice that these marine reserves are small and limited in habitats. The other phases of the life cycles of these fish are not protected. So functionally, these reserves help reduce one serious threat -- overfishing of adults at spag sites – but cannot conserve the species in the long term. Most researchers believe that spags species mostly self-recruit that is the larvae drop into seagrass beds and other nursery grounds within 100 km of the spawning site. However, larvae can drift for weeks, so a certain percentage of the eggs may recruit at greater distance, providing connectivity among Turneffe Atoll and other sites on the Meso-American Barrier Reef or even further away.

Just as importantly, the mangroves and seagrasses provide primary productivity. The Atoll is isolated – 8 miles outside the barrier reef and separated from it by a pelagic abyss. So the food web on Turneffe Atoll is self-sustaining, and it's built on mangroves and seagrass. Mangrove litter – leaves, sticks, and twigs -- and propagules as well as algae that grow on the roots provide plant material for herbivores. The forests support nearly all the marine life at Turneffe.

2.3.4 Socio-Economic Context

Turneffe Atoll has always been known as the Wild West of Belize, a far-off place for pirates and adventurers. Although Turneffe has no permanent community, fishers and tour operators from Belize City, San Pedro, Caye Caulker, and Sarteneja use the Atoll. Fishers have exploited Turneffe heavily, not only spags sites but also lobster and other species. Several dive shops take clients to Caye Bokel; it is considered to be one of the finest dive sites in the country. Most dive operators drift along the west face of the elbow and do little damage. Hardly any tourism takes place at Dog Flea Caye. In fact little fishing takes place there now that the spawning aggregations have declined. A few fishers use Caye Bokel regularly, and the Fisheries Department has issued up to four special licenses for snapper fishing during the aggregations in April, May, and June in 2005-2007.

Table 1: List of Stakeholders

Stakeholder	Role
Ministry of Fisheries	Regulates both fishery and protected areas. Wants maximum sustainable yield
Belize Tourism Board	Uses protected areas – especially marine – to showcase Belize's natural resources
Resort Developers	Build resorts on Turneffe which is remote and logistically challenging. Often take short cuts that impact the environment.
Fishing coops	Encourages increased catch. Speak for fishermen
Scientists at UB	Study unique system with snapper and grouper spawning sites overlying one another.
Conservation organizations	Maintain viable populations of species that aggregate to spawn.
Dive operators in Belize City, San Pedro, and Caye Caulker	Carry groups to dive, particularly at the Elbow. Also right up the eastern wall, especially in winter.

2.4 Physical Environment of Management Area

2.4.1 Climate

The following climate description is taken from the Master's thesis of Zetsche (2004):

> Tropical to sub-tropical conditions prevail in Belize, with predominant winds being north-easterly trades at 3-8 \ms (Macintyre and Aronson, 1997; Garcia and Holtermann, 1998). Predominantly easterly winds blow for most of the year at Turneffe. There is a dry (March to June) and a rainy season, with tropical storms and the hurricane season in the Caribbean (June to November) controlling the latter. Rainfall varies from year to year, ranging from 1524 mm in the north to 4064 mm in the south (Chi, 2003), and is believed to be higher on the mainland compared to the cayes. Weather patterns from October to April are dominated by the so-called `northers', peaking in activity in December and January. These cold fronts i.e.\ cold air masses from continental North America bring periods of strong northerly winds (gusts of up to 31 \ms), heavy rain and cold temperatures as low as 10ºC (Stoddart, 1962).

2.4.2 Geology

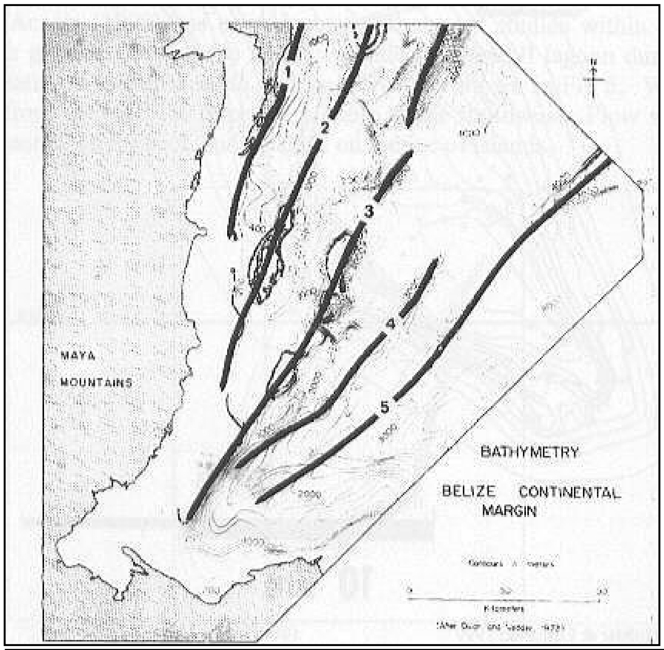

Figure 5: Undersea Ridges Underlying the Belize Barrier Reef (after James & Ginsburg 1979)

The underlying geology derives from an ancient split in the Yucatec-Honduran Block which slowly pulled apart. It opened like jaws leaving five submarine ridges; they parallel the major rivers in northern Belize and are thought to be fault controlled (James and Ginsburg, 1979). The first three of the five ridges form the foundation for the barrier reef platform. The best-developed ridge forms the southern edge of the continental shelf and extends north, becoming the foundation for Glover's Reef and Lighthouse Reef; the depth reaches 3,000 m on the east side. The most poorly defined ridge makes up the northern part of the barrier reef in Belize and Ambergris Caye. The bases of the ridges are believed to be of continental origin as they are thought to consist of material very similar to that of the Maya Mountains. Drilling has shown that much of the relief on these ridges is due to coral growth.

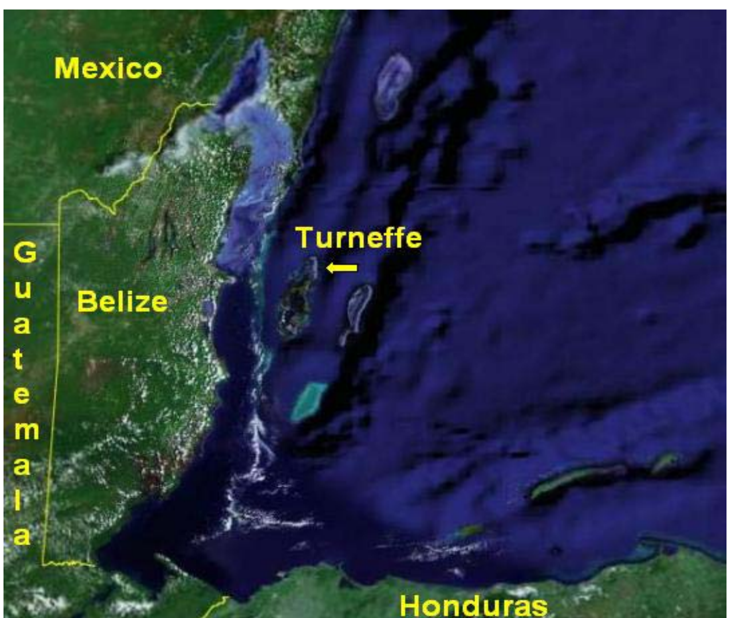

Figure 6: Satellite image showing deep trenches between the ridges

The ridges run NE to SW, the fourth and fifth dropping down the eastern wall of the Cayman Trench that reaches depths of 7.5 kilometers. The ridges show up quite clearly in satellite images. The wiggly black lines in Figure 6 are deep valleys between the ridges.

Turneffe Atoll sticks up like an enormous limestone post made of limestone – old reef – on the second ridge. It grew upwards as sea levels rose. It is roughly lens-shaped, with a maximum length of 50 km and a width of 16 km at its widest point. Turneffe is separated from the barrier reef by a 10-16 km wide, 275-300 m deep channel. It is bounded by a drying reef to the north and by Bokel Caye to the south. There is a well-defined narrow reef on the windward, eastern side. The reef crest is narrow and fringes the outer edge of a reef-flat less than 400 m wide. The reef is highly segmented, with about 23 gaps, or channels, most of which are less than 50 m wide and 6 m deep.

2.4.3 Bathymetry

Both sites carry the typical topography of spawning aggregation sites. A pointed shelf at about 20-30 m protrudes from the fore reef dropping off steeply on both sides. A joint effort by The Nature Conservancy and Texas A&M University has yielded underwater, 3-D maps of the spawning sites at both Marine Reserves. Shinichi Kobara, a graduate student of Dr. William D. Heyman, prepared these beautiful maps.

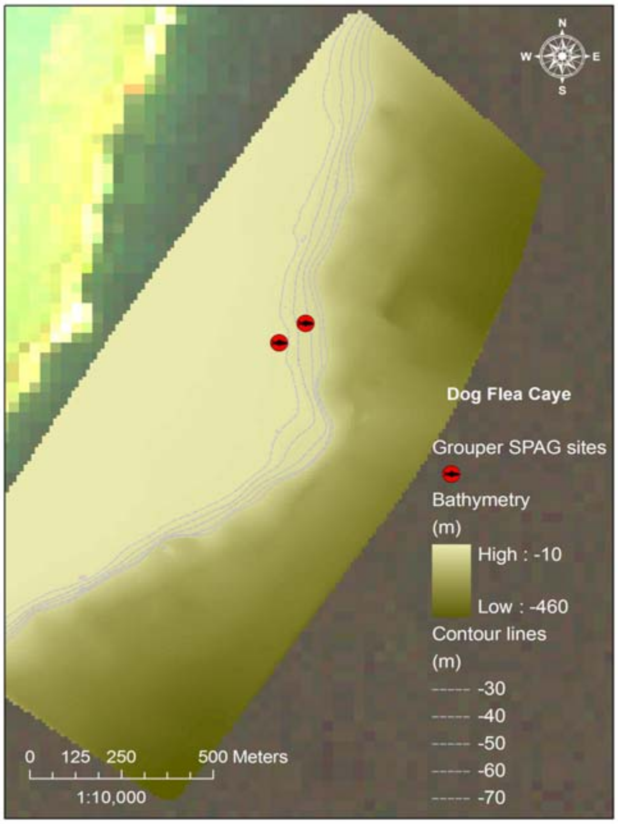

Fig 7a: Bathymetry of Dog Flea Caye Site

Figure 7b: 3-D Image of Dog Flea Caye Spawning Site (contour line is at 30m.)

The centers of spawning activity at Dog Flea Caye lie on the edge of a narrow shelf on a windward reef promontory. The sides of the point drop off very steeply. The shelf is tucked in the corner formed by the promontory and the reef itself. This site is much less exposed that the Caye Bokel site.

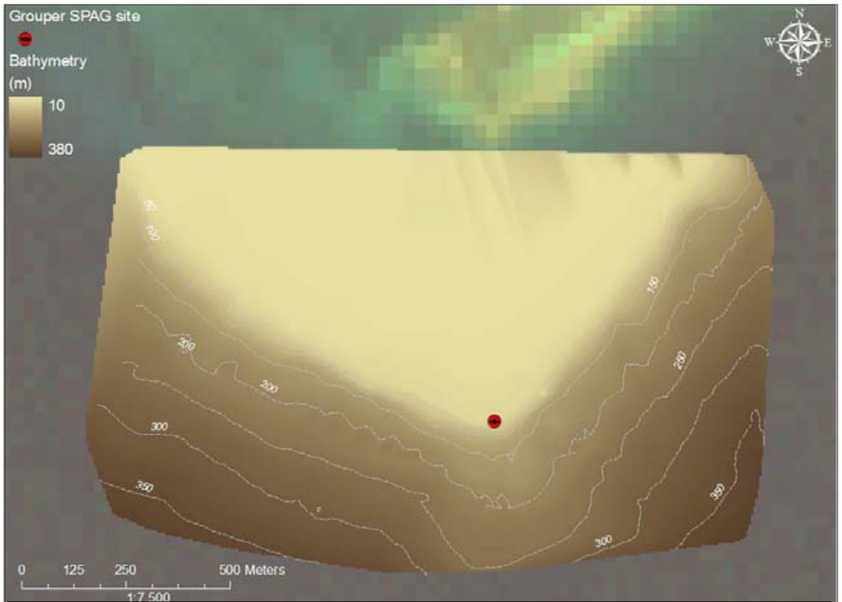

Figure 8a: Bathymetry of Caye Bokel Site

Figure 8b: 3-D Image of Caye Bokel Spawning Site

At Caye Bokel, the site sits on the windward edge of the promontory near the point. As at all sites, the sides drop off very steeply into the deep. Here the spawning site is more exposed to the prevailing winds.

2.4.4 Tides and Water Movement

Along the coast of Belize, wind-generated currents are more influential than tidal currents. Inside the barrier reef, the prevailing currents are southerly. Seaward of Turneffe Atoll, winds are northerly (1 m s^{-1}), but part of the current flows westward around the northern part of the atoll, creating a southerly drift along the leeward side. Inside the atoll lagoons, water currents flow west, creating a westward drift; the flushing rate is quite poor. Stoddart (1962) observed a large N/S-oriented drift on the eastern side of Calabash Caye, between the sandy ridge shoreline and the fringing reef at the front. Tides are generally less than 0.5 m and on the atolls further reduced to no more than 0.3 m, however, they may reach 0.8 m during northers (Garcia and Holtermann, 1998).

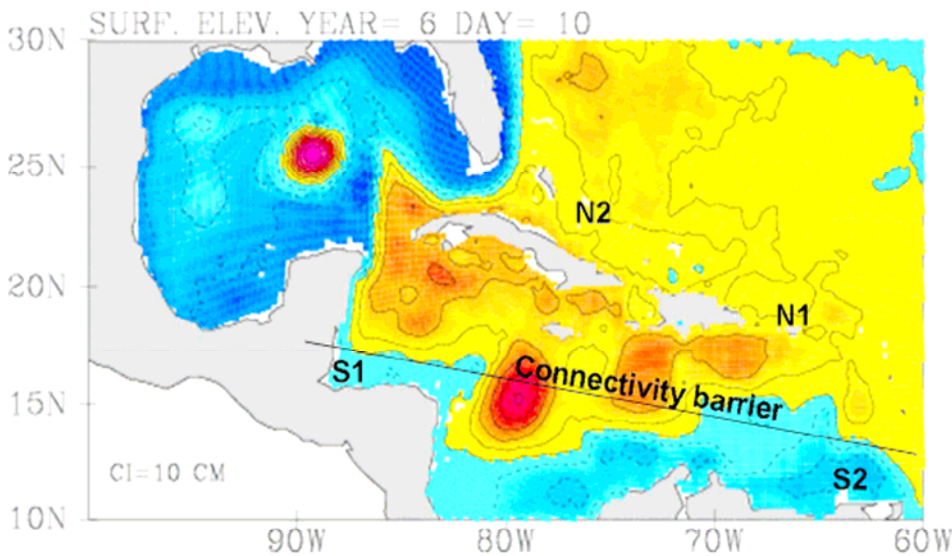

Figure 9: Connectivity Barrier Hypothesized by Heyman et al. (2007)

. Shown is an example of a synoptic sea surface height field with blue/red shades represent low/high values (from the Ezer and Mellor, 2000 model). A barrier to connectivity may be created along the MBRS where cyclonic eddies diverge from anti-cyclonic eddies. Inter-reef connectivity is likely to be enhanced within northern (N1 and N2) and southern (S1 and S2) regions, while inter-reef connectivity across the boundary is likely to be reduced or halted. These hypotheses can be tested using analysis of mitochondrial DNA.

Heyman et al. (2007) use sea-surface-height analysis to postulate that a counter-clockwise gyre creates a barrier to connectivity that slices across the Caribbean creating two compartments. This barrier touches the Belize Barrier Reef between Tobacco Caye and Caye Emily. They tested current flow on either side of their hypothesized line and found currents flowing in opposite directions.

Turneffe Atoll has affected the very structure of the Belize Barrier Reef. The central region is continuous and well-developed. It has a certain form – back reef, reef crest, fore reef with extensive spur and groove formation, and an outer fore reef that has a sand trough and coral ridge. Burke (1982) claims that these structures can only develop in areas protected from long-period, storm waves generated by prolonged and severe winter storms (see Figure 10). Belize's three atolls create a wave shadow that protects the central region of the reef. "Where open ocean waves have full access to the Barrier Reef, durable and slow-growing communities dominate, and shallow water reefs are narrow and discontinuous" (Burke, 1982).

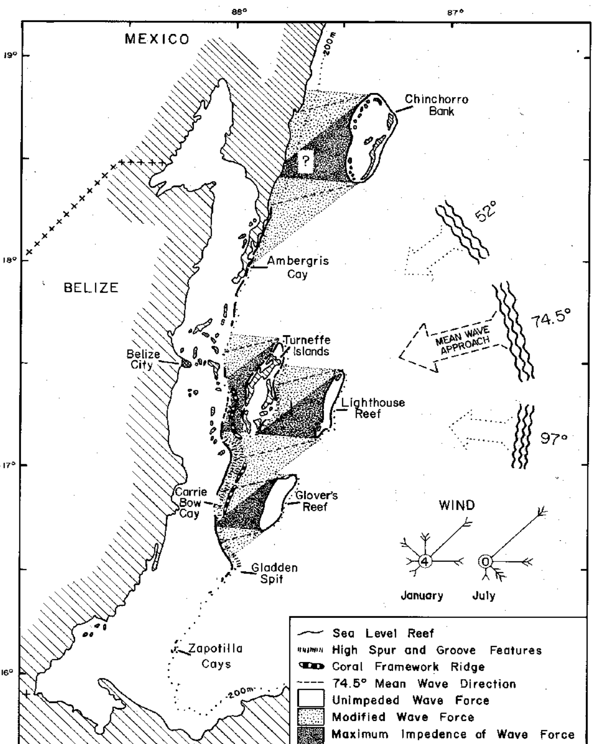

Figure 10: Wave shadows on Reef from Burke (1982)

2.4.5 Water Parameters

Surface water temperatures were recorded in the shelf lagoon near the barrier reef in July and August 1991 (29°C and 30°C), and the bottom temperature was 0.5-1.0° colder. Average oceanic surface temperature off the coast of Belize ranges from 25.5°C in February to 28.5°C in August. as well as a mean cumulative rainfall of 1901 mm and 1847 mm for 1996 and 1997 respectively. Previous rainfall figures recorded in the summer months by Stoddart (1962) showed a considerable variation (558mm in 1937, 379 mm in 1938, and 121 mm in 1939).No cold-water upwellings, which may alter seawater temperature, are known to occur in Belizean waters, although there are some farther north, off the Yucatan Peninsula (Stoddart, 1962). Normal seawater salinities of 35-37 ‰ have been recorded offshore, approaching the barrier platform (Zetsche 2004).

2.5 Biodiversity of Management Area

2.5.1 Ecosystems

Both Marine Reserves have their landward edge on the fore reef. They include any shelves that have formed on the fore reef and then cover pelagic open ocean. So both Reserves have only a single ecosystem – Caribbean Coral Reef (Ecosystem #78 in Belize's Classification). Please note that Turneffe Atoll as a whole was the highest rated gap in the protected area system mainly because of potential linkages with the nearby mangrove forests and seagrass beds.

Belize Code #78: (S.A.1.d.(2).) Caribbean Coral Reefs

> The Belize Barrier Reef is the largest in the Western Hemisphere. It extends for approximately 220-250 km. To the east of the barrier reef lie three coral atolls separated from the barrier reef by water 360 – 1,100 m deep. Fringing reefs are restricted to the coastal area of the south of Belize. Although vegetation is not the main component of the reef, the reef is a very important ecosystem in Belize. A total of 65 coral species have been identified for Belize including 53 reef-building species.(Meerman & Sabido 2001).

2.5.2 Flora

The Reserves cover two very specific marine formations which are composed of coral. Although a few marine plants undoubtedly exist, their presence is not ecologically significant. One exception is macroalgae which may provide shelter for grouper larvae and juveniles. The other significant plant group consists of the algal symbiotic companions to the corals.

Coral reefs are the most diverse and beautiful of all marine habitats. The development of these structures is aided by algae that are symbiotic with reef-building corals, known as zooxanthellae. Coralline algae, sponges, and other organisms, combined with a number of cementation processes also contribute to reef growth. The dominant organisms are known as framework or reef builders, because they provide the matrix for the growing reef. Many grow in colonies or sheets facing the sun and secrete a substance which hardens to limestone beneath and around them. This is the same substance that chalk, teeth, and bones are made from. Thus, the corals themselves build the rocks that they cover. Although the entire coral reef looks like a lot of large rocks, the top surfaces are actually covered with new coral colonies that are actually very much alive. The brain coral, for example, has a very clear pattern where the polyps make little cup-like indentations to make shelter for themselves. Sheets of these tiny builders constructed all the huge reefs in the world. Coral polyps build coral reefs very slowly. Although it depends on the type of polyps and the place where they are growing, it takes about 250 years to build one single meter of a coral reef. Some of the world's largest coral reefs began to form 450 million years ago.

The reef is topographically complex. Much like a rain forest, it has many strata and areas of strong shade, cast by over-towering coral colonies. Because of the complexity, thousands of species of fish and invertebrates live in association with reefs, which are by far our richest marine habitats. In Caribbean reefs, for example, several hundred species of colonial invertebrates can be found living on the undersides of platy corals. It is not unusual for a reef to have several hundred species of snails, sixty species of corals, and several hundred species of fish. Of all ocean habitats, reefs seem to have the greatest development of complex symbiotic associations.

Tropical ocean waters are very clear because they are very clean. Food is concentrated in some places like coral reefs. Since fish can swim, they can move around to find and capture food. Sessile creatures that grow stuck to rock and wood can't move and have to find novel ways to survive.

Corals are tiny polyps with tentacles. Polyps are soft-bodied animals that are related to sea anemones and jellyfish. They are invertebrates, meaning they have no backbone since they don't have any skeleton.

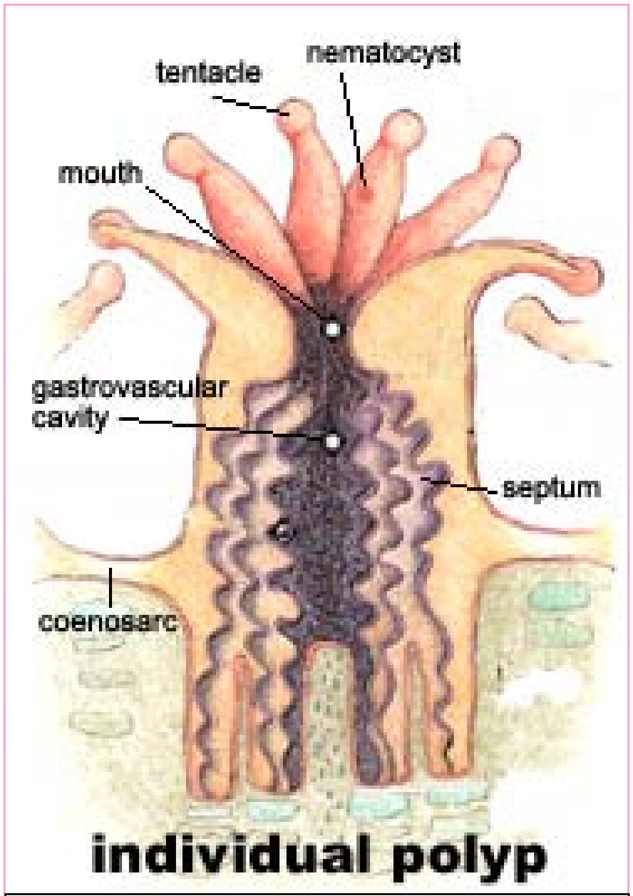

Figure 11: Structure of Typical Coral Polyp

Coral polyps grow larger in number by reproducing asexually. This simply means they divide themselves into two identical parts. One part stays in it old cup, and the other creates a new one, making the colony larger. This process of growth and reproduction is very slow. Coral heads grow at a rate of 1/2 to 5 inches per year. Coral polyps also reproduce sexually, and this is how they release new colonies. The polyps release eggs and sperm into the water. Fertilized eggs then drift to the ocean currents. If they land in a suitable place to live, a new colony will begin to grow from each fertilized egg.

The polyps stretch their bodies out and use their tentacles to capture food. They prey on zooplankton – tiny animals that float around the ocean, many of which are larvae or early life stages of creatures that we recognize – lobster, conch, snappers, and many others. This food is rich in protein, a building block of living tissue. But because the waters are so clean, the corals can't really survive on zooplankton alone. Instead, corals have a tiny plant that grows inside them, an alga (also known as a phytoplankton). Plants grow by photosynthesis, taking the sun's energy and making sugar. So the little plant feeds the coral polyp sugar to make energy, and the coral shares its protein with the plant so it can grow and repair itself. Alone they can't survive; together they live large.

Corals and their reefs only grow where light can penetrate because of the tiny plant. As for other growth requirements, some corals require full salinity of open oceans. Other species of coral can tolerate diluted seawater – low salinity -- as would occur near river mouths. These corals flourish on fringing reefs. Another kind of coral grows into leaf-like fans that wave gracefully on the bottom -- gorgonians. They are similar to hard corals, but they feed during the day. Hard corals generally come out at night. Soft corals do not build reefs. They secrete a flexible or soft skeleton which enables them to bend or sway in the water. Soft corals thrive in strong currents where they have access to lots of plankton.

Since corals grow in sheets, any sediment in the water can settle on them. So corals secrete a special mucus over their entire surface that traps any dirt or sand. Small cilia or hairs move the mucus slowly, removing any sediment and keeping the surface clean. This mucus layer is crucial to the survival of the colony.

Corals are a highly specialized species with a low reproductive rate, a small population size, and high rates of in-breeding. The specialization allows them to maintain maximum competitive advantage over their neighbors. Their response to unusual events is poor, but their precise specialization allows them to win out when conditions return to normal.

Corals have a variety of strategies for reproduction. Some are hermaphroditic; some maintain separate male and female colonies. Fertilization is internal in most corals. Spermatazoa swim in through the mouth and enter the gastric cavity to fertilize the eggs hanging by the mesenteries. The larvae mature inside the polyp. They remain attached to the septa breaking free and swimming out of the mouth when they reach maturity. Some species release larvae in bursts, others all year round.

Most larvae are consumed right away by predators. First they swim upward to the light using cilia for propulsion. After a few days, they reverse and swim downward, eventually settling on the bottom to become polyps and begin a new colony. This occurs only if the larvae land on a suitable stratum – hard, clean, silt-free bottom. Larval dispersal is the main force in the spread of coral. However, there must be a balance between the amount of energy available for dispersal and the amount left over for growth and survival of the new colony. The larvae can drift for 17-25 days. Thus they can be potentially distributed over vast distances. This connectivity is crucial here in the age of global warming and coral death.

Coral Bleaching:

Corals only grow at tropical temperatures. Indeed, corals are very sensitive to temperature. They can't tolerate temperatures much below 60•F or above 85•F. At elevated temperatures, the zooxanthellae exude chemicals that irritate its coral host. Eventually, the coral expels the alga. This leaves the coral colorless and transparent, a process known as coral bleaching. In many cases the alga returns after the temperature goes back down. But many corals die after bleaching.

Major coral bleaching events have occurred throughout the tropics during the last 25 years, and many reefs in the Caribbean bleached repeatedly throughout the 1980's and early 1990's. The reefs of Belize did not suffer a widespread bleaching event until the summer of 1995. At the time of mass bleaching water temperature and solar radiation were elevated and wind speeds were low. In October-November 1995, 52% of corals surveyed were affected by bleaching, compared to only 7% in May 1996. No spatial trends were found, although some taxa had significantly different levels of bleaching at different depths.

There was a significant difference in the extent of bleaching between corals reported to host different clades of zooxanthellae. By May 1996, 25% of the originally bleached, tagged specimens experienced at least partial tissue mortality. It is estimated that approximately 10% of all coral colonies experienced some partial tissue mortality by May 1996 as a result of this bleaching event. Such bleaching-induced partial tissue mortality may decrease the structural integrity of the reef framework and decrease the ecological competitiveness of corals and other symbiotic reef organisms. (McField 2000).

In 1997 –98, the highest sea-surface temperatures ever recorded caused severe coral bleaching worldwide. In Belize mass coral bleaching was evident in both fore reef and lagoonal environments during the summer and fall of 1998. In late October 1998, just a few months after peak bleaching temperatures, Mitch a Category

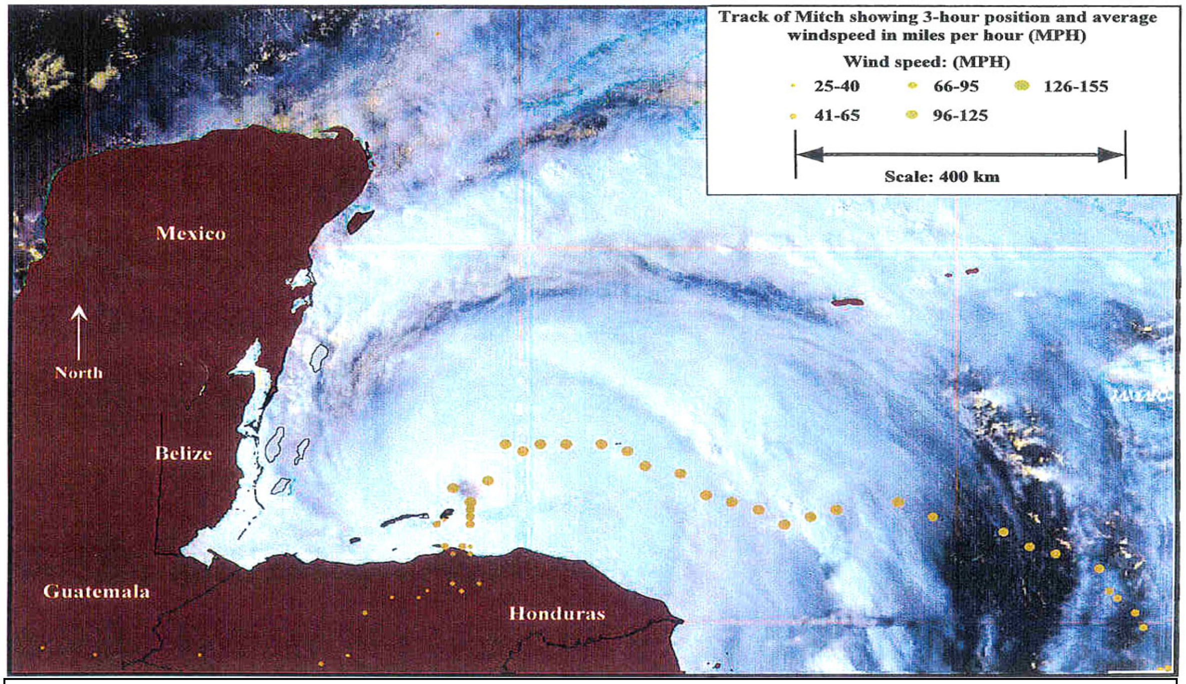

Figure 12: Track of Hurricane Mitch (Kramer & Kramer 2001)

V Hurricane swooped into the Gulf of Honduras and stopped. The storm sat off the coast of Honduras for two days and pounded the Reef before slipping slowly onto the mainland and destroying 50% of the infrastructure of Honduras and Nicaragua -- 11,000 dead and 2,000,000 homeless.

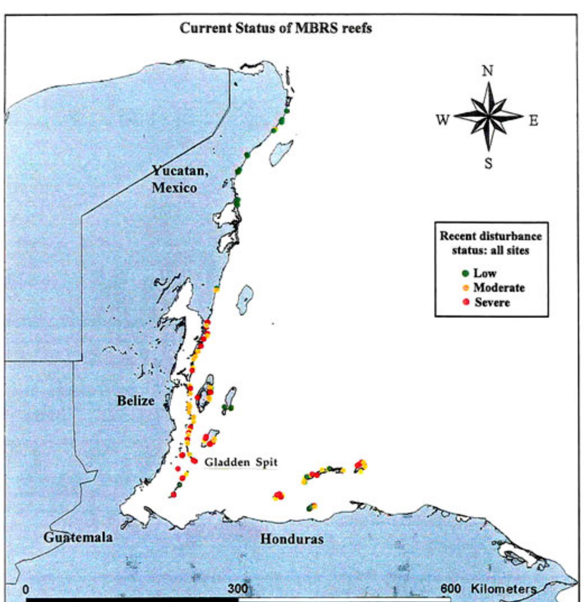

Figure 13: Hurricane Damage from Mitch (Kramer & Kramer

In Belize the storm tide of Mitch reached 2.8 m, and damage to coral was extensive -- up to 29% of colonies surveyed in 1999 remained damaged (Kramer & Kramer 2001). However the main impact of the storm was physical damage to reef structure since bleaching mortality was already widespread by the time the storm passed through. Secondary effects like sediment runoff

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are incalculable (Kramer and Kramer, 2001).

The cumulative effect of the 1998 stresses will have long-term ecological consequences for the entire region. Coral mortality was extremely high -- 49% for shallow reefs and 33% for deep reefs (See Figure 9). Spur and groove formations along the reef were wholly or partially devoid of living *Agaricia tenuifolia* and *Porites porites* (the other common constituent of these spurs) because the blades of the former and branches of the latter had been sheared off. Damage was patchy within and among spurs. In shallower water, living and dead *Acropora palmata* had been broken off and moved around, causing further damage (Kramer & Kramer 2000). The extensive loss of reef-building species (*Agaricia tenuifolia, Millepora complanata, Diploria spp. and Montastrea spp.)* combined with increasing effects of global warming is of particular concern (Kramer & Kramer 2001).

Baseline Coral Data:

In March 2007, World Wildlife Fund carried out a survey of the two Marine Reserves in order to establish baseline values for the biodiversity. They used a modified AGRRA protocol that aligns with MBRS Synoptic Monitoring System.

Table 2: Caye Bokel: % Coral Cover (April 2007)				
	Caye Bokel - Shallow		Caye Bokel – Deep	
Type of Cover	Inside Reserve	Outside Reserve	Inside Reserve	Outside Reserve
Mean Coral	11.9%	6.5%	22.7%	7.5%
Mean Macroalgae	10.2%	11.0%	16.9%	17.7%
Mean Coralline	9.6%	27.5%	4.6%	10.6%
Mean Sponge	6.7%	6.0%	20.6%	3.5%
Mean Turf	35.0%	19.0%	--	--

At Caye Bokel, percent coral cover inside the Reserve was higher than outside in both back reef and fore reef. High percentages of turf cover the back reef.

Table 3: Caye Bokel: Coral Types (April 2007)				
	Caye Bokel - Shallow		Caye Bokel – Deep	
Hard Corals	Inside Reserve	Outside* Reserve	Inside Reserve	Outside Reserve
Total N	57	31	109	36
Diploria	12.3%	3.2%	11.9%	11.1%
Porites	8.8%	9.7%	20.2%	11.1%
Millepora	42.1%	25.8%	13.8%	13.9%
Siderestrea	28.1%	22.6%	10.1%	11.1%
Agaricia	--	9.7%	13.8%	27.8%
Acropora	--	--	0.9%	5.6%
Myctephyilla	--	--	1.8%	--
Leptoseris	--	--	0.9%	--
Montastrea	8.8%	29.0%	26.6%	19.4%

* This site is actually just inside the boundary of Caye Bokel Marine Reserve in shallow back reeef.

Millepora is common on both back reef and fore reef. Montastrea is very common on the fore reef along with *Agaricia*.

Dog Flea Caye Marine Reserve: Baseline Coral

Table 4: Dog Flea Caye: % Coral Cover (April 2007)				
	Dog Flea Caye - Shallow		Dog Flea Caye – Deep	
Type of Cover	**Inside Reserve**	**Outside Reserve**	**Inside Reserve**	**Outside Reserve**
Coral	**8.8%**	**7.9%**	**15.6%**	**6.9%**
Macroalgae	**15.4%**	**16.3%**	**37.5%**	**39.7%**
Coralline algae	**20.8%**	**20.2%**	**13.6%**	**15.8%**
Sponge	**3.1%**	**2.3%**	**7.2%**	**5.6%**
Turf	**32.3%**	**25.6%**	**21.4%**	**30.3%**

Dog Flea Caye is in an isolated area and unlikely to be subject to human impacts. Yet back reef and fore reef, inside and outside the Reserve, all have low percent coral cover. In addition, all sites have high percentage turf.

Table 5: Dog Flea Caye: Coral Type (April 2007)				
	Dog Flea Caye - Shallow		Dog Flea Caye – Deep	
Hard Corals	**Inside Reserve**	**Outside Reserve**	**Inside Reserve**	**Outside Reserve**
Total N	**28**	**27**	**36**	**16**
Diploria	25.93%	7.14%	0.00%	12.50%
Porites	14.81%	10.71%	5.56%	31.25%
Millepora	7.41%	17.86%	11.11%	12.50%
Siderestrea	7.41%	28.57%	27.78%	12.50%
Agaricia	18.52%	7.41%	27.78%	--
Acropora	--	--	--	--
Myctephyilla	--	--	--	--
Leptoseris	--	--	--	--
Montastrea	18.52%	28.57%	27.78%	31.25%
A. palmata	7.41%	--	--	--

Montastrea covers the highest percentage at three of the sites and sits high on the fourth.

2.5.3 Fauna

In March 2007 along with the coral monitoring, WWF undertook a baseline study of the fish communities in the two Reserves.

Caye Bokel Marine Reserve – Baseline Fish Data:

Table 6:Caye Bokel: Fish Density (#/100m²) March 2007				
	Caye Bokel - Shallow		**Caye Bokel – Deep**	
Type of Fish	**Inside Reserve**	**Outside Reserve**	**Inside Reserve**	**Outside Reserve**
Surgeon Density	7.17	10.17	9.50	7.33
Parrot Density	9.00	8.00	3.67	5.17
Grunt Density	15.50	29.83	1.50	17.67
Snapper Density	6.83	7.50	1.83	17.67
Grouper Density	1.00	0.67	0.33	2.17
Angel Density	0.83	0.83	0.17	0.83
Butterfly Density	3.00	4.00	5.33	4.50
Leatherjack Density				
Density of all others	0.33	7.33	3.00	1.17

At the back reef of Caye Bokel, fish densities were similar inside and outside the Reserve except for the grunt family which was depleted by 50% within the Reserve. In the fore reef, grunts, snappers, and groupers were severely depleted within the Reserve.

Table 7: Caye Bokel: Fish Biomass (g/100m²) March 2007				
	Caye Bokel - Shallow		**Caye Bokel – Deep**	
Type of Fish	**Inside Reserve**	**Outside Reserve**	**Inside Reserve**	**Outside Reserve**
Surgeon Biomass	290.20	402.40	536.30	561.12
Parrot Biomass	578.09	543.77	479.57	633.64
Grunt Biomass	864.70	1757.96	32.82	1583.56
Snapper Biomass	295.60	583.50	59.88	383.45
Grouper Biomass	32.83	73.91	10.94	65.38
Angel Biomass	92.90	157.65	19.56	270.72
Butterfly Biomass	79.01	84.31	126.26	155.92
Leatherjack Biomass				
Biomass of all others	28.94	311.87	151.08	80.87

In the back reef area, biomass was lower inside the Reserve for all families except the parrot fishes. Evidently, fish within the Reserve are smaller than their counterparts outside. In the fore reef, several families – grunt, snapper, grouper, and angel – exhibited very large increases in biomass outside the Reserve.

Distribution and frequency of the main fish groups

Figure 14: Caye Bokel:
Inside Reserve Back Reef (Shallow)

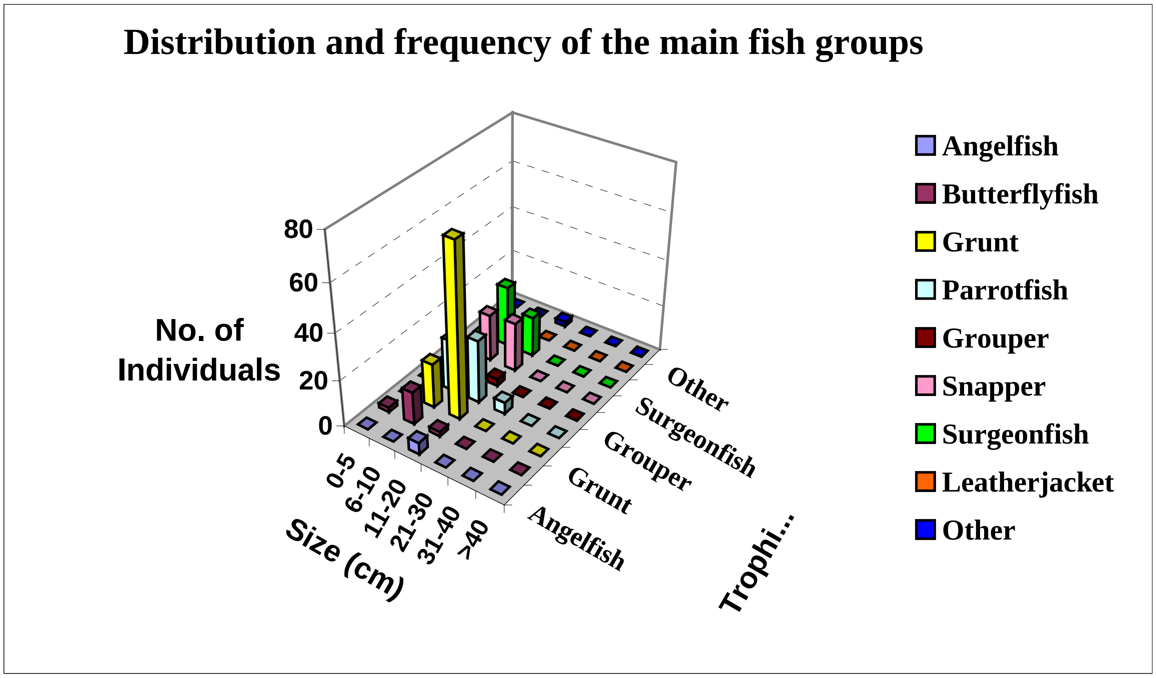
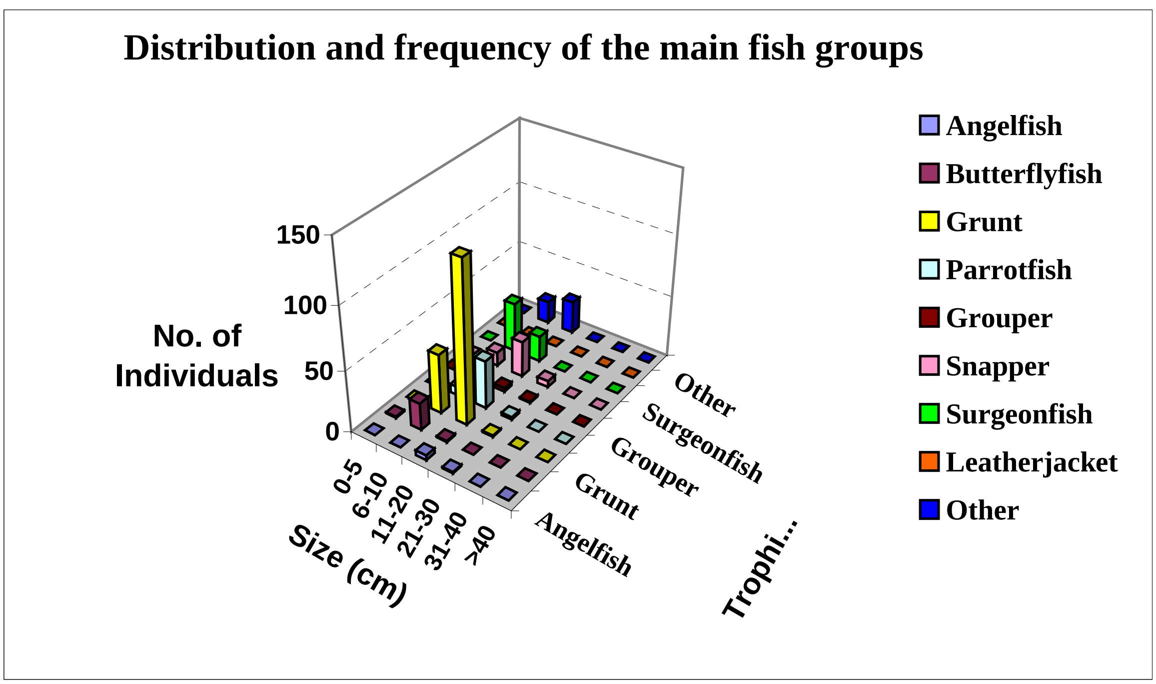


Figure 15: Caye Bokel:
Outside Reserve Back Reef (Shallow)



Herbivores vs. Carnivores

Figure 16: Caye Bokel:
Inside Reserve Back Reef (Shallow)

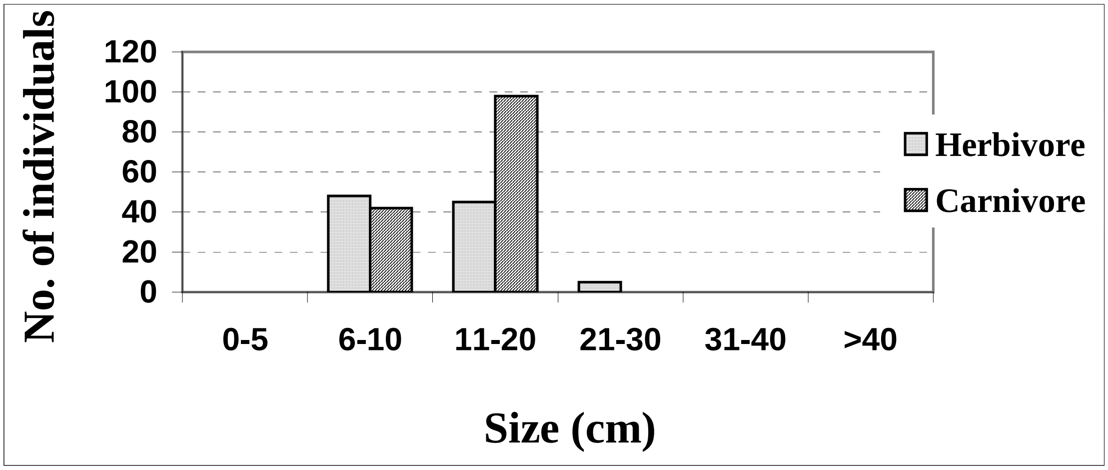
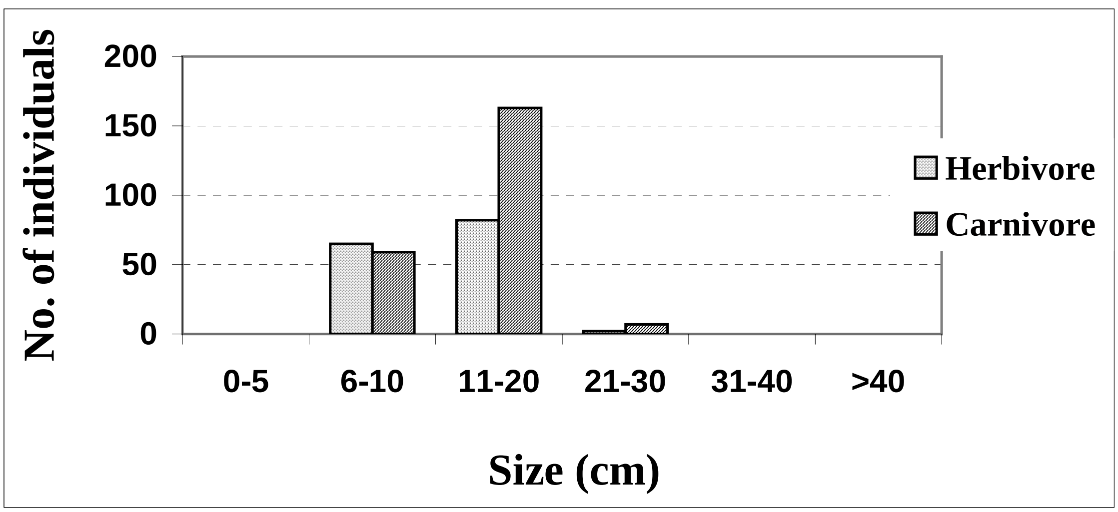


Figure 17: Caye Bokel:
Outside Reserve Back Reef (Shallow)



Herbivore vs. Predator (Ichthyobenthophage)

**Figure 18: Caye Bokel:
Inside Reserve Back Reef (Shallow)**

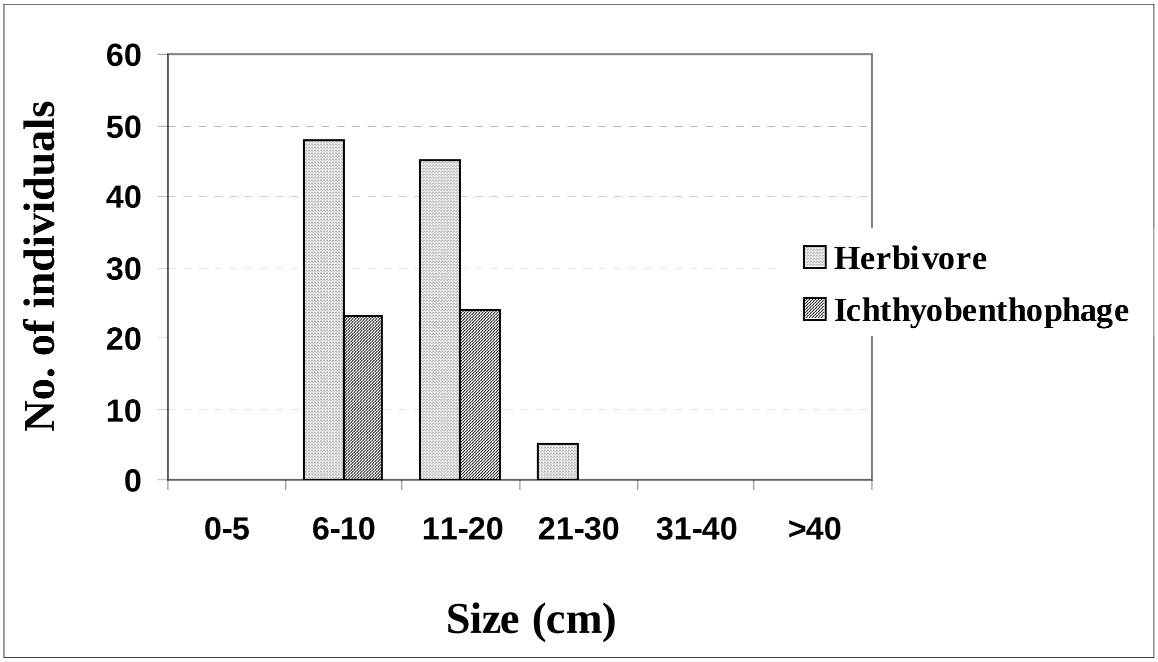


**Figure 19: Caye Bokel:
Outside Reserve Back Reef (Shallow)**

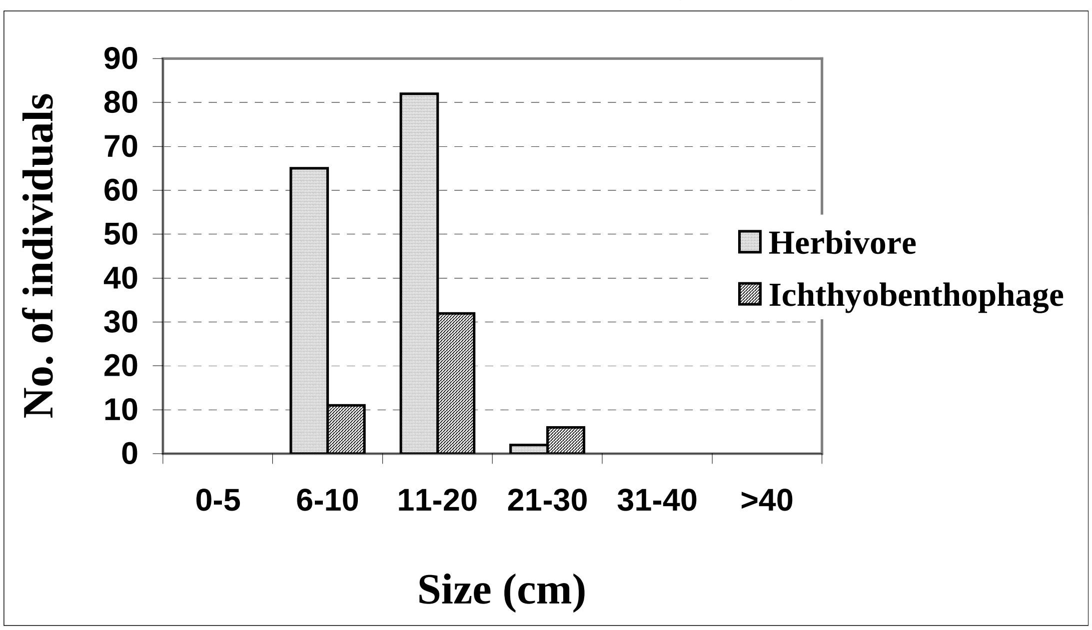


Figure 20: Caye Bokel:
Inside Reserve Fore Reef (Deep)

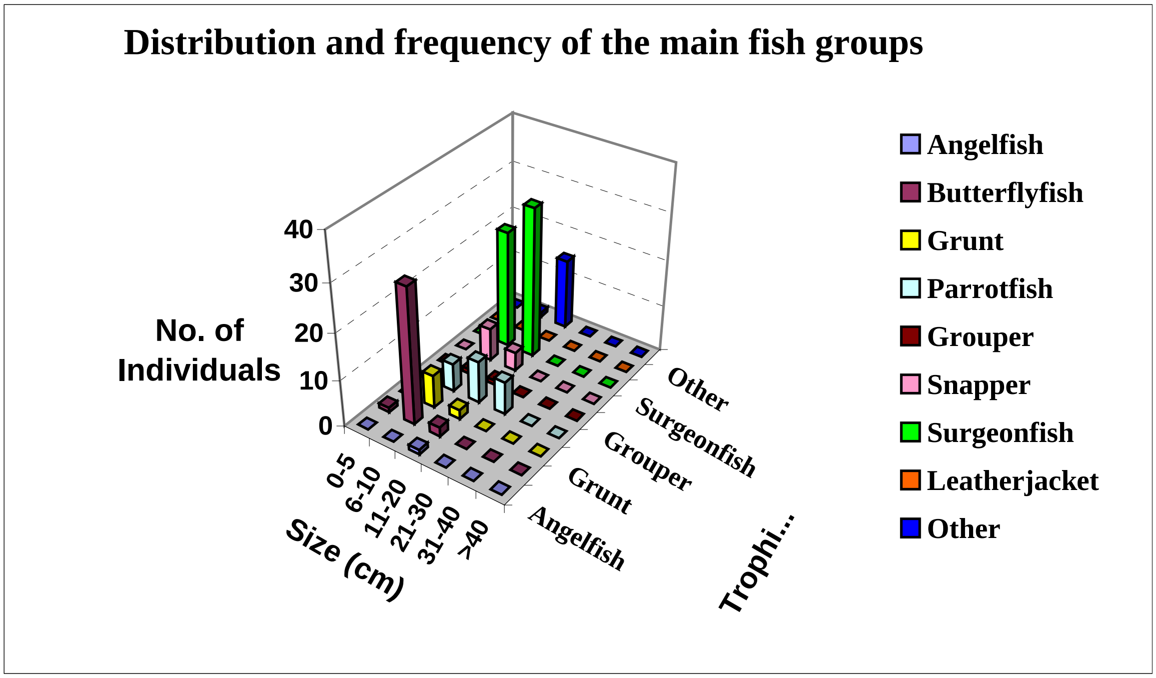
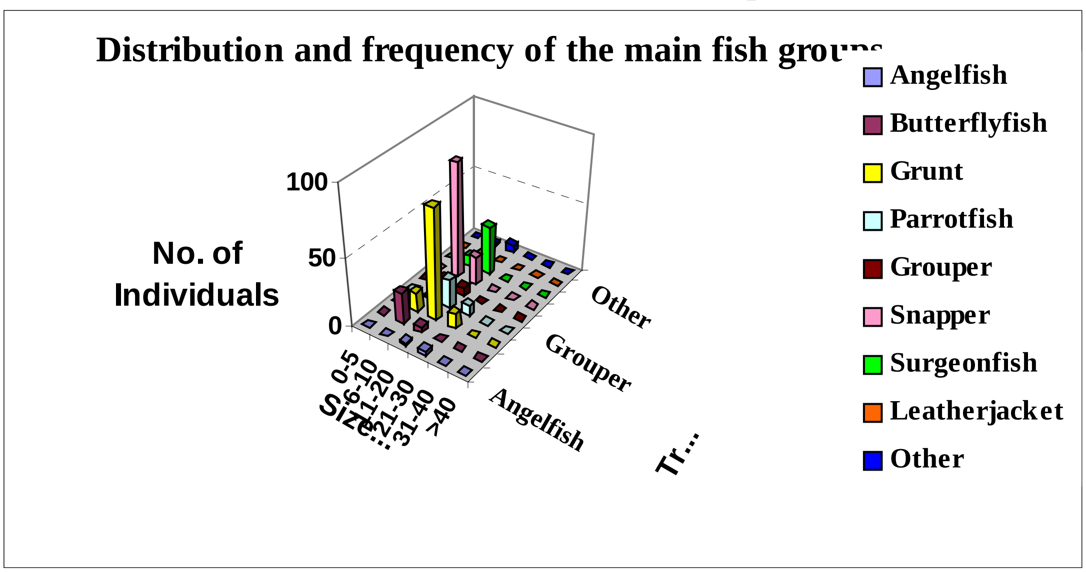


Figure 21: Caye Bokel:
Outside Reserve Fore Reef (Deep)



Herbivores vs. Carnivore

Figure 22: Caye Bokel:
Inside Reserve Fore Reef (Deep)

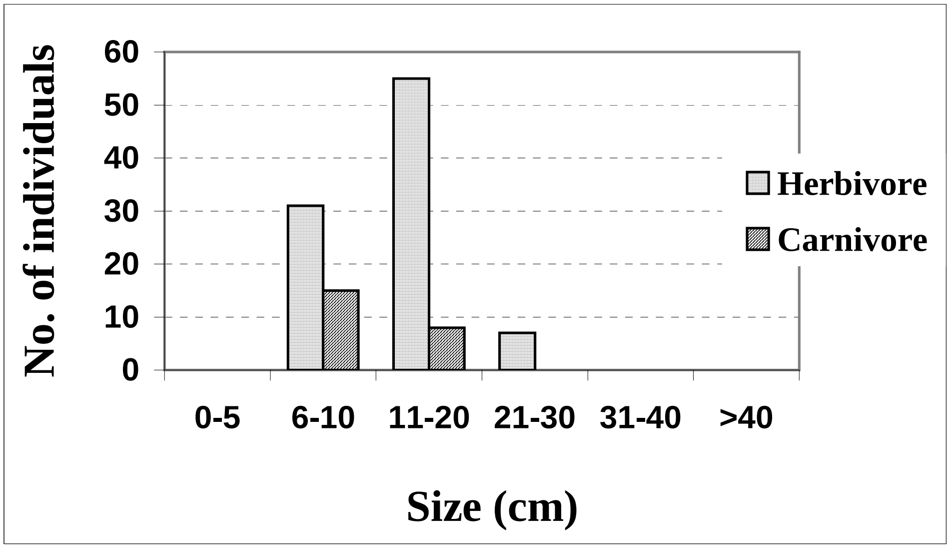
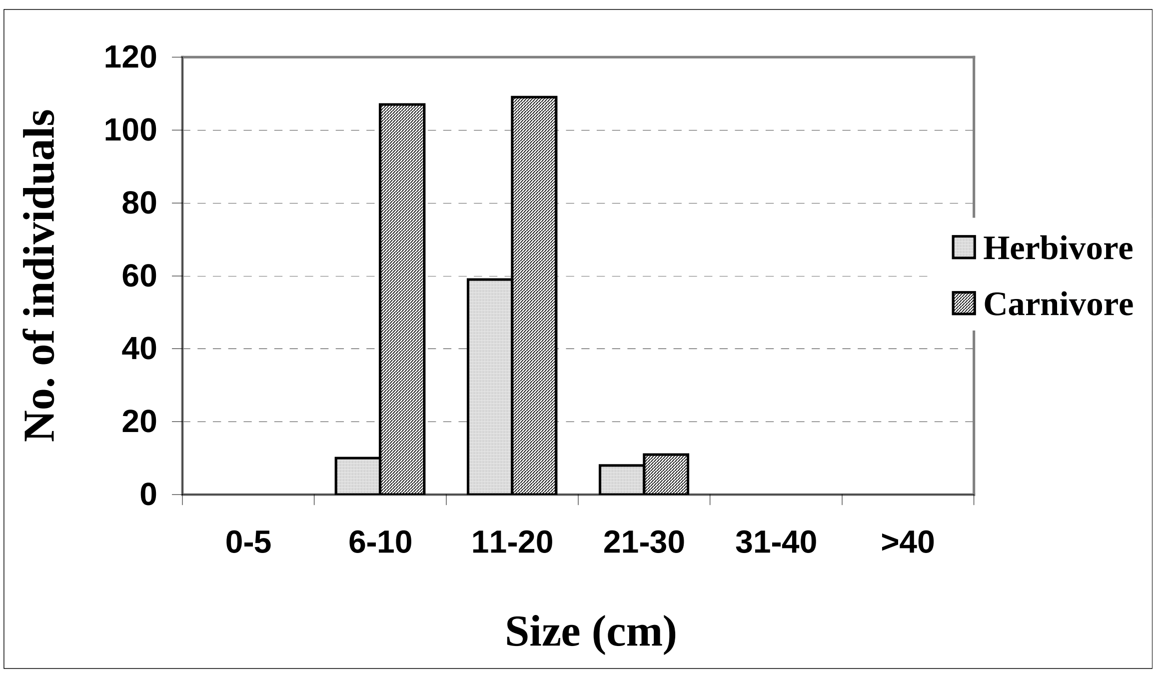


Figure 23: Caye Bokel:
Outside Reserve Fore Reef (Deep)



Herbivore vs. Predator (Ichthyobenthophage)

Figure 24: Caye Bokel:
Inside Reserve Fore Reef (Deep)

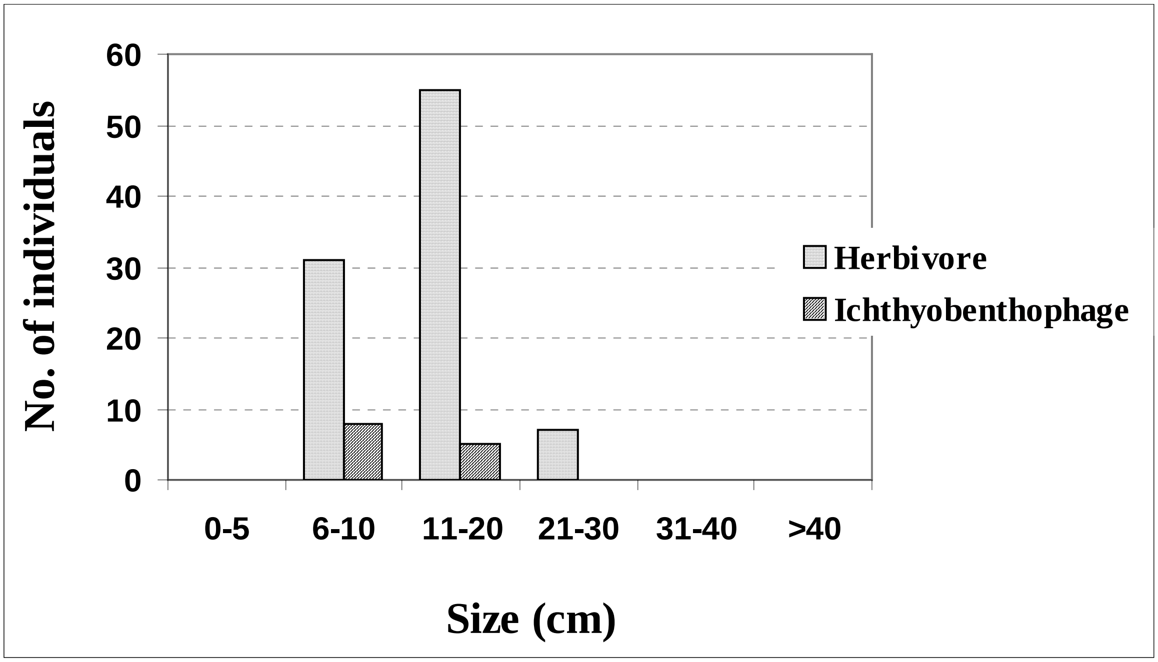
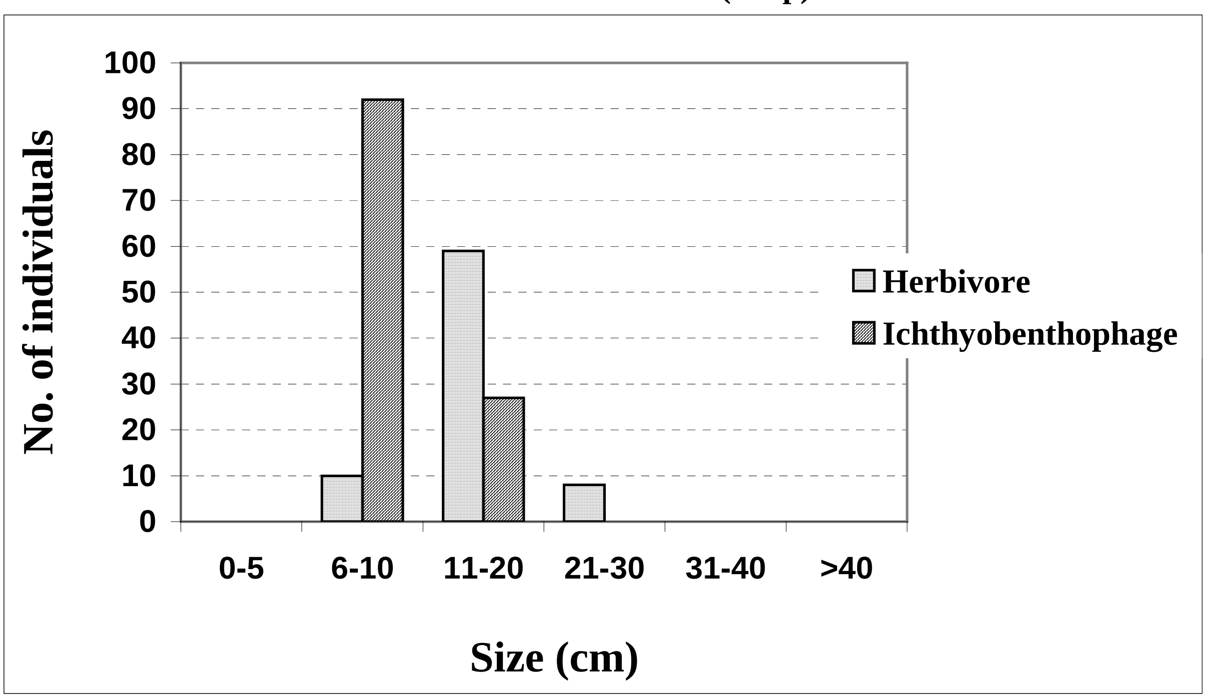


Figure 25: Caye Bokel:
Outside Reserve Fore Reef (Deep)



Dog Flea Caye – Baseline Fish Data

Dog Flea Caye: Fish Density (#/100m^2) March 2007				
	Dog Flea Caye - Shallow		**Dog Flea Caye – Deep**	
Type of Fish	**Inside Reserve**	**Outside Reserve**	**Inside Reserve**	**Outside Reserve**
Surgeon Density	9.67	12.50	15.83	12.50
Parrot Density	6.00	10.83	8.17	10.33
Grunt Density	3.17	6.25	6.17	3.17
Snapper Density	7.83	11.04	4.50	1.33
Grouper Density	3.00	1.88	1.17	2.67
Angel Density	0.33	0.83	0.67	0.17
Butterfly Density	0.83	3.33	2.00	2.00
Leatherjack Density	0.33		1.33	
Density of all others	1.50	1.46	4.67	0.67

In the back reef of Dog Flea Caye Marine Reserve, densities were roughly comparable with no family showing major differences except that grunts had half the density inside the Reserve. In the fore reef area, no big differences between inside and outside. Snappers and grunts had greater densities inside the Reserve while groupers had twice the density outside.

Dog Flea Caye: Fish Biomass (g/100m^2) March 2007				
	Dog Flea Caye - Shallow		Dog Flea Caye – Deep	
Type of Fish	Inside Reserve	Outside Reserve	Inside Reserve	Outside Reserve
Surgeon Biomass	738.17	700.23	985.28	775.48
Parrot Biomass	286.68	431.93	779.23	1004.58
Grunt Biomass	215.49	199.23	386.47	295.55
Snapper Biomass	558.87	440.76	196.93	106.56
Grouper Biomass	172.04	86.52	85.88	135.56
Angel Biomass	35.80	71.26	60.93	84.48
Butterfly Biomass	54.29	142.69	124.75	50.89
Leatherjack Biomass	39.54		158.17	
Biomass of all others	68.21	17.71	9.81	54.47

Biomass comparisons show few big differences in the back reef. Groupers have twice the biomass inside the Reserve; they were also twice as dense. On the fore reef, groupers showed the reverse pattern; they had more biomass outside the Reserve, and they were twice as dense.

Figure 26: Dog Flea Caye:
Inside Reserve Back Reef (Shallow)

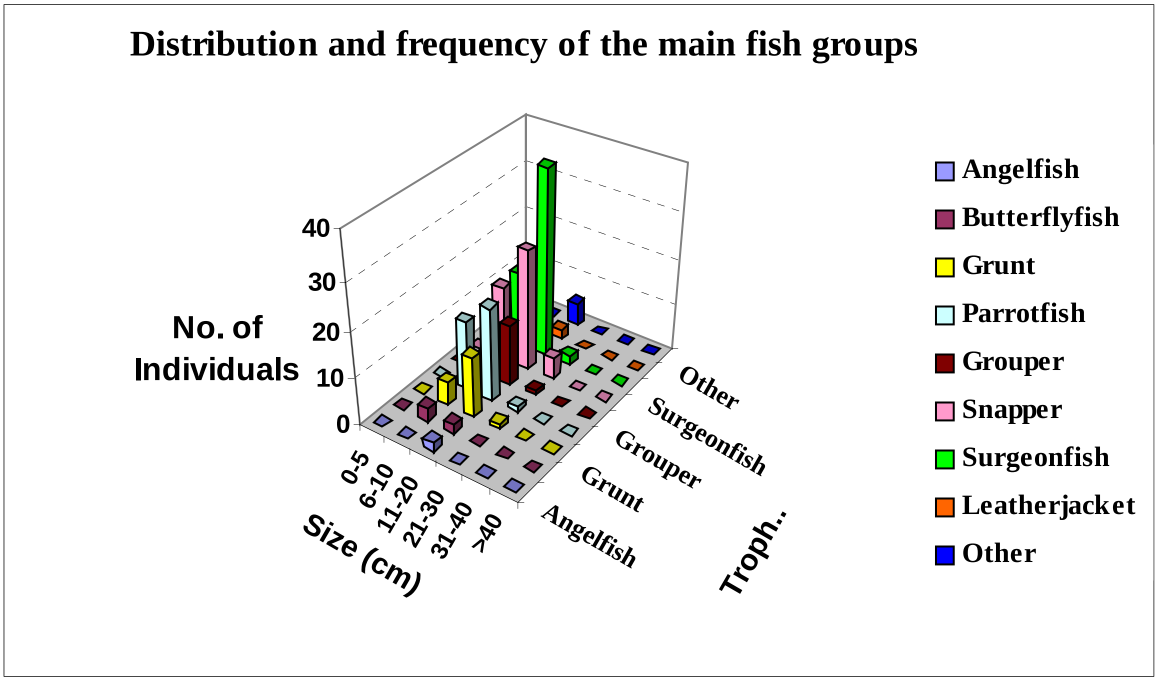
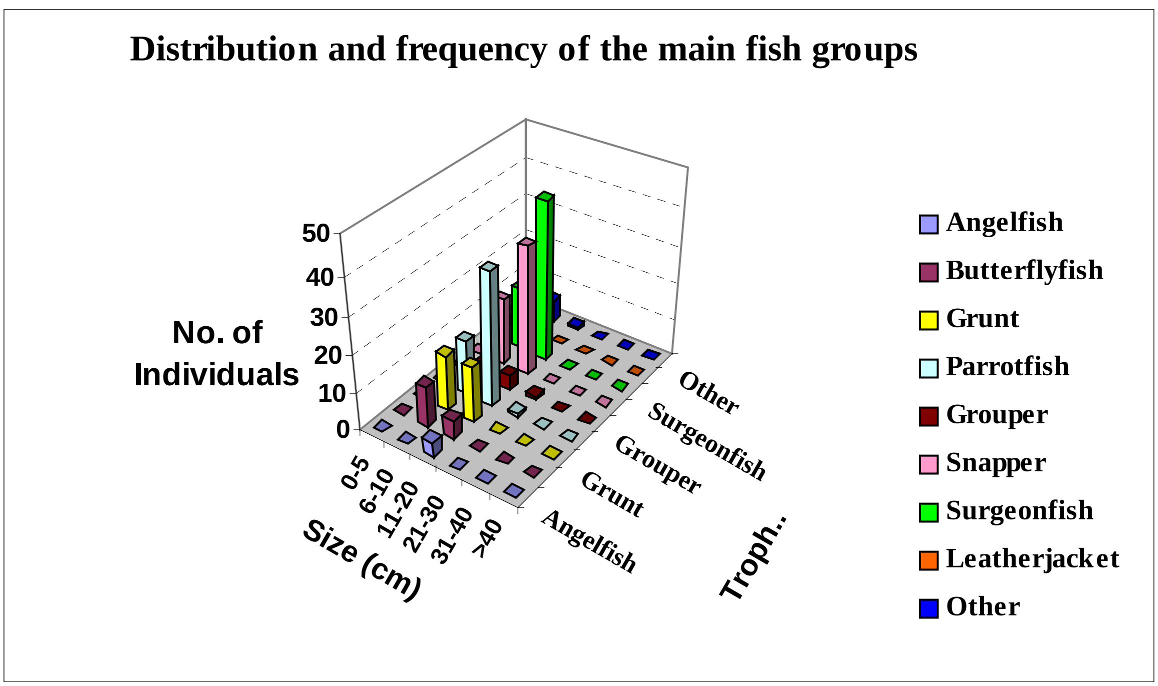


Figure 27: Dog Flea Caye:
Outside Reserve Back Reef (Shallow)



Herbivores vs. Carnivore

Figure 28: Dog Flea Caye:
Inside Reserve Back Reef (Shallow)

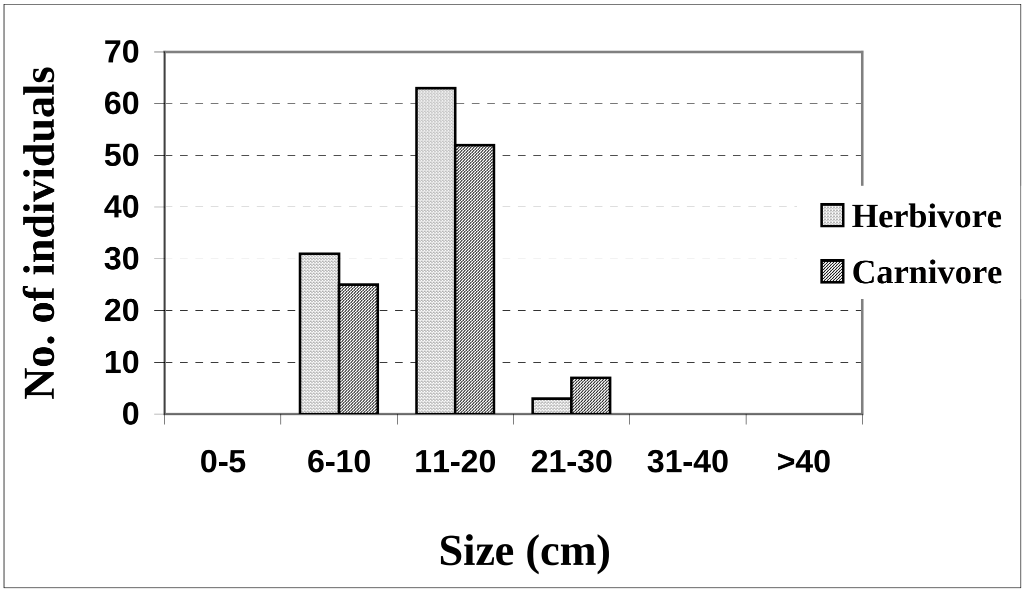
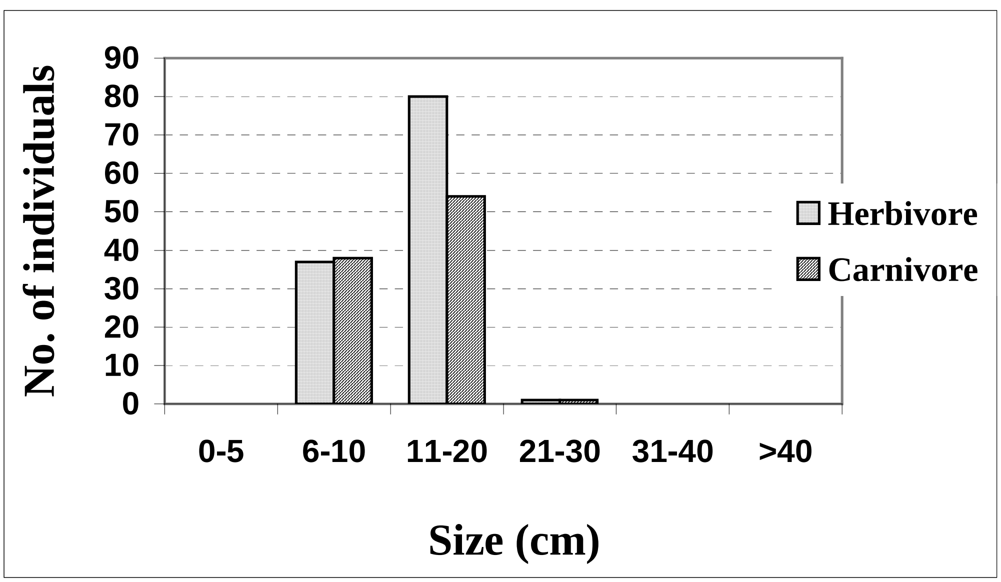


Figure 29: Dog Flea Caye:
Outside Reserve Back Reef (Shallow)



Herbivore vs. Predator (Ichthyobenthophage)

Figure 30: Dog Flea Caye:
Inside Reserve Back Reef (Shallow)

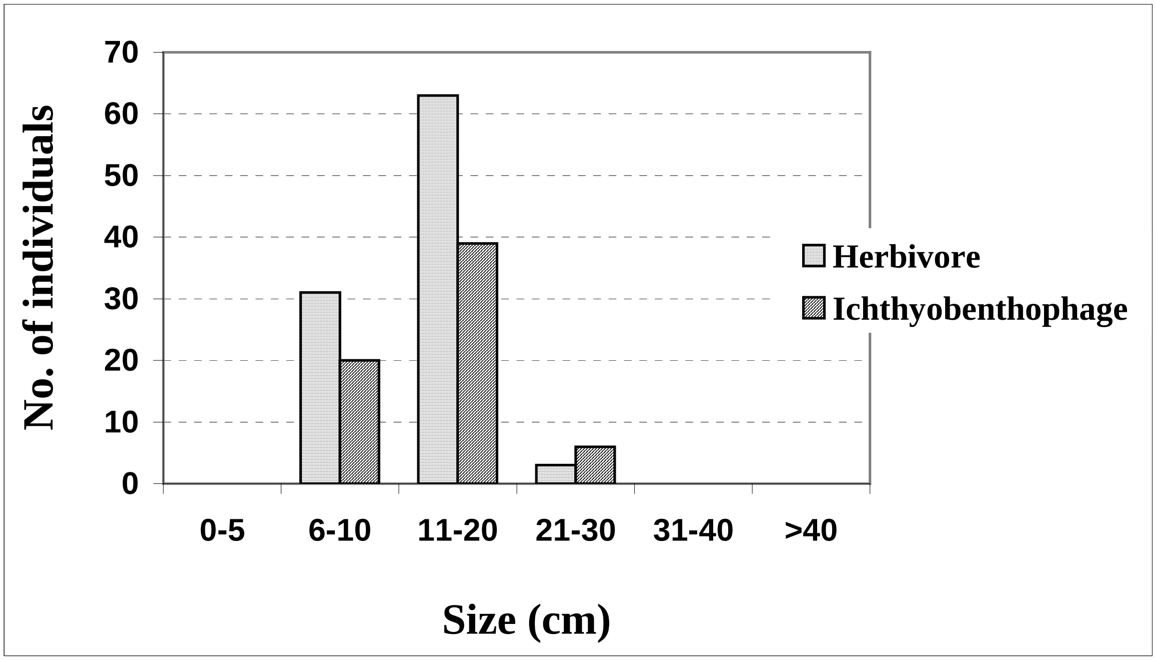


Figure 31: Dog Flea Caye:
Outside Reserve Back Reef (Shallow)

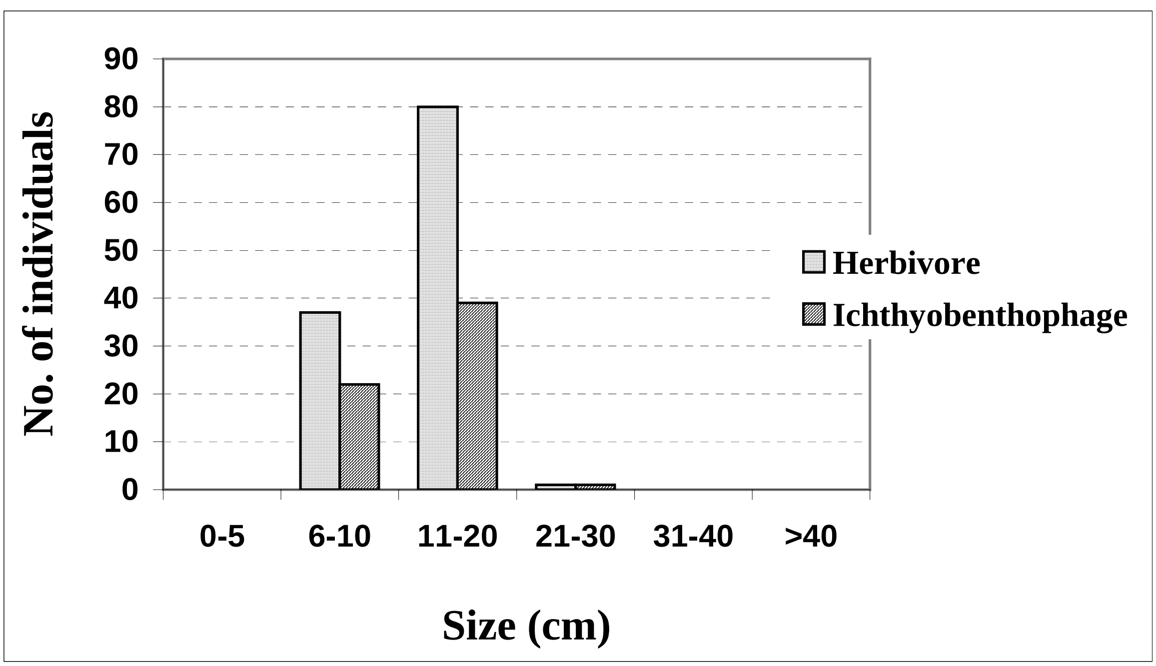


Figure 32: Dog Flea Caye:
Inside Reserve Fore Reef (Deep)

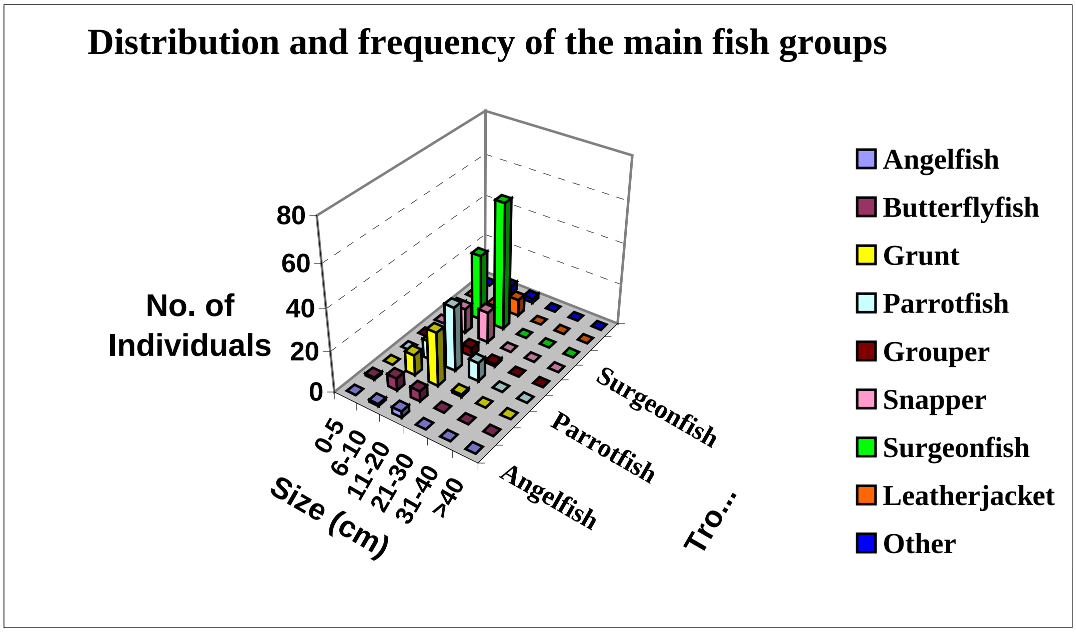
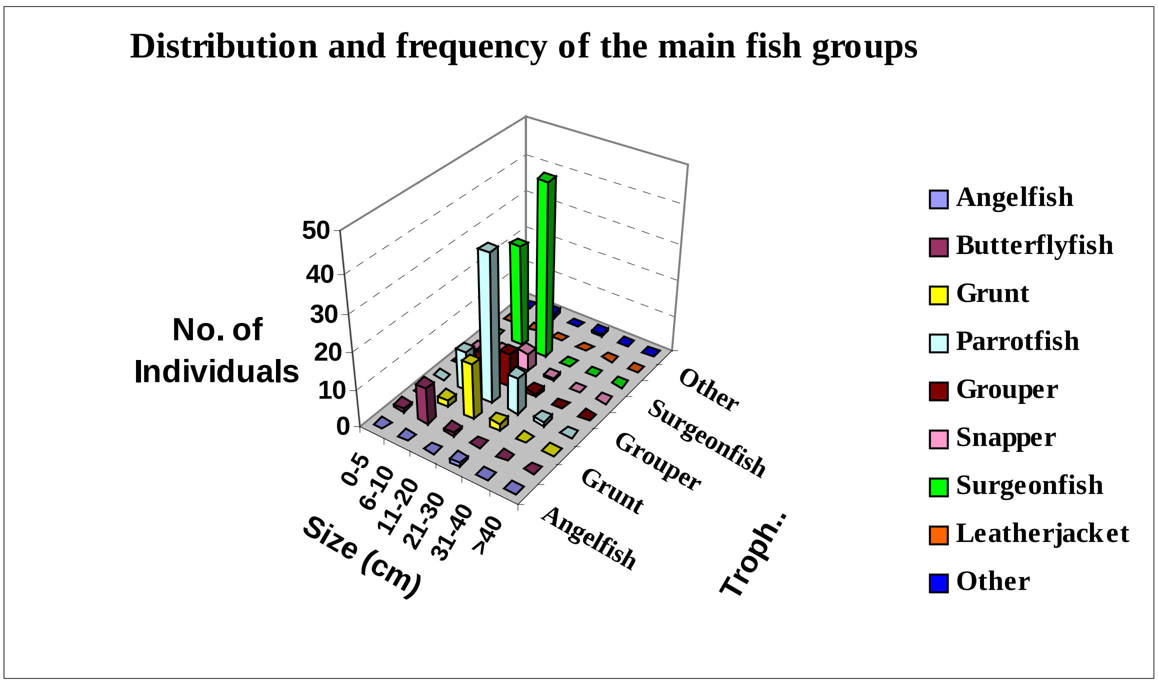


Figure 33: Dog Flea Caye:
Outside Reserve Fore Reef (Deep)



Herbivores vs. Carnivore

**Figure 34: Dog Flea Caye:
Inside Reserve Fore Reef (Deep)**

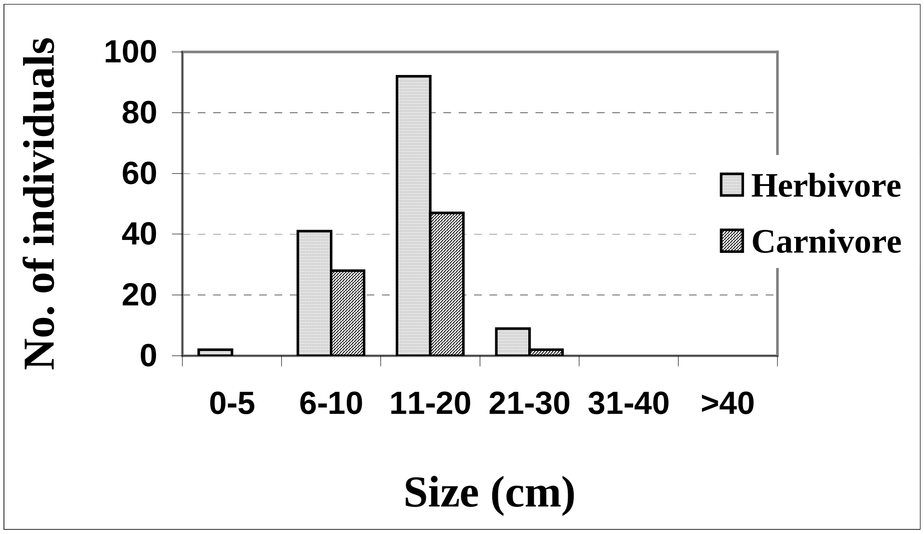
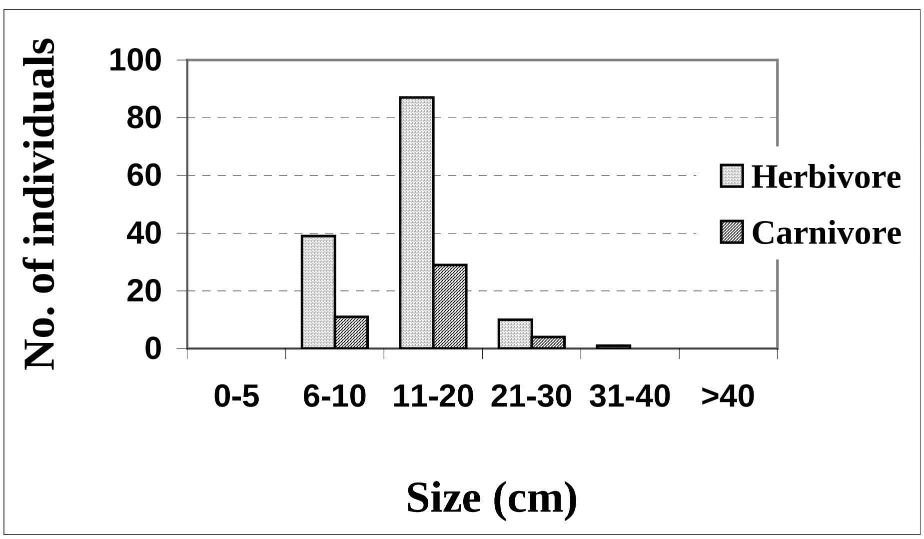


**Figure 35: Dog Flea Caye:
Outside Reserve Fore Reef (Deep)**



Herbivore vs. Predator (Ichthyobenthophage)

**Figure 36: Dog Flea Caye:
Inside Reserve Fore Reef (Deep)**

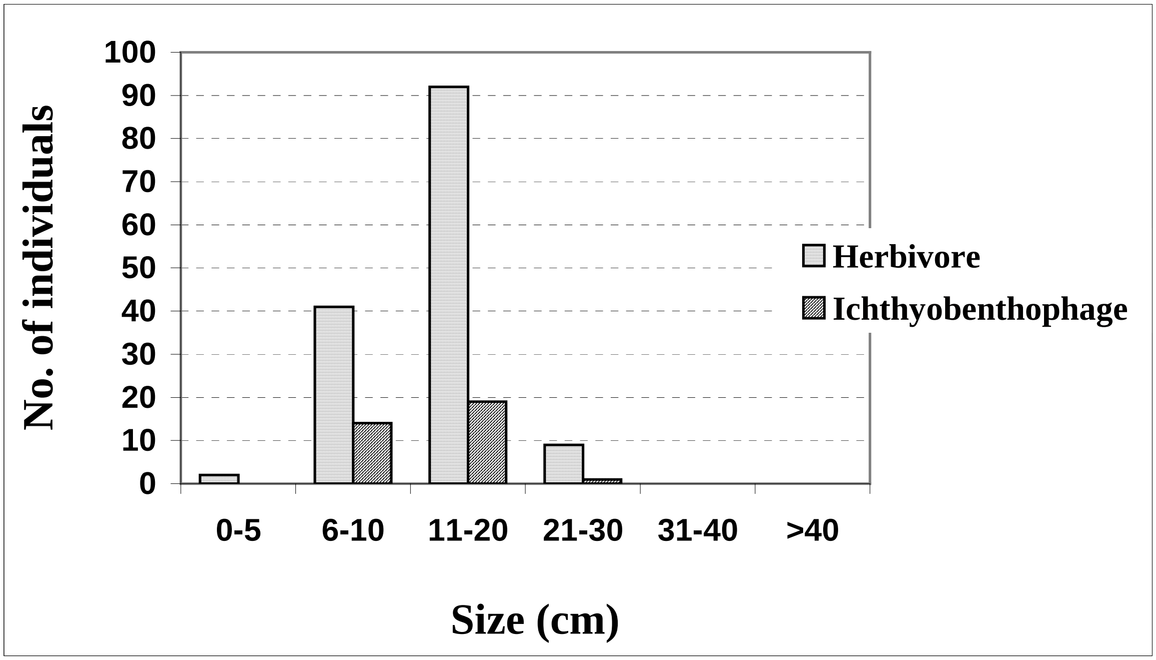
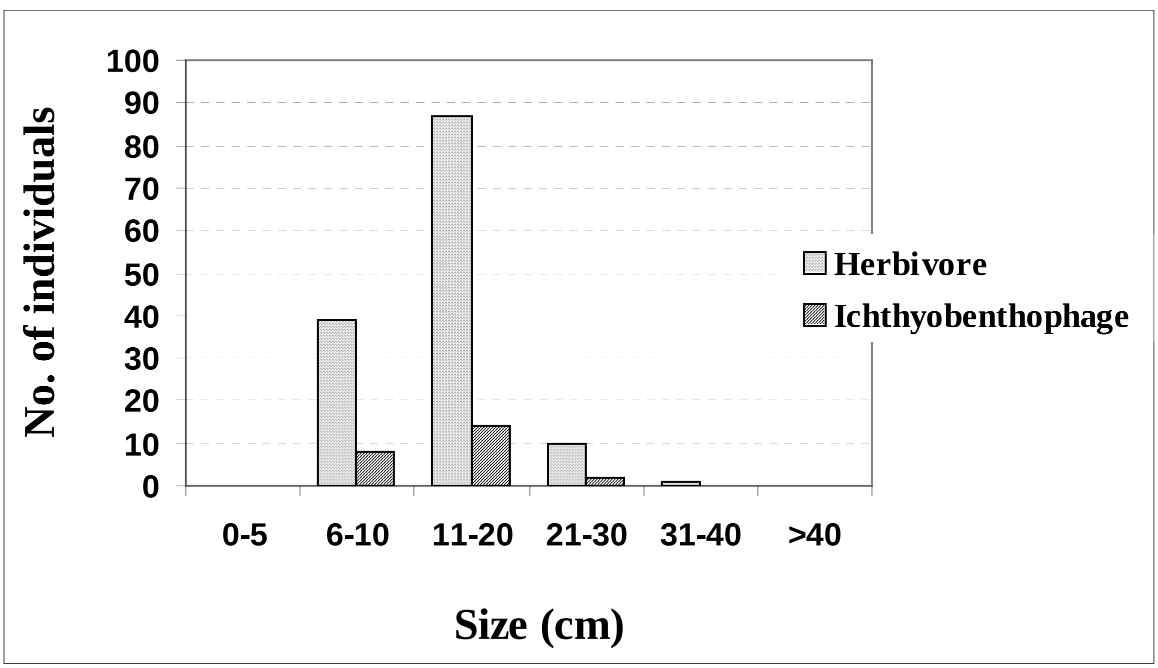


**Figure 37: Dog Flea Caye:
Outside Reserve Fore Reef (Deep)**



Spawning Aggregations:

Ocean fish all around the world meet at specific places at specific dates and times to spawn together. Researchers have documented at least 557 sites where a total of 119 species from 18 families spawn. The majority of species are from just five families: in particular, the groupers. The 18 families and numbers of species in each are:

Table 6: Families & Species of Fish that Aggregate

Family	#	Family	#
Groupers (Serranidae)	36	Jacks (Carangidae)	7
Surgeonfishes (Acanthuridae)	11	Mackerels etc.(Scombridae)	1
Snappers (Lutjanidae)	14	Mojarras (Gerreidae)	1
Bonefishes (Albulidae)	1	Sea chubs (Kyphosidae)	3
Mullets (Mugilidae)	6	Rabbitfishes (Siganidae)	8
Triggerfishes (Balistidae)	1	Wrasses (Labridae)	6
Goatfishes (Mullidae)	3	Porgies (Sparidae)	2
Fusiliers (Caesionidae)	1	Emperors (Lethrinidae)	7
Parrotfishes (Scaridae)	8	Barracudas (Sphyraenidae)	2

Nearly half the records (270) are from just eight species (Fig. 14). Four of these occur in the western Atlantic: Nassau grouper (*Epinephelus striatus*), Mutton snapper (*Lutjanus analis*), Black grouper (*Mycteroperca bonaci*) and Cubera snapper (*Lutjanus cyanopterus*). The remainder, Squaretail coralgrouper (*Plectropomus areolatus*), Camouflage grouper (*Epinephelus polyphekadion*), Leopard coral-trout (*Plectropomus leopardus*) and Brown-marbled grouper (*Epinephelus fuscoguttatus*) are widespread Indo-Pacific species. By far the most records for a single species are of the Nassau grouper, historically the most important commercial grouper in the western Atlantic and one of the first reef fishes to be documented as forming spawning aggregations (from Cuba in the 1800s, reported as spawning migrations or

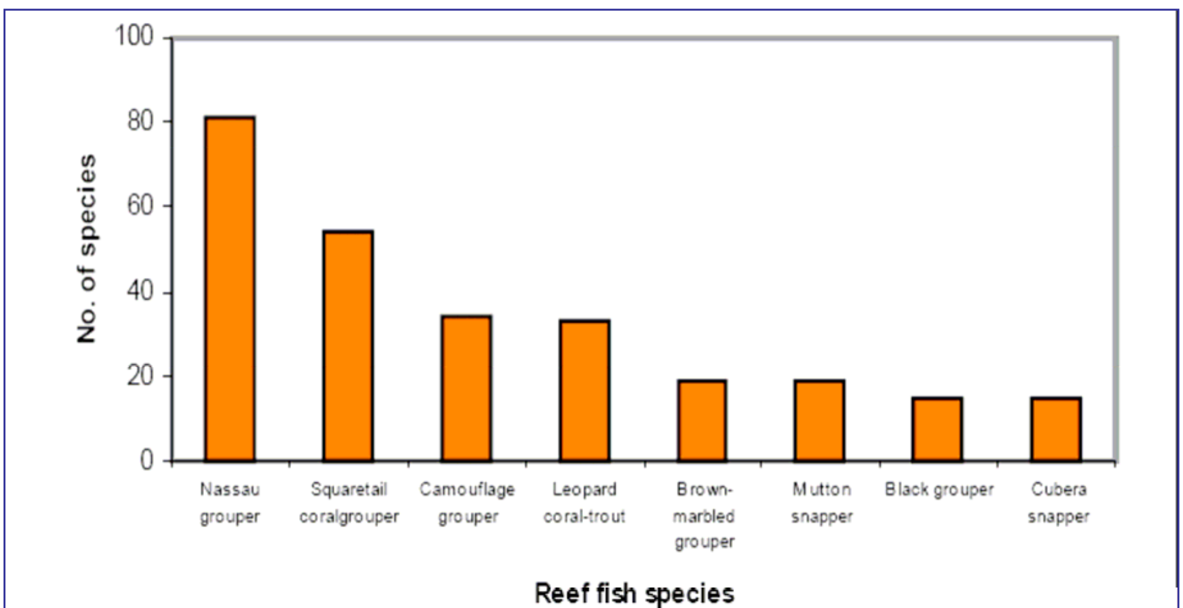


Figure 38: Reef fish species with most records in the database (n=270) (SCFSA 2005)

‘corridas’) (SCFSA 2005).

The Society for Conservation of Fish Spawning Aggregations has a website dedicated to a world-wide database of aggregation sites. They have also kept track of species that spawn, whether sites are declining, and types of management at sites.

Spawning aggregations are well studied in the western Caribbean particularly in Cuba and Belize. Some of these aggregation sites host a single species; often multiple species attend. Participants in these aggregations often come only at certain times of the year like groupers, for example, that spawn December to March in the Caribbean while snappers visit from April to July. Spawning events result in hundreds of millions of larvae being released into the ocean, usually close to breaches in the reef.

Some spawning fish are resident; their migration is minimal because they inhabit the nearby reef. Some species like Nassau grouper and mutton snapper may travel hundreds of kilometers to reach the site. There is some evidence that for some species, the location of the spawning site is learned behavior. There is also evidence that site fidelity is very strong (Starr et al. 2007). The fish arrive at a site – typically a sharp promontory that sticks out on the windward side of the reef. Most species stay at the site for 24-72 hours and carry out a series of courtship moves – changing color and dancing with one another. At specific times of the day, some species form columns of revolving fish that rise to the surface – females first releasing their eggs; males follow dispensing their sperm. A few species spawn almost transiently, notably mutton snapper. They arrive at the site in small groups, mill around briefly, spawn, and take off again.

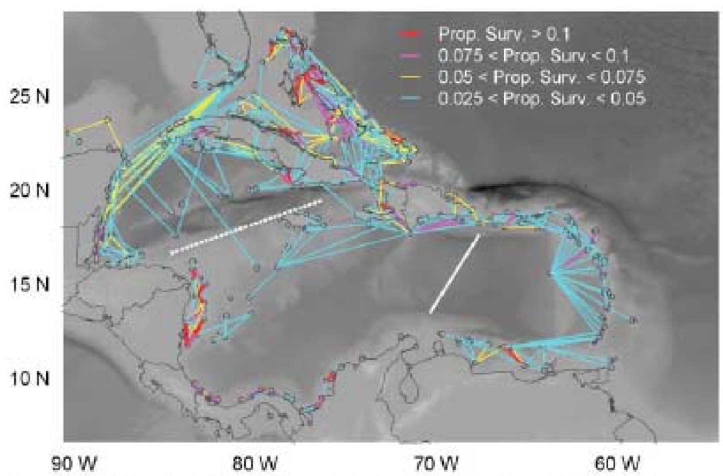


Fig. 4. Connectivity network for reef fish populations in the wider Caribbean plotted for various levels of larval exchange (proportion surviving) between each reef site (or node N, where center location is represented by a small gray circle; note that there is no directionality represented in the exchange). Two major meridional biogeographic breaks are identified: one in the eastern Caribbean Sea (white line) and the other one at the northern edge of the Nicaraguan Rise (dotted white line), which separate the eastern and western Caribbean. Two enclaves stand out: the Bahamas Bank, including the Turks and Caicos Islands, and the Nicaraguan Archipelago, which are both strongly intraconnected. The Panama-Colombian Gyre subregion is also largely isolated from the rest of the Caribbean, with little connection between Panama and Colombia. Note that connections at levels below 0.05% (proportion surviving) are not likely contributing appreciably to ecological connectivity but are shown here because they may become important when accumulated from different sources at one particular location.

Figure 39: Compartmentalization of Larval Dispersion in the Caribbean Basin (Cowans et al. 2007)

Larvae are dispersed passively at first depending on tides, currents, and winds to propel them. These have species-specific retention times and most have an active-swimming larval stage. Most

Fish Spawning Aggregations (FSAs) self-recruit; that is, they deposit their larvae in seagrass within 100 km of the spawning site. Along the Belize Barrier Reef, Cowen et al. (2007) predict that about 70% of larvae self-recruit. In Figure 39, Cowen also models currents, winds, and dispersion for the entire Caribbean and shows that four sections retain larvae; little mixing takes place among them.

At the end of the passive float, the larvae sprout some fins and swim down into seagrass beds, their ultimate destination. Indeed, a recent study suggests that the larvae can 'smell' their home reef (Gerlach et al. 2007). Once they are safely hidden in the blades of grass, the larvae metamorphose into tiny fish. Then they migrate to the root systems of mangroves where they find security for years while they grow out. Some species vary slightly. Nassau grouper, for example, prefer to grow out around coral heads of small fringing reefs. They live in crevices and are very hard to find. Gray snapper moves back into sea grass from the mangroves and grows out there. This dictates that sea grass and mangrove habitat must be protected along with Spag sites, preferably those within 50 km of the spawning site.

By all accounts, the aggregations at Dog Flea Caye (419 895.00 N 1 935 283.00 W) and Caye Bokel (16Q0 403 522 N UTM 1 896 932 W) are significant in size – thousands of individuals of some species – and in diversity. So far, researchers have identified 15 species that spawn at Dog Flea Caye and 18 species at Caye Bokel.

Dog Flea Caye Spags Species:

Epinephelus striatus	Nassau grouper
Mycteroperca tigris	Tiger grouper
Mycertoperca venenosa	Yellowfin grouper
Mycteroperca bonaci	Black grouper
Melichthys niger	black durgon
Anisotremus surinamensis	Black margate
Lutjanus cyanopterus	Cubera snapper
Caranx latus	Horse-eye jack
Clepticus parrae	Creole Wrasse
Scomberomorous maculatus	spanish mackerel
Canthidermis sufflamen	Ocean triggerfish
Elagatis bipinnulata	Rainbow Runner
Caranx rube	Bar jack
Ocyurus chrysurus	Yellowtail snapper
Kyphosus sectatrix	Bermuda chub

Caye Bokel Spags Species:

Trachionatus fulcatus	Permit
Epinephelus striatus	Nassau grouper
Mycteroperca tigris	Tiger grouper
Mycteroperca bonaci	Black grouper
Caranx rube	Bar jack
Caranx latus	Horse-eye jack

Scomberomorous maculatus	spanish mackerel
Acanthostracion quadricornis	Scrawled Cowfish
Kyphosus sectatrix	Bermuda chub
Anisotremus surinamensis	Black margate
Lutjanus griseus	Black snapper
Lutjanus jocu	Dog snapper
Ocyurus chrysurus	Yellowtail snapper
Lutjanus cyanopterus	Cubera snapper
Lutjanus analis	Mutton snapper
Clepticus parrae	Creole Wrasse
Canthidermis sufflamen	Ocean triggerfish
Lactophrys triqueter	Smooth trunkfish

S.I. 161 of 2003 that protects the spags reserves covers several multi-species spawning sites and protects many kinds of spawning fish. But the real driving force behind the protection was the severe decline of Nassau grouper. Indeed, groupers have often been seen at Dog Flea Caye. In January 2003, researchers counted 5,000 – the highest count anywhere on the Reef in the 21st century. In January 2006, they saw 1 fish. The Dog Flea site is not known as a snapper site, although yellowtail and cubera snappers have been seen there. Grouper spawning takes place December to March. Dog Flea Caye lies on the Northeast corner of the Atoll. Two other grouper spawning sites are known to fishermen there – Maugre Caye and Three-corner Caye. In those months, the prevailing winds come from the north-northeast, and would undoubtedly sweep the eggs from all three sites into the lagoon, either over the reef or through the large breaks in the reef at Cockroach Bay and the cut on the northwest tip of Turneffe.

Grouper larvae can survive long, but at a certain size, they drop into seagrass beds or, preferably, fleshy macro-algae where they are more cryptic and have 200% better chance of survival. It's intriguing that heavy stands of macro-algae lie at Maugre Caye and Cockroach Bay. Juvenile grouper prefer to live in crevasses in coral heads in shallow water. They are rarely seen. The massive flats in north Turneffe and all along the inside of the reef platform create excellent habitat for Nassau grouper.

Caye Bokel is not a major spawning site for grouper; however, snappers are known to spawn in great numbers at the Elbow. More than 10,000 dog snappers as well as 5,000 cubera snappers are frequently seen. They generate enough spawn to attract occasional whale sharks to the area during the peak months of April to June. This also the time between Easter and the rainy season when the winds turn hot and dry and swing around from the southeast. These prevailing winds would be perfect to sweep larvae up into Turneffe's central lagoon with its massive seagrass beds outlined by mangrove forests. Snappers generally grow up in seagrass and mangrove roots, using the roots as protection from predators.

Turneffe is also unusual in that it has relatively sterile tropical waters that enable a rich coral population that, at the same time, surrounds an island of rich productivity. Within the Lagoon, leaves, stems, and propagules of the mangroves and seagrass beds form the foundation of the food chain. The extent of the forests supports enormous populations of fish. A dive operator's website describes the fish along one of the reef dives:

> There are literally thousands of fish in a single shoal [sic] with more than one shoal often in sight. Individual fish sizes range from 5 to 30 pounds (2- 4 kg), but the size of all fish in any single shoal [school] is always uniform, as they were spawned together and have grown together. The diver will frequently encounter this in shallow water where the fish will be 2 or 3 inches (5 or 8 cm) long, but as the fish grow they tend to disperse as they need more individual space to feed. Here [on Turneffe], the concentration of nutrients and the resultant populations of smaller fish is so great as to sustain shoals of larger fish which feed on them.
>
> -- Aqua Dives --

ICRI has recommended that governments establish management programs for sustaining and protecting reef fish and their spawning aggregations, including a range of spatial and seasonal measures that can be adapted to local needs and circumstances. Further, international and regional fisheries management organizations as well as non-governmental organizations should take action to promote and facilitate the conservation and management of fish spawning aggregations, including by raising awareness of the long term ecological, economical and societal values of spawning aggregations and in respect of their high vulnerability to uncontrolled fishing.

2.5.4 Past and Present Research

Diploria spp., Siderastrea spp. And Montastrea spp. are known as reef-building corals; they produce large boulders that make up much of the mass of the reef. A 2003 study by Walsh compared back reef and fore reef sites in both reserves. Many of the reef-builders showed signs of damage from bleaching. At Caye Bokel, fore reef sites showed 24% bleaching and the back reef showed 50% mortality. At Dog Flea Caye, 52% of the fore reef and 81% of the back reef.

In July, 2003, McField and Walsh began to study the coral-zooxanthellae symbiosis across the Mesoamerican Reef in order to understand historical patterns of coral bleaching and contribute to the prediction of future reef resilience. In the first phase of the program, they designed a sampling scheme that would allow them to compare patterns of zooxanthella diversity to the well described patterns of bleaching in the 1995 mass-bleaching event (see McField 1999). Colonies of the *M. annularis* complex were the most affected corals across the region (76%). The extent of bleaching observed across the region was most similar within habitat types.

Five of the ten most common scleractinian corals exhibited significant differences in bleaching across habitats. *M. annularis* and *S. siderea* were more bleached in forereef sites, while *Porites porites*, *Agaricia tenuifolia*, and *Agaricia* were more bleached in backreef sites. Also, corals previously reported to host *Symbiodinium* C (Baker and Rowan 1997), were significantly more bleached (P = 0.005) than corals reported to host *Symbiodinium* B (Baker and Rowan 1997).

Without knowledge of the distribution of zooxanthellae hosted by *M. annularis* on the Mesoamerican Reef, the observed patterns of bleaching in *M. annularis* and the general spatial pattern of bleaching across the region could not be fully explained in terms zooxanthellae conferred resistance to bleaching. However Walsh's analysis of the distribution of zooxanthellae hosted by colonies of *M. annularis* has now provided some insight into these patterns. She sampled corals at seventeen sites across the Mesoamerican Reef that were chosen to represent the main regions of reef system: northern, central, and southern barrier reef and atolls; both Dog Flea Caye and Caye Bokel Marine Reserves hosted sample sites. At each location, samples were collected from colonies of *M. annularis* in each of the available reef habitats. In backreef habitats, 11% of colonies host *Symbiodinium* A, while 89% of colonies host *Symbiodinium* B. However, in forereef habitats, 79% of colonies host *Symbiodinium* B, while 21% of colonies host *Symbiodinium* C. This observed distribution of zooxanthellae would have predicted the bleaching patterns observed in 1995. *M. annularis* was more bleached in forereef sites likely because a higher percentage of colonies host stress in-tolerant zooxanthellae (*Symbiodinium* C) and less bleached in backreef sites because a higher percentage of colonies host stress tolerant zooxanthellae (*Symbiodinium* A). The pattern in *M. annularis* may have also accounted for the general pattern of bleaching to be more similar within habitat types because *M. annularis* is the dominant reef-building coral and was the most affected during the 1995 mass-bleaching event.

The Mesoamerican Reef has a unique distribution of zooxanthella compared to other regions in the Caribbean. It is dominated by *Symbiodinium* B, while stress tolerant *Symbiodinium* D is conspicuously absent (Waqlsh & McField, in press).

Walsh & McField recommend a research program that "will contribute to the conceptual understanding of the factors controlling the resilience of corals to bleaching while informing the design of a resilience-based management strategy. Understanding the actual characteristics that confer resilience to corals is critical to management because it allows managers to measure specific parameters and adapt their management strategies based on known relationships.

Resilience-based management will provide specific solutions to the problems that climate change has posed to coral reef management (Walsh & McField, in press).

In a letter to *Nature*, Mumby et al. (2004) compared fish biomass on several atolls in the Caribbean. Turneffe with its mangrove/seagrass system was compared with Glovers, Lighthouse, and Banco Chinchorro. Their study showed that several reef fish species reach much greater biomass when mangroves are present. For example, *Haemulon sciurus* had 25 time the biomass on Turneffe than other atolls. The biomass of *O. chrysurus* doubled when its preferred *Montastraea* habitat was adjacent to rich mangroves.

In 2006, an AGGRA study was conducted at many sites up and down the reef. Three spots are close to the Reserves on Turneffe:

#1071: about 2 miles northwest of Caye Bokel along the fore reef
#1075: about 5 miles north of Dog Flea along the fore reef
#2073: about 3 miles north of Dog Flea along fore reef.

Table 11: % Coral Cover (AGGRA 2006)

Parameter	#1071	#1075	#2073	Average: all Fore reef sites
Average Live Coral Cover (corrected)	11.6%	6.7%	9.4%	10.8%
Average Crustose Macro-algae	40.5%	23.2%	25.5%	11.8%
Average Fleshy Macro-algae	10.6%	8.6%	4.8%	12.4%
Average Turf Agae/Bare Substrate	26.8%	52.8%	51.0%	49.7%

The two sites near Dog Flea have reduced coral cover as compared to all fore reef sites. Crustose macro-algae are elevated, particularly near Caye Bokel. Fleshy macro algae are reduced, especially near Dog Flea.

Table 12: Fish Biomass & Density (AGGRA 2006)

Parameter	#1071	#1075	#2073	Average: all Fore reef sites
Total Fish Biomass	2,680	4,171	3,388	3,344
Herbivorous Fish Biomass	1,754	3,170	2,469	1,912
Commercial Species Biomass	437	496	416	701
Total Fish Density (#/ 100 m2)	45.3	45.3	43.5	38.4
Commercial Species Density(#/100 m2)	9.2	8.2	10.0	8.3

Total fish biomass is reduced at the site near Caye Bokel; near Dog Flea, fish biomass is above average. Herbivorous biomass is much higher than average at the Dog Flea sites. Commercial fish biomass is reduced by 35-40% at all sites. At the same time, fish densities were elevated at all sites, including commercial species. Thus, fish must be smaller at these three sites than the average at fore reef site.

2.6 Cultural and Socio-Economic Value of Management Area

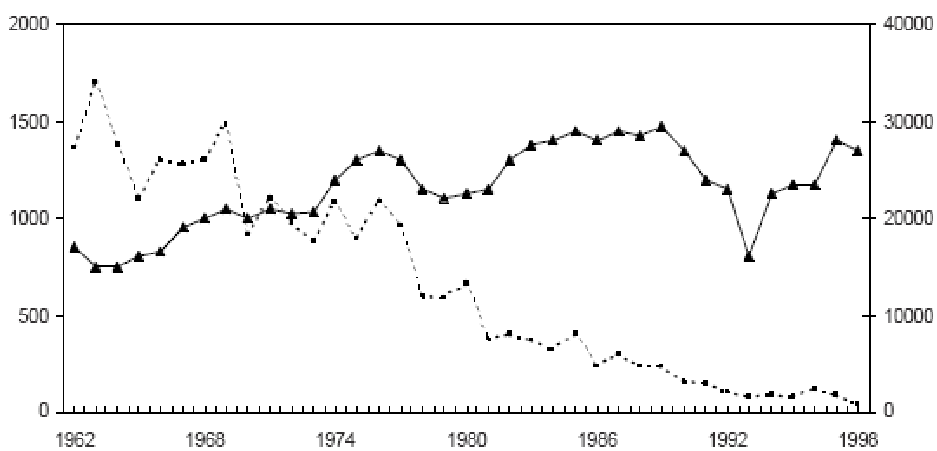
2.6.1 Community and other Stakeholder Use

In the 20th century, coconut plantations and sponge farming in Central Lagoon were industries. Fishermen avoided the place until the 60's and 70's when outboard engine technology enabled fishermen in numbers to ply their trade at Turneffe.

The Atoll was bountiful. When the spawning site at Caye Glory collapsed, fishermen switched to the next best grouper banks – Turneffe. The leading producer at Northern Fishermen's Cooperative has perennially been from Turneffe. Fishermen from Turneffe supplied more than 40% of National Cooperative's total production in the early 1990's. In those days, lobster fishermen could make $80- 90,000 BZ per year. Turneffe fishermen live in camps for days at a time, working in teams, usually family members. However, catch has declined precipitously and fishermen are anxious and pessimistic about the future of fishing at Turneffe. Recently, sailboat fishermen from Sarteneja have frequented Turneffe. Their village was devastated in Hurricane Dean. It is unclear what the tragedy means for their fishing practices.

In any event, Turneffe spags have declined precipitously like the rest of the sites in the region. Figure 40 shows recent data for Nassau grouper in Cuba; declines in Belize show similar patterns.

Figure 40 : Decline of Nassau grouper in Cuba



Annual landings in mt for all finfish species combined (solid line and triangles) and just for Nassau grouper, Epinephelus striatus, (dotted line) in Cuba between 1962 and 1998 showing results of aggregation overfishing of this species relative to other reef fishes (with kind permission of Rodolfo Claro and Ken Lindeman)

In tourism, Turneffe Island Lodge by the Elbow and Turneffe Flats further north near Cockroach Bay are two long-standing, high-end resorts. They specialize in luxurious isolation, fly-fishing, and diving. The owner of Turneffe Flats was involved in committees and actions to attain some protection for the Atoll. Turneffe Island Lodge has had a more checkered history, including several serious disputes with fishermen and dredging up acres of seagrass in violation of the permit. Figure 41 shows the extent of the disturbance by the dredging.

Figure 41: Dredging at Caye Bokel by Turneffe Island Lodge. Photo by TICAC

Enormous development pressure is building up at Turneffe Atoll. Since 2000, the issuing of leases and titles to parcels on Turneffe Atoll have sky-rocketed. Resorts are planned. Mangroves are already being cleared. Former Government Ministers are among the developers.

2.6.2 Archaeological Sites

No known Archeological Sites are found within the Reserves.

2.6.3 Tourism and Recreation Use:

The Elbow at Caye Bokel is one of the most popular dive sites in the region. In season, the lodges located on the Atoll send approximately 1,000 divers. Two live-aboard vessels stop at Turneffe weekly; each carries about 20 divers. In addition, several dive shops from San Pedro, Caye Caulker, and Belize City offer trips to Caye Bokel. All in all, approximately 4,000 divers visit Caye Bokel annually. Visits are limited because operators need a vessel big enough to cross open ocean to reach Turneffe.

Nearly all dive operators said they do drift dives at the Elbow, usually starting in the northwest corner of the Reserve. This is generally a wall dive with few opportunities for direct damage. Two management issues here are overcrowding and disturbing of the actual spag site. Dive operators mention that occasionally in season the site is crowded. Most groups enter the water on the western wall. The specific spag site along the eastern wall is not used as often. Indeed, divers on the east could disturb fish that have come to spawn.

2.6.5 Other Economic Use

The two marine reserves are small and their geographies are similar. The only common activities are fishing and recreation.

2.6.4 Education Use

Little education has taken place within the Reserves; they are remote and tiny. However, one of the major interests of UB's involvement in managing them is practical training in natural resource management. In addition, fishermen will need education about conservation.

3.0 Conservation Planning

3.1: Conservation Targets

3.1.1: Identification of Conservation Targets

- **Community of Spawning Aggregations**
- **Nassau grouper**
- **Cubera snapper**
- ***Montastrea spp.* (reef building species focus)**
- **Permit**

Conservation Target #1: Community of fish that aggregate to spawn:

Many spawning sites are used by more than one species often simultaneously. Such sites have characteristics that make them attractive to fish that aggregate. Where water movements that transport pelagic eggs and larvae into the water column or offshore facilitate the pelagic phase of development. The geomorphology offers a platform or 'arena' for spawning events, and topography facilitates males setting up territories and offers refuge for females to hydrate eggs and rest from the attention of males. Large numbers of pelagic eggs released simultaneously might swamp the ability of egg predators to feed (Johannes 1978). Also, aggregations might facilitate the ability of individuals to find mates and to synchronize physiological readiness to spawn (Russell 2003).

In Belize, multi-species spawning sites have been well studied. At Gladden Spit, for example, up to 38 species spawn at other sites over the course of a 12-month period. We have no reason to assume these sites at Turneffe are any different. Already 18 species have been seen at Caye Bokel and 15 seen at Dog Flea Caye. It may take a few years of monthly counts to identify all the species that use these sites.

Some features of the site are physical and unlikely to change in the medium term. The number of species could decrease for other reasons. Those that are commercially fished could obviously drop off from overfishing. Spawning fish are particularly vulnerable when they migrate to the site. Fishermen could intercept them en route and hit them hard before they have a chance to spawn.

If other species start to disappear, it could indicate a broader problem like pollution of the water. An oil spill for example, would affect a broad spectrum of species. Likewise nets and traps do not discriminate among species. Pressure on other life-cycle stages such as loss of habitat might also affect several species at once.

Starr et al (2007) found that Nassau grouper exhibit strong site fidelity at Glovers Reef. There is also some evidence that spawning fish train others to find their site. So if site densities decrease below a minimum, the species may lose collective memory of the site. This seems to be the case with some Nassau grouper sites.

Conservation Target #2: Nassau grouper

The Nassau grouper (*Epinephelus striatus*) in parts of the Caribbean is threatened by aggregation fishing and, as a result, is classified as Endangered on the IUCN Red List.

Figure 2-8. Distribution of Nassau grouper (***Epinephelus striatus***) in the tropical western Atlantic and locations of spawning aggregations that are still fished or are believed to have disappeared (from Sadovy, 1993).

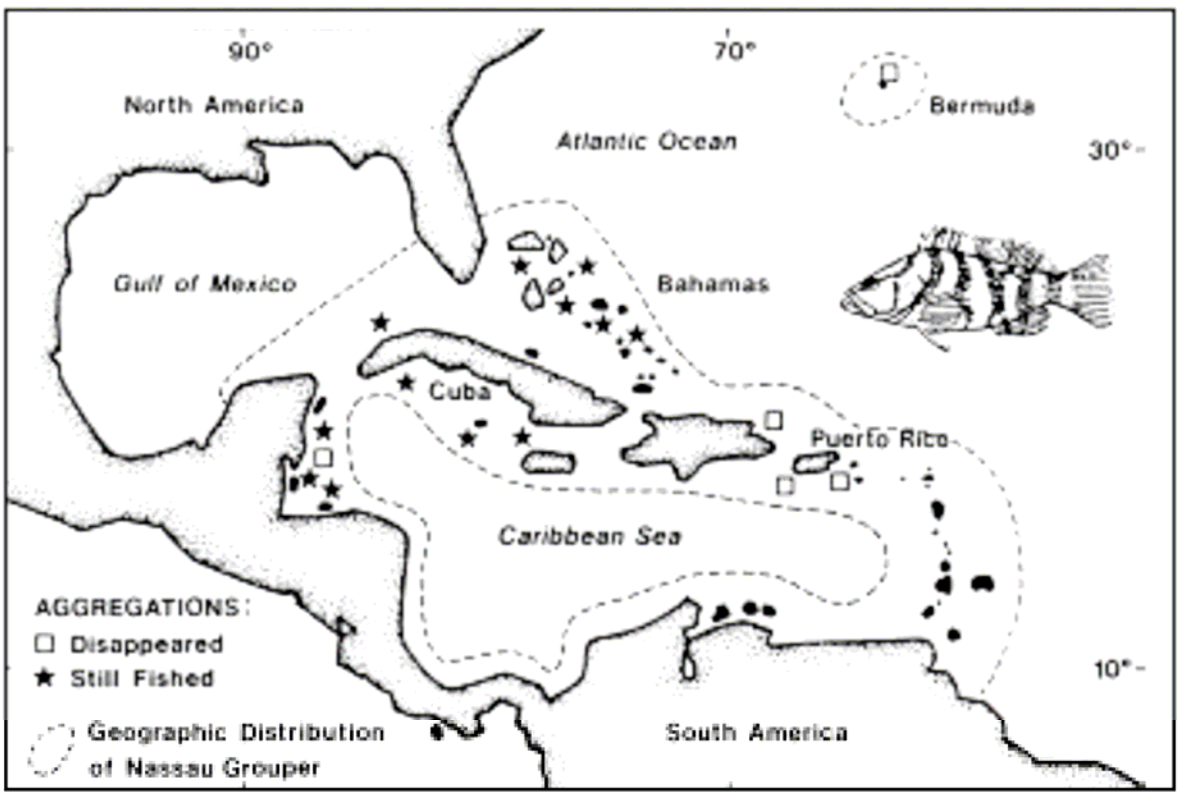


Figure 42: Distribution of Nassau grouper

The Nassau grouper is historically one of the most important food fishes inhabiting Caribbean coral reefs. It once formed enormous spawning aggregations throughout the

Caribbean, each of which contained up to 100,000 individuals. Roughly one-third of these aggregations have been eliminated by fishing (Sadovy and Eklund 1999). The Nassau grouper population has been so overfished that it is now fully protected in the United States, is a candidate for the U.S. Endangered Species List (Sadovy and Eklund 1999), and is listed as threatened by the American Fisheries Society (Sala et al. 2001).

The Nassau grouper was once the second most commonly caught fish in Belize. Although fishing persisted year round, the most intensive fishing occurred for about six weeks during the time of the full moon in December and January, on localized Nassau grouper spawning aggregations. At least nine Nassau grouper spawning sites were known to occur along the Belize barrier reef and offshore reefs (Heyman 2001; Paz and Grimshaw 2001). Fishermen mostly used handlines to fish Nassau grouper. Belizean fishermen often rig 3 to 15 hooks per line. The spear gun, so effective at removing groupers and other fish from Belize's seas, was not commonly used in fishing spawning aggregations (Wade 2001, Arceo 2001). Up until the 60s, there was little fishing pressure on aggregations, but from 1955-65 things changed and up to 300 boats would work one aggregation. By 1982, 1,200 fishers representing 570 boats were exploiting grouper spawning grounds. In Belize 30% of all groupers caught are Nassaus. Catches from aggregations declined about 50% from 12,200 kg per year to 5,900 over a ten-year period ending in the late 1980s while total annual landings declined from 90,900 kg in 1984 to 21,000 kg in 1991 (Sadovy & Eklund 1999). One of the spawning sites Cay Glory had been fished since the 1920s and provided a catch rate of up to 1,200–1,800 Nassau groupers per boat per spawning season during the 1960s. In 2001, fishers caught only 9 Nassau groupers out of an aggregation of 21 groupers at the same site (Paz and Grimshaw 2001).

This decline in abundance is not unique to Cay Glory. A survey in January 2001 showed that only 2 out of the 9 traditional spawning sites in Belize had more than 150 Nassau groupers; the rest of the sites have now been fished out (Heyman 2001; Paz and Grimshaw 2001). The impacts of fishing on spawning aggregations may not be limited to Nassau groupers because other species of groupers and other reef fishes have been observed spawning simultaneously at the same sites in Belize and elsewhere.

Heavy fishing of spawning aggregations especially using gear like nets, spearfishing, and capture of juveniles in fine mesh fish traps are almost certainly causes of massive declines across the Caribbean. Most alarming are the declines of spawning sites (25-50% no longer form) and in numbers at the spawning aggregation sites. These represent the entire reproductive output of Nassau grouper; below a certain point, the species will not be able to maintain itself.

In 2004, researchers studied Nassau grouper caught at a spag site on Turneffe – Maugre Caye which lies just north of the Dog Flea Caye Site. Mean length of the fish was 60.5 cm. And 19% of them were either immature sexually or their gonads were in the early stage of development. So at Maugre Caye in 2004, landings show that 88% of fish had lengths between 50 and 70 cm. This is the mid-range of reproductive size. Indeed, 18% of them had immature or early developing gonads. At the same time, observation were taken at Dog Flea Caye which showed a very distinct shift to smaller fish. More than 95% of Nassau grouper seen had less than 40 cm. None of these fish were caught and fecundity analyzed, but they all lie at the shorter end of the reproductive size range. Most likely, these fish are not yet able to spawn. A rough analysis show that CPUE of 1.2 fish per hour. If the mean weight is 4.5kg then dressed is ca 3.0 kg: at $10BZ/kg = 36 per hour for two men.

During the National Monitoring Survey of January 2003, no significant number of Nassau groupers were observed at any of the banks except for Dog Flea. Three days after the full moon, researchers observed approx. 5,000 individuals. There were two boats fishing the site that day with a total number of 5 fishermen. Jack Barrows' boat fished about 100 Nassau and 3 Blacks. The other boat (Abel Rodriguez and Bang from fisheries) fished about 30 Nassau. During the dive, the majority of the nassau were light phase and normal phase with a few bi-colors and dark phase. On the fifth day after the full moon, we did two dives at the site. On the first dive (2:45PM) about 1,000 Nassau grouper were observed, most were bicolor. On the second dive (5:30) the school had move from the edge of the drop-off to deeper water. No spawning was observed.

The data collected also indicate that of the roughly 15,000 Nassau groupers observed in the 2005 spawning season, 31.71% were between 31 and 50 cm in length, while 54.77% were between 51 and 70cm. Only 11.65% were above 70 cm in length which is a similar proportion to fish observed in closed sites in 2004. Groupers generally reach sexual maturity between 30 and 80cm (Spags newletter 2005).

In general, slow-growing long-lived species with limited spawning periods and, possibly a small recruitment window are extremely susceptible to overexploitation. Species which produce pelagic eggs over limited time periods, may be subject to highly variable recruitment success, making them particularly vulnerable to failure in poor years or when population sizes are low. In addition, groupers at spawning sites are highly concentrated and tend to be less cautious and easier to catch.

Nassau grouper, because of its previous abundance, may be a keystone species in many reef communities. As a top predator, it would have played a major role in maintaining ecological balances and its loss must have caused many shifts and changes in local food webs.

Small juvenile Nassau grouper are common in shallow sea grass beds, macroalgae, and around clumps of *Porites spp*. Soft Corals. Juveniles preferentially settle into the interstices of macroalgal clumps remaining several months before associating with other microhabitats in macroalgal beds. Monthly repeated censuses of a cohort indicated that juvenile density decreased sharply after settlement, until fish emerges from algal habitat at several months of age, and thereafter remained relatively constant. Abundance is probably higher in macroalgal beds to avoid high post-settlement predation in the sea grass beds. Juveniles shift to patch reefs within about three months when total length reached 120-150 mm. (NOAA 2001).

Nassau grouper can reach 29 years of age; they mature sexually at 4 years, and most are fished commercially at 2-9 years. Most fish at market range from 2-11 kg, but they can reach 27 kg. As adults, groupers are unspecialized bottom-dwelling, solitary predators. Feeding takes place all day, and the larger individuals take more crustaceans. They also follow and feed with other predators like octopus, triggerfish, or eel. Mean monthly growth rates are 8.4 to 11.7 mm per month. Nassau groupers may remain in the same place for extended periods and seem to recognize their home base by visual clues. They do not usually move far from home or even far from cover. But migrations to spawning sites can be substantial distances, and at least some Nassau grouper, travel to their site in groups of up to 5,000.

An excellent resource is a paper attached to Paz & Truly (2007), 'The Nassau Grouper Spawning Aggregation at Caye Glory: A Case Study' called "Vulnerability of Nassau Grouper to Overfishing" (see Appendix 4).

Conservation of Nassau grouper is problematic. Quotas have been introduced as management measure in Cuba and elsewhere. Gear and seasonal restrictions have been used. Marine reserves and closures have potential to be excellent management tools. In the US an analysis by SAFMC found that the maximum sustainable yield required a minimum size limit of 24 inches (610 mm). Stock SSBR (Spawning stock biomass per recruit) should be maintained at 30-40% of their virgin spawning stock biomass. Reproduction temperature is very specific with N. grouper – 25 – 26 C.

Nassau grouper is also a prime candidate for aquaculture. All the conditions necessary for rearing have been developed in the laboratory. Indeed, juveniles raised from eggs were used to test the feasibility of restocking reefs. Some tagged recruits were still seen up to 9 months later (Roberts 1995). The potential for stock enhancement has yet to be determined. Nassau grouper females have a fecundity of 3-5 eggs/mg of ripe ovary. Females 45-50 cm would then carry 4-5 million eggs each. Eggs are driven mainly by offshore winds. For Nassau grouper recruitment occurs in short discrete pulses perhaps only once per year.

Conservation Target #3: Cubera Snapper

CUBERA SNAPPER

Order: Perciformes

Family: Lutjanidae

Genus: *Lutjanus*

Species: *cyanopterus*

Figure 43: Cubera snapper

Cubera snapper have been observed aggregating to spawn at Caye Bokel in May and June. Cuberas spawn at other sites along the Barrier Reef from April to September, and they probably do so at the Elbow. Routine monthly UVAs will yield those data. Fishermen at Tuneffe are fishing cuberas on a routine basis, usually at night when the cuberas bite best. Nearly every night, 2 or 3 boats are fishing at Caye Bokel; some are using lights as local aggregators. Fisheries Department wants to offer special licenses for fishermen during snapper season at the Elbow.

The cubera snapper is considered "vulnerable" by the International Union for Conservation of Nature and Natural Resources (IUCN). But at Caye Bokel, in 2003, multiple counts showed 5,000 cuberas aggregating at the Elbow. This is reasonably healthy population, but routine counts at other sites are often much higher. At Gladden Spit for example, cubera counts routinely reach 14-15,000 in June, July, and August. Managers there use a count of 3.500 – median count over two years of monitoring – as a minimum. Caye Bokel should remain above 3,500 as well. So once monitoring begins, Turneffe fishermen are eligible for special licenses as long as peak counts don’t drop below 3,500.

An important issue is the health of other life-cycle stages. Spawning species at atolls may represent a special case. Using tags, Starr et al (2007) found that the population of Nassau grouper n Glovers is a relatively closed population, i.e. they grow at Glovers, spawn there and generally do not leave the Atoll. It's possible that the cuberas of Turneffe behave similarly; the snappers may also be a closed group.

Thus, the study of connectivity and the fate of the larvae that emanate from the spawn ought to be high priority subjects of study. Indeed, monitoring of juvenile populations should be a more sensitive measure of the health of this population, but the methods need to be established.

Conservation Target #4: *Montastrea spp.*

Several species of corals are known as reef-builders; they produce large boulders that make up much of the mass of the reef: *Diploria spp., Siderastrea spp. And Montastrea spp.* are examples.Reef-building corals may occur in a variety of growth forms, and there often is strong variation in coral shape even within a species. In this photograph, we can see the branching elkhorn coral *Acropora palmata* (upper left), with arms showing strong orientation into an oscillatory current between left and right. In the right foreground is the mound-shaped coral *Montastrea annularis*. It is of great interest that such differently shaped corals can occur side by side.

Figure 44: **Branching and Mound-Shaped Corals** Photo by Phil Dustan

In deeper waters (ca. 30 m) in the reefs of the north coast of Jamaica, one finds a greatly flattened species of *Montastrea*, which is a very close relative of the mound-building shallow water *Montastrea annularis*. The flattened mushroom-like shape may be an adaptation to capture light efficiently.

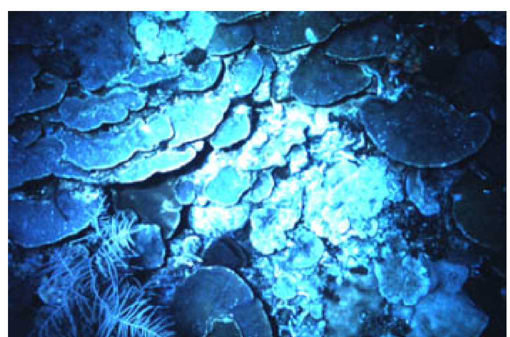


Figure 45: **Deeper Water form of "*Monastrea annularis*** Photo by Phil Dustan

Boulder coral (M. annularis) is the commonest Caribbean coral. Boulders are 1.5 m or more in diameter. Green, tan, or brown lobate heads, often showing white damaged areas. Cups are shallow circular, about 2.5 mm. In diameter. With radiating septa in 3 cycles first 2 fusing in center with collumella and fine regular teeth on septa. This variant forms shingle-like colonies in deep water. Boulder corals are the main reef-builders on fringing reefs. It forms irregularly shaped boulders up to 62 m. tall. Depressions may fill with detritus and leave scars. They are tan or green boulders that have equidistant star-like cups with sepia extending from each cup like rays of light. In the rear zone of the reef crest, Boulder coral often forms lobed colonies with white patches. Sea urchins and snails occupying dead depressions further grind down the rock, so some of them may look multi-lobed.

Boulder coral are spherical and boulder-like near the surface and flattened and plate-like in deep waters. This gives it a progressively larger polyp surface area relative to skeletal mass. The interplay of light reduction at depth (and the consequent reduction of photosynthetic activity by the xooxanthelae) with increased reliance on plankton ingestion has affected the manner in which the polyps have designed the coral head.

In 1995, the Meso-American Barrier Reef underwent its first major bleaching event. Melanie McField's study was unique because of its rapid initiation (2 weeks after start of mass bleaching) and its broad spatial coverage of a major Caribbean reef system. During the 1995 mass-bleaching event, colonies of the *Montastrea annularis* complex were the most affected corals across the region (76%). The extent of bleaching observed across the region was most similar within habitat types. Five of the ten most common scleractinian corals exhibited significant differences in bleaching across habitats. *M. annularis* and *S. siderea* were more bleached in forereef sites, while *Porites porites*, *Agaricia tenuifolia*, and *Agaricia* were more bleached in backreef sites. Also, corals previously reported to host *Symbiodinium* C, were significantly more bleached (P = 0.005) than corals reported to host *Symbiodinium* B (McField 2001).

In 1998, the Belize Barrier Reef underwent another major and extensive elevation in sea-surface temperature and corresponding coral bleaching. Right at the peak of bleaching, Hurricane Mitch struck, further damaging fragile corals. The combination was deadly. In 1997 for example, average coral cover on the Belize Barrier Reef stood at 28%. In 1999, coral cover had fallen to 15%, a drop of 48%. At Calabash Caye on Turneffe Atoll, mean coral cover dropped 56%. Diversity on reefs off Calabash dropped more than 30% (McField 2001). *Montastrea* species dropped from a reef-wide average cover of 11.08% in 1997 to 5.45% in 1999.

Patterns of bleaching were not fully consistent, thus some deep water areas bleached more than shallow areas even though deep water temperatures are cooler. Such variations may be caused by different types of zooxanthellae living in the coral. For example, McField (2001) found that corals hosting clade C symbionts were more prone to bleaching than clade B symbionts. Highest mortalities occurred in species capable of harboring multiple clades of zooxanthellae like *M. annularis* complex. Massive, reef-building corals on the fore reef were most affected of all (Kramer & Kramer 2000).

Montastrea spp. includes *M. annularis*, the common Star Coral, and *M. cavernosa*, the large Star Coral which is seen here. It has some of the largest polyps, nearly 1 cm in size and colonies can grow quite large. This picture *(M. annularis)* was taken as the coral was reproducing and the orange balls are bags containing eggs and sperm. The bags float to the surface where they burst and fertilization takes place. Most of the corals of this species release at the same time, generally 7-9 days after a full moon, about 2 hours after sunset. The next day, we commonly get calls reporting "pollution" on the reef! The white substance in the upper right corner is mucus released from the surface of the coral.

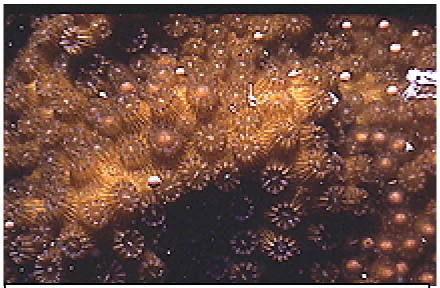


Figure 46: *M. annularis* reproducing

Conservation Target #5: Permit

PERMIT

Order - Perciformes

Family - Carangidae

Genus - *Trachinotus*

Species - *falcatus*

Carolus Linnaeus originally described the permit in 1758, classifying it within the jack family carangidae. He initially named it *Labrus falcatus*, but later taxonomists reclassified the permit within the genus *Trachinotus Falcatus*, a Latin adjective that translates to "armed with scythes," appropriately describes the large sickle-shaped dorsal fin that breaches the surface when permit feed.

Permit inhabit the western Atlantic from Massachusetts to southeastern Brazil. They occur throughout the West Indies and the Gulf of Mexico, and less-frequently in Bermuda. The species has been reported in the eastern Atlantic, but does not regularly occur there.

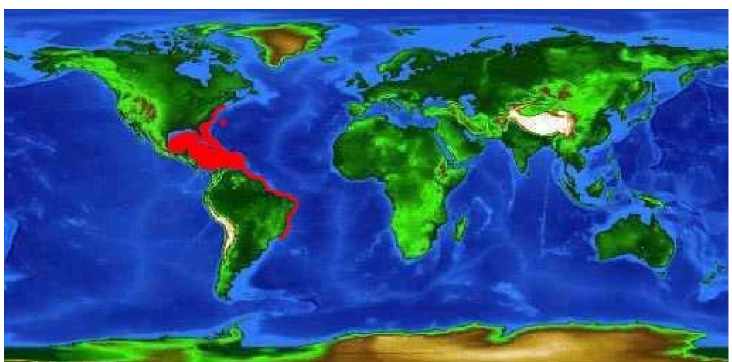


Figure 47: World distribution map for the permit

Permit primarily occupy inshore regions such as flats and sandy beaches, and deeper cuts, channels, and holes adjacent to these areas. The substrate of the flats may vary from sand, mud, marl, or sea grass. Permit often swim in water depths less than 2 feet, though due to large body depth, large individuals cannot occupy waters as shallow as other flats species such as bonefish. In deeper waters up to 30 m, permit often congregate around structures such as reefs, jetties, and wrecks where they frequently occur in large schools.

Permit reach a maximum length of at least 48 inches (122 cm) and a weight of 79 pounds (36 kg). They grow rapidly until an age of 5 years, at which point growth slows considerably. Permit reach sexual maturity at about 2.3 years for males, and 3.1 years for females. Their size at sexual maturity ranges from 19.1 inches (486 mm) for males and 21.5 inches (547 mm) for females. Permit can attain an age of 23 years, though they probably live longer.

Permit primarily forage on flats and intertidal areas, entering shallow water on incoming tides from deeper adjacent channels and basins. They usually travel in schools of about ten, but may school in larger numbers; larger permit tend to be more solitary, feeding alone or in pairs. Permit also congregate around wrecks and other deeper-water structures.

The permit uses its hard mouth to dig into the benthos and root up its prey. These food items usually consist of crustaceans and mollusks, which the permit crushes with its granular teeth and pharyngeal bony plates. However, as opportunistic feeders, permit will eat a variety of animals, including amphipods, copepods, mollusks, polychaetes, fish and insects. Developmentally, permit exhibit planktivorous feeding habits as juveniles, eating copepods, amphipods, mysids, larval shrimp, and fish. As they increase in size, permit begin to feed on benthic prey including mole crabs, coquin clams, flatworms, gastropods, and sessile barnacles. Larger adults feed on gastropods, sea urchins, bivalves, and crabs.

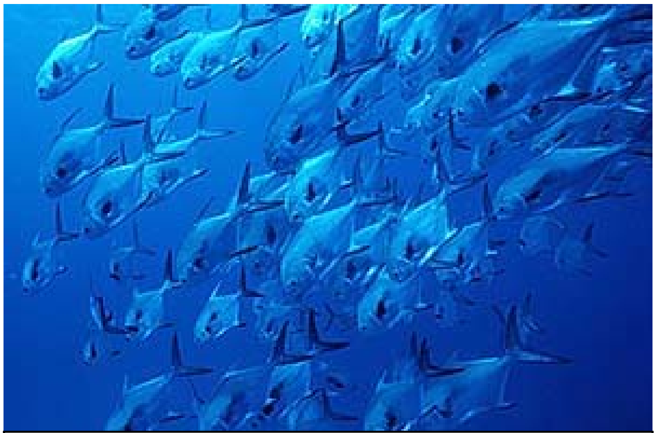


Figure 48: Schooling permit ©Doug Perrine

Permit spawning may last all year, but occurs primarily from May through June in the Florida Keys. Spawning peaks during these summer months, with extended spawning seasons occurring outside this main period and a decrease in spawning activity during the winter months. Researchers have found that permit may spawn over natural and artificial reefs or in nearshore waters in the middle and lower Florida Keys. Males reach sexual maturity earlier than females, 2.3 versus 3.1 years, and at respective sizes of 19.1 inches (486 mm) and 21.5 inches (547 mm). Fish farmers have only recently begun to experiment with the mariculture of permit, raising them in large near-shore pens for commercial sale.

Sportfishers consider the permit an important gamefish, and this fish, in addition to the bonefish and tarpon, supports a large fly fishing industry. Many anglers regard the permit as one of the most difficult gamefish to catch, and consider a permit caught on fly the highlight of their angling achievements. Many fishing guides and anglers highly esteem the permit and release the fish unharmed – catch and release. Studies are currently underway to determine survival rates after catch and release.

Figure 49: A happy permit angler! This fish was released to fight another day.
© *Sean Morey*

Though susceptible to overfishing, the World Conservation Union (IUCN) does not currently list the permit as an endangered or vulnerable species. The IUCN (a global union of states, governmental agencies, and non-governmental organizations in a partnership) assesses the conservation status of species.

In Belize, Turneffe Flats has recently commissioned an extensive and intensive study of the economic value of catch-and-release sport fishing for three species – bonefish, permit, and tarpon:

- Tourists contribute nearly $400 million (BZ) annually to the Belizean economy and support more than 13,000 jobs which accounts for nearly 17% of the Belize GDP.
- Sport fishing for bonefish, permit and tarpon creates an annual economic impact of over $25 million (BZ) in direct expenditures in the Belizean economy plus an additional $31 million in Value Added expenditures for a total yearly economic impact of roughly $56 million. This amounts to approximately 6% of the Belize's tourist economy.
- Sport fishing for these three species results in approximately $2.7 million in Hotel Tax, Property Tax, Business Tax, GST, Employee (income and social security) Taxes, and Airport Exit Taxes generated for the Belizean treasury.
- Nearly $30 million in annual wages and salaries as well as 1,800 full-time jobs are supported by these three species.
- In 2007, more than 100 independent fishing guides provide services to approximately 4,800 international fishing guests at hotels and resorts throughout Belize, and at least 13 fishing lodges hosted nearly 1,000 international anglers from Europe, Canada, the United States and elsewhere.
- Virtually all bonefish, permit and tarpon caught by sport fishermen in Belize are released back to the water alive making this annual economic contribution fully sustainable. Therefore, with adequate management, it is quite realistic to suggest that sport fishing for bonefish, permit and tarpon will generate an economic impact of roughly $600 million for Belize over the upcoming decade (Fedler 2008).

3.1.2: Assessment of Target Viability

The five targets were then evaluated for viability or biological integrity. Each target has key attributes that influence essentials aspects of its biology. Attributes generally fall into one of three categories:

- Landscape Context – environmental processes like fire, connectivity, migration, etc.,
- Condition – population structure, biotic interactions, etc.
- Size – species abundance, minimum dynamic area, etc.

Table 13: Viability Ratings for Conservation Targets

Conservation Target	Landscape Context	Condition	Size	Overall Viability Rating
1. Community of Spawning Species	Fair(2.25)	--	--	**Fair(2.25)**
2. Nassau grouper	Fair(1.75)	Poor(1.0)	Poor(1.0)	**Poor(1.25)**
3. Cubera snapper	Good(3.5)	Good(3.5)	Good(3.5)	**Good(3.5)**
4. *Montastrea spp.*	--	Good (2.6)	Fair(2.0)	**Fair (2.3)**
5. Permit	Good(3.5)	Fair(2.5)	Fair(2.5)	**Fair(2.83)**

Viability Ratings:

Very Good: Viability criteria at or above desired future status
Good: Viability at or above minimum threshold for biological integrity
Fair: Viability criteria at or above a minimum restorable level
Poor: Viability criteria below minimum restorable status (probably unrecoverable)

See Appendix 4 for detail of criteria and ratings.

The maximum rating for 'Community of fish that spawn' is based on the number of species that spawn in 12 months (38) at Gladden Spit, a different site on the Belize Barrier Reef. The sites may not be comparable in this way. However, no routine monitoring has ever been done at Turneffe so at least Gladden Spit gives a figure to work with.

The plight of Nassau grouper is well known and well studied. Our viability ratings reflect the state of the population worldwide. The fact that most Nassau grouper recently seen at Dog Flea are below 40cm is particularly disturbing. Cuberas still have a healthy population and their nursery grounds at Turneffe are still in excellent shape. We target Cuberas because they will be fished during snapper season; we want to watch them closely. Permit receive a fair rating because the spawning population peak counts are relatively small and because the 50% are below mean reproductive size.

Table 14: Numeric Ranking of Targets			
Conservation Target	**Overall Viability Rating**		**National Priority Rating**
Community of Spawning Fish	Fair	2.25	2
Nassau Grouper	Poor	1.25	3
Cubera snapper	Good	3.50	1
Montastrea spp.	Fair	2.3	1
Permit	Fair	2.83	2

Montastrea spp. are reef building corals that have suffered greatly from global warming and high sea-surface temperatures. Bleaching events in 1995 and 1998 led to more than 50% mortality among *Montastrea spp*. in some areas. The predominant clade of zooxanthellae in *Montastrea* is C, the least tolerant of heat stress.

A rating-improvement goal is set for each target along with a SMART objective and indicator for each. Most targets also represent other similar groups or species. For example, *Montastrea spp.* could stand in for all reef-building corals.

Table 16: Conservation Target Assessment			
Conservation Target	**Current Rating**	**Goal**	Justifications
1. Community of Spawning Species	Fair	Good	Justification: Both sites are multi-species. Severe decline causes loss of spawning ability. Connectivity
			Other systems represented: Spag sites on MBRS
			Objective: # of species increase or remain the same by 2012
			Indicators: # of species identified in 12 months
2. Nassau grouper	Poor	Fair	Justification: Rapid decline; species nearly extinct
			Other systems represented: All grouper species that aggregate to spawn
			Objective: Peak counts reach 3,000 by 2012
			Indicators: Peak underwater visual assessments; size-class graph
3. Cubera snapper	Good	Very Good	Justification: Still see high numbers spawning, but targeted by fishermen; monitor closely
			Other systems represented: All snapper species that aggregate to spawn
			Objective: •UVAs will be greater in 2012 than peak count from 2000-2007.
			Indicators: Peak underwater visual assessments; size-class graph
4. *Montastrea spp.*			Justification: Global warming affecting reefs world-wide. Reef-builders hard hit.
			Other systems represented: Stony, reef-building corals.
			Objective: % coral cover of *M.ann*. greater in 2012 than in 2007
			Indicators: % coral cover; % of coral area; % bleaching
5. Permit	Fair	Good	Justification: Population fished commercially; crucial for lucrative fly-fishing
			Other systems represented:
			Objective: At least 1,500 permit will spawn at Caye Bokel in 2012.
			Indicators: Peak underwater visual assessments; size-class graph

3.2: Threats to Biodiversity

The conservation targets were selected because their biological integrity is threatened. In this section, we list the major threats to the targets:

1. Illegal Fishing
2. Over-Fishing
3. Loss of Habitat
4. Pollution
5. Global Warming.

Each threat is summarized in the following tables that also rate the threats by a number of characteristics (see Guidelines for Ratings criteria). The table also offers a preliminary list of management actions to abate the threat. These actions lead to our management strategies.

Table 16: Threat#1 -- Illegal fishing		
Using special gear – nets, traps, spears – to fish aggregations; any fishing of Nassau grouper; any fishing in the reserves july-march.		
Status	Active	
Target	Spawning Aggregation Species	
Source	Traditional fishermen on Turneffe	
Area	2	Just at spawning site but small reserves
Severity	3	Spags are declining precipitously; many locally extinct
Urgency	3	Spags declining right now
Recovery Time	2	Ten years s minimum, so use 11-100. Groupers and snappers are longlived and slow to mature
Probability of Occurrence	1	Threat is occurring now.
Management Actions	Daily patrols, Demarcation, Fishermen Outreach, Alternative livelihood	

Table 17: Threat#2 -- Overfishing		
Even using handlines can take too many fish		
Status	Historic	
Target	All spag commercial species	
Source	Traditional fishermen on Turneffe; poor management practices	
Area	2	Spags sites heavily fished
Severity	3	Some species may go extinct
Urgency	3	Even with populations low, fishermen still work them
Recovery Time	2	Slow maturing species, may need 2 or 3 generations
Probability of Occurrence	0.50	Already occurred for some species; may happen for others
Management Actions	Regular monitoring, Fishermen Outreach, Alternative livelihood	

Table 18: Threat#3 -- Loss of habitat		
Dredging up seagrass, clearing mangrove for development, siltation		
Status	Active	
Target	Nursery grounds for spags -- seagrass and mangrove habitat	
Source	Greedy developers and ministers	
Area	1	Isolated areas and small so far, but leases given out increasingly
Severity	1	Aerial photos show sea grass lost and mangroves cut down
Urgency	2	Developers poised to build in next few years.
Recovery Time	1	Mangroves will return in 10 years; seagrass need water quality
Probability of occurrence	0.5	There's money to be made
Management Actions	Lobby for compliance with law and stiffer penalties, rangers to monitor, outreach to developers	

Table 19: Threat#4 -- Pollution		
Locally follows development (low flushing in lagoon); sedimentation; also oil from bilge & spills		
Status	Potential	
Target	Fore reef corals; nursery grounds for spags	
Source	Poorly planned development; dredging; oil spills	
Area	1	Likely to be local unless massive oil spill; central lagoon
Severity	0	Not happening yet
Urgency	1	Development could show effects within 10 years
Recovery Time	2	Generally devastating impacts
Probability of Occurrence	0.25	Unlikely to occur during this management cycle
Management Actions	Lobby for compliance with law and stiffer penalties, rangers to monitor, outreach to developers	

Table 20: Threat#5 -- Global Warming		
Leads to coral bleaching; Also spawning fish sensitive to temperature		
Status	Active	
Target	All	
Source	Anthropogenic practices	
Area	4	Global phenomenon that affects everything
Severity	2	By itself may not kill entire population
Urgency	0	Full effects later in the century
Recovery Time	2	Recovery depends on adaptation; may take decades
Probability of Occurrence	0.25	Climate change effects may take decades to show up
Management Actions	Monitor water temp with loggers; monitor spags; Study temp resistant zooxanthellae;	

Table 21: Overall Threat Rankings								
Threat		Criteria Ratings					Total Score	Ranked Threat
		Area	Severity	Urgency	Recovery	Probability		
#1	Illegal Fishing	2	3	3	2	1	30	5
#2	Overfishing	2	3	3	2	0.5	15	4
#3	Loss of habitat	1	1	2	1	0.5	1.5	2
#4	Pollution	1	0	1	2	0.25	0	1
#5	Global Warming	4	2	0	2	0.25	4	3
Threats ranked with 1 = least severe								

The two top-ranked threats are fishing. This is not surprising given that the two reserves are small and were designed to protect commercially fished species. Illegal fishing entails using nets, traps, longlines or any fishing within the reserves. During snapper season, a few special licenses for traditional fishers may be issued. Without careful monitoring and management, those species may decline also from over-fishing. The threats are then weighted for the consequences of non-intervention and the two fishing threats stand out even stronger.

Table 22: Weight of Non-intervention			
Primary Threat	**Threat Ranking**	**Non-Intervention Weight**	**Weighted WCS Threat Score**
Illegal fishing	5	2	10
Overfishing	4	2	8
Loss of habitat	2	1	2
Pollution	1	1	1
Global Warming	3	1	3

Conservation planning continues by combining the Target Viability

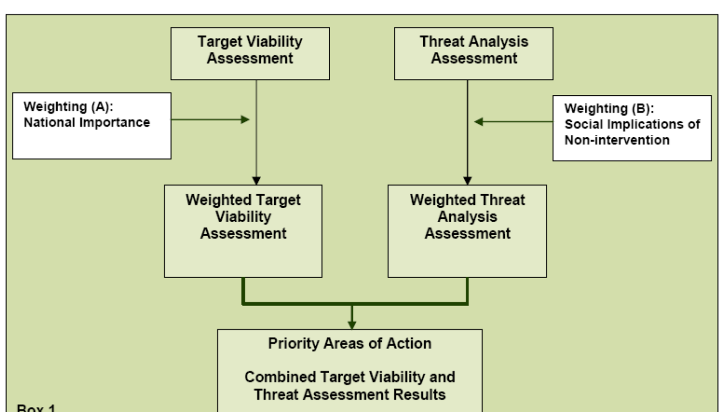


Figure 50: Adding Weights

Analysis with the Threats Analysis which will then lead us to strategic actions as shown schematically in Figure 26.

The combination of Viability and Threats are shown in Table Prioritization. As we would expect, Nassau grouper is by far the highest priority with a score of 24.0; 'Community of spawning fish' is next at 8.9.

Table 23: Prioritization

Conservation Target	Primary Threat	Viability Score	National Priority	WCS Threat Score	Prioritization Score	Ranked Priority
Community of Spawning Fish	Illegal fishing	2.25	2	10	8.9	2
Nassau grouper	Illegal fishing	1.25	3	10	24	1
Cubera snapper	Overfishing	3.50	1	8	2.3	4
Montastrea spp.	Global warming	2.33	1	3	1.3	5
Permit	Overfishing	2.83	2	8	5.7	3

$P = (1/V) * N * T$

Table 24: Priority Areas for Action

Priority	Rank	Conservation Target	Threat
High Priority	1	Nassau grouper	Illegal fishing
	2	Community of Spawning Fish	Illegal fishing
Medium Priority	3	Permit	Overfishing
	4	Cubera snapper	Overfishing
Low Priority	5	*Montastrea spp.*	Global warming

Illegal fishing of Nassau grouper came in as the highest priority by far. Given the likelihood that the population spawning in these reserves is closed, isolated on the Atoll, offers a more clear picture of factors and solutions to the N. grouper decline. The population is even more vulnerable than we originally thought, but management actions might be easier to implement. A population limited to the Atoll is much easier to envision. Global Warming earns Low Priority mainly because of low Urgency.

3.3: Strategies to Reduce Threats

Now that we have pinpointed priorities for action, what shall we do? Table Threat Abatement offers strategies and management actions that will alleviate threats; both direct and indirect threat are considered:

Table 25: Threat Abatement		
Threat	Type	Strategies and Actions
Illegal Fishing	Direct	Strategy: Enforce fisheries law
		Actions: Daily patrols, Demarcation, Fishermen Outreach
Low income of coastal residents	Indirect	Strategy: Alternative livelihood
		Actions: Fishermen outreach, surveys, training for research, dive-master, other based on surveys
Overfishing	Direct	Strategy: Monitor fished populations with fishermen
		Actions: Monthly UVAs at spag sites, size-class charts, quarterly monitoring of juveniles, monitoring all landings from reserves
Poor understanding of conservation among fishermen	Indirect	Strategy: Educate by inclusion
		Actions: Train fishermen to monitor fish populations, hold focus group education sessions, investigate mariculture with fishermen
Too many fishermen for the resource	Indirect	Strategy: Develop targeted, major alternative-livelihood program
		Actions: Train fishermen to monitor and research, dive master training, use fisheries data to target fishing populations by village and available resources
Not all life stages protected	Indirect	Strategy: Lobby for protection of entire Atoll
		Actions: Contact forestry
Global warming	Direct	Strategy: Minimize carbon footprint
		Actions: Use 4-stroke engines, renewable energy where possible
Coral Bleaching	Indirect	Strategy: Seek resistant corals
		Actions: Map & monitor a variety of sites with different environment, study clades of zooxanthellae to find temp resistant strains
Juvenile habitat destruction	Direct	Strategy: Monitor closely

		Actions: Quarterly aerial surveys, landsat?, water quality, monthly visual survey
Illegal? Development	Indirect	Strategy: Monitor MNR
		Actions: Monthly calls to mangrove license office, NEAC, contact developers in non-compliance

3.4: Monitoring Success of Strategies -- Implementation

Finally, how will we know if we are succeeding with the strategies we are using? How can we evaluate the effects of our programs? How can we improve? Monitoring provides feedback to management. The following table summarizes a monitoring database to follow the progress of our strategies. These data should accompany and inform all management decisions.

Table 26: Monitoring Success of Implementation

Strategy/Action	Target	What to Monitor	How to Monitor	Indicator
Reduce illegal fishing/ enforce law	Fishermen using extra gear at spag sites or fishing N grouper	Amount of illegal activity in reserves	Daily patrol reports	# infractions per quarter
Reduce illegal fishing/ Outreach workshops	Regular fishermen at Turneffe	# attendees at workshops Knowledge gained	Attendance lists, pre-and post-tests	% fishermen attending workshops; Change pre- to post-test
Improve coastal income/ alternative livelihood	Fishermen especially youth who are willing to change	Amount $$ earned (difficult), # of jobs created	Surveys	% fishermen with alternative income
Reduce overfishing/ monitor all life stages	Commercially fished species	Abundance and size of juveniles, adults, landings	UVA reports, spags database, monitoring reports	Peak UVA per species, size-class graphs, juvenile density?
Reduce Overfishing/ train fishermen to carry out monitoring	Fishermen from Turneffe who want to supplement their income	# of fishermen who take training, # who actually get paid for it	Attendance lists and certificates, UB payroll records	% fishermen trained, % fishermen hired, % fishermen working after 3 years
Reduce overfishing/ involve fishermen in monitoring results	All fishermen at Turneffe	# of fishermen who participate in workshops and discussions	Attendance lists, participation	% fishermen taking part
Reduce overfishing/reduce	All fishermen at Turneffe	# of f’men who find other	Periodic surveys, self-	% fishermen hired in other

number of f'men by alternative livelihood		livelihoods	reports	field, % fishermen working after 3 years
Global Warming/ reduce footprint	UB/Calabash Caye infrastructure	Kilowatt production	Field station logs	%kWatts from renewable; gallons fuel burned
Coral bleaching/ study & monitor	Reef-building stony corals	Growth and survival studies on *Montastrea spp.*	Monitoring reports, research reports	% survival among sites, zooxanthellae survival rates
Juvenile habitat destruction/ Monitor Area	Mangrove & seagrass beds on Turneffe	Aerial extent of forests and beds	Quarterly aerial photographs	% change in surface area
Juvenile habitat destruction/ Monitor	Development process: government records	Leases with development plans, NEAC, licensing eg dredging, mangroves etc	Government records/public officers	% legal leases, # development licenses and acres

4.0: Management Planning

4.1: Management and Organizational Background

Fisheries Department holds ultimate responsibility for marine resources including marine reserves. Their strategy for managing is to partner with an NGO or other organization who takes care of day-to-day management of the parks. Fisheries has always coveted an alliance with an organization that carries out research. In 1996,the University of Belize built a field station on Calabash Caye on the eastern shore of Turneffe Atoll that lies between Dog Flea Caye Marine Reserve and Caye Bokel Marine Reserve.

The University of Belize Marine Science Institute is anxious to implement management of protected area as a teaching platform, a way to provide practical on-the-job experience for students. UB also wishes to establish a variety of research programs utilizing the undisturbed areas for scientific study -- particularly now, when the reef is under threat on so many fronts – global warming, depleted stocks, hyper-development of marine real estate.

UB's Institute of Marine Science and Fisheries Department have informally agreed to co-manage the two reserves, and a Memorandum of Understanding has been signed between them (see Appendix 4). The development committee facilitated by Coastal Zone Management Authority called Turneffe Islands Coastal Advisory Committee (TICAC) plays a prominent role as Advisory Board to the co-managers. Management will be based at UB's Calabash Caye Field Station.

The immediate aim of park management is to create suitable management structures within UB, to establish a management presence within the Reserves, to create a security apparatus including park rangers, delineation of Reserve boundaries, and the continued building up of a partnership with the communities. Management envisions a process whereby capacity will be built up over the five-year period covered by this plan.

UB and Fisheries have some excellent colleagues. World Wildlife Fund recognizes Turneffe Atoll's conservation value and has supported work at Turneffe for years. Indeed, WWF facilitated this grant from Oak Foundation. The Oceanic Society has maintained a field station at Turneffe since 1992. Turneffe also resides in The Nature Conservancy's portfolio of Conservation priorities.

4.2 Review of Previous Management

Although the Reserves were declared in 2003, little management has taken place so far. In 2007 Rangers were hired but stopped after a few months because of logistical problems. Since 2005 Fisheries has issued a few special licenses each year for snappers at Caye Bokel.

4.3 Management Goal

GOAL: To maintain spawning aggregations and other biodiversity within Dog Flea Caye and Caye Bokel Marine Reserves while still providing benefits to fishermen and tourists.

4.4 Management Strategies

4.4.1 Management Zones

The Reserves are relatively small; Dog Flea Caye and Caye Bokel both cover less than 600 hectares. At Caye Bokel, the actual site of spawning is located on the east side of the Elbow. Diving should be restricted to the western face of the Elbow where the wall is steeper. This should not create a burden for dive operators who prefer to use the western side which is protected from the prevailing east winds.

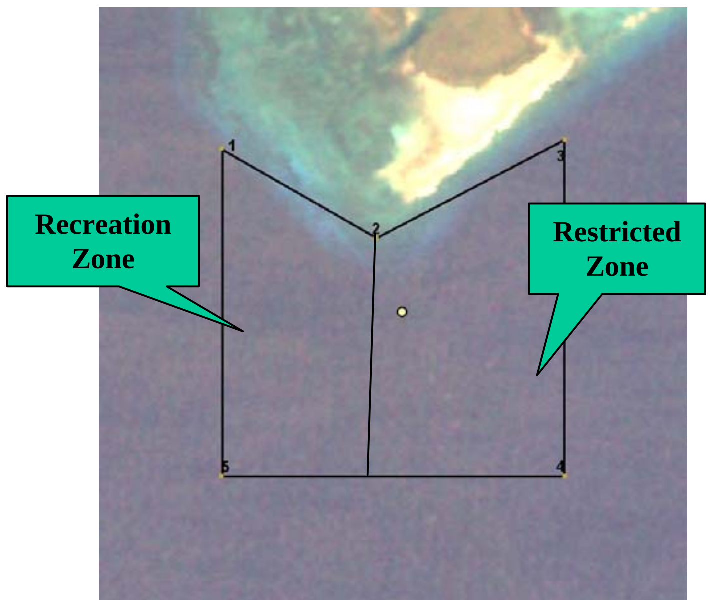


Figure 51: Management Zones, Caye Bokel

4.4.2 Limits of Acceptable Change

The Reserve at Caye Bokel is arguably the finest dive site on the Belize Barrier Reef. It's an isolated, wild place; only big boats can travel there. Some of the bigger dive operators from Belize City, Caye Caulker, and San Pedro make the trip. They generally dive on the western face of the Elbow because the prevailing winds are from the east and the biodiversity is a big attraction. The windward face where the spawning fish gather is zoned as no-entry for divers.

Reserve management wants to facilitate what is already an excellent recreational experience while, at the same time, minimize visitor impact on biodiversity. Staff will have all appropriate safety measures in place with buoy placement for maximum security.

Dive trips to the Elbow are sold as adventurous and pristine. Crowded conditions will negate this characterization pretty quickly. Reserve management should work closely with dive operators to carry out detailed visitor surveys, characterizing and evaluating the dive experience at Turneffe. After consultation, Reserve staff will establish a set of indicators to monitor the recreational experience at Caye Bokel. At a minimum, indicators will include counts of damage to corals, # of divers in water, visitor satisfaction with the recreational experience.

4.4.3 Management Constraints and Limitations

Turneffe Atoll where the Reserves are located is remote, so logistics are problematic. UB has experience operating their field station, and these valuable lessons will serve Reserve staff well. In addition, the Reserves are both at Turneffe but separated by about 20 miles, a good distance on the sea. So staff will have to be creative about infrastructure design and maintenance.

Fishermen and other interest groups are unlikely to react well to limitations, and management risks alienating key stakeholders. Current management staff has limited experience. Accordingly, management should be phased in. For the first six months, Rangers should work with fishermen to understand the way they use the Reserves, gather data on all landings, and gain valuable experience in data collection and hospitality skills. In addition, implementation of user fees for divers should be delayed until tourism stakeholders are comfortable with and see the benefits of management.

Strategic Areas of Management Programs

- Understand and conserve spawning aggregations
- Involve fishermen in caring for their stocks.
- Research with a purpose – Turneffe as laboratory.
- Frequent routine monitoring for informed decision-making.

4.5: Management Programs and Objectives

4.5.1: Natural Resource Management Program

The immediate aims of management are to create suitable management structures within UB. A security apparatus including the hiring of Reserve rangers and the delineation of Reserve boundaries will also be necessary to protect the biodiversity. Finally, a partnership with fishermen will ensure long term stewardship of the Reserves. Management envisions a process whereby capacity will be built up over the five-year period covered by this plan.

The immediate concern is to establish a routine presence at the Reserves. A staff of rangers is being hired in October 2007. To the extent possible, they will visit both Reserves daily. Headquarters for Ranger staff is at Calabash Caye Field Station. Dog Flea Caye is further away from Calabash Caye. Until a second boat is secured, patrols to the Reserve will strain resources. During aggregating days, monitoring teams will visit the site monthly to carry out routine UVAs. Their presence will help act as deterrent to illegal fishing. Any visit to either of the two Reserves should produce a written report or log with basic data.

More activity takes place at Caye Bokel. Tony Leslie owns a piece of land on the Caye that looks out over the Elbow. He has given tentative agreement to allow a small ranger station to be built there. This headquarters would allow for better data collection, an overnight camp, and an information center. Mr. Leslie has a watchman on-site 24/7.

Every boat visiting the Reserve should be checked for # of visitors, main activities, and captain name. Eventually, tourists will be charged a $10US entry fee, but fee collection should be suspended until dive operators have seen the benefits of management. *Sun Dancer* secured a mooring buoy in the Reserve years ago. Rangers should help maintain it for general use. Rangers should also observe dive groups and survey captains to determine sites of other mooring buoys for safety's and convenience's sakes. Fishermen with special licenses will not be charged to enter the park. Limited fishing is allowed April to June, handlines only. No nets, traps, spear guns, nor any other gear can be used.

With exception of special licenses, both Reserves are completely closed to fishing. This will protect all the groupers, many of whom are dwindling. It also makes surveillance easier. In snapper season, fishing is allowed with handlines only, but fishermen must obtain special license and agree to help gather data on landings. These data will be aligned with nursery monitoring data, size-class analysis, and UVAs to provide a snapshot of the health of the snapper population. Based on this analysis, the Advisory Board will meet every August to decide whether any additional restrictions need to be put into place for the following year.

All landings should be measured, so we can know how much of the resource is being removed. Size-class is crucial here. Interviews with fishermen for CPUE are also needed. Rangers are responsible for lots of data collection; they should be trained and have some practice time.

Rangers should spend much of the first year learning their job, training, and getting to know users. Experienced rangers from other co-managers such as Friends of Nature or Hol Chan could be hired to run patrols with the Spags Rangers to pass on some of their discipline and experience. Over the first year, they should develop excellent skills including GPS, data collection, Fisheries Officers, hospitality training. However, heavy staff turnover trumps this strategy, so management has to be perceptive about hiring. Salary above other sites or, better, bonuses can stimulate job stability.

Management Actions					
Biodiversity Protection					
Objective: to maintain # of species and their abundance at Caye Bokel and Dog Flea Caye					
Management Action		**Present Status**	**Desired Status**	**Yr**	**People & Budget**
	Finish Demarcate Both Reserves	Pins in seabed	Cables & buoys in place	1	3 days, 2 divers:1.5K Buoys& cables: 10K
	Daily Patrols	Interrnittent	Daily patrols with log entries	1 2	2 head rangers: 24K/y 8 PT Rangers: 48K/y Boat Captain: 6 K/y SS,etc: 7.8K/y Fuel: 60K/y Maint: 4K/y Uniforms: 2.5K
	Water Quality	No testing	Sample H2O 2X annually	2	Sampling x4: 400 Testing 16 x 100
	Train Rangers: patrols	Untrained	Hire ranger from other Reserves to work with them for two weeks	1	1,000/wk x 2 weeks x 2 Rangers: 4K
	Train Rangers: Fisheries Officers	Untrained	At least two to receive from Fisheries: cost? Schedule?	1	2 weeks in Belize City; 500/Ranger x4= 2,000

Management Actions					
Management of Focal Species					
Objective: to allow no decrease in abundance of Nassau grouper, cubera snapper, permit					
Management Action		**Present Status**	**Desired Status**	**Yr**	**People & Budget**
	Night Patrols Caye Bokel	No night patrols	4 night patrols monthly during cubera season	1 2	16 Patrols with Coast G or FD: fuel, supplies 16 @ 500 = 8,000
	Enforce ban on gear Daily patrols, both	Intermittent enforcement	No nets, no traps, no aggregators	1 2	(see above)

	reserves				
	Outreach to Fishermen	None	Informed about biology and reproductive behavior of spags	1 2	Focus groups at fishing camps by biologist 8/yr: fuel & materials 8 @ 250 = 2,000/yr

One of the most important dangers to the spawning fish is lack of management of the nursery grounds, particularly at Turneffe where the population is isolated. From 1999, the Turneffe Islands Coastal Advisory Committee (TICAC) has lobbied for management of the entire Atoll. For these two spawning aggregation reserves, A committee with similar make-up to TICAC will serve as Advisory Committee.

Management Actions					
Lobby for Protection of Nursery Grounds					
To establish management over other life stages of spags fish					
Management Action		**Present Status**	**Desired Status**	**Yr**	**People & Budget**
	Meet with Forestry quarterly	Protection recommended	Management in place	1 2	8 meetings: transport, materials, etc. 8 @ 250 = 2,000
	Recruit scientists to study Atoll	A few important studies	Scientists investigate all life stages of spawning fish	1 2	Build mailing list Make brochure 1,000
	Lobby developers	No organized initiative	TICAC to develop strategy	1 2	Extra meetings, fuel: 2,000

4.5.2: Research Program

Research is the main link between the co-management partners. The goal of the IMS is to enhance the body of knowledge pertaining to marine science. The Institute aspires to be a research institution. So UB should encourage its faculty to use the field station at Calabash Caye. Undergrad, graduate, and faculty research programs should be established.

Fisheries stated reason for seeking co-management with UB is the access to a research institution. Accordingly, Fisheries and UB should form a research committee with several missions:

- Set research priorities – for example, they could establish a focus on coral resilience &/or connectivity.
- Recruit – The committee could also publicize the field station and its capacity to carry out scientific studies.

- Include Traditional knowledge – Find ways to involve – and pay – fishermen in research, perhaps acting as local informants and research assistants.

Certainly the astounding biodiversity on Turneffe Atoll would be part of the appeal. Facilities at Calabash Caye are more amenable to live-in students and researchers. The facilities are currently being extensively upgraded to make the site more a top-notch research station. Scientists at Smithsonian Institute have also expressed interest in expanding their studies from the South Water Caye area to Turneffe. Fortunately, the scientific coordinator at Smithsonian's Carrie Bow Field Station is Dr. Melanie McField who has a keen interest in Turneffe.

Management Actions					
To facilitate practical research					
Management Action		Present Status	Desired Status	Yr	People & Budget
	Establish Research committee	None	Quarterly Mtgs	2	4 @ 500 2,000
	Recruit scientists	None	5 active research projects	2	Mailing list, brochures 1,000 Booth at GCFI 3,000
	Liaise with Carrie Bow	None	Quarterly Meetings	2	4 @ 500 2,000

Specific topics for research suggested by data in this plan include continuing the studies by Walsh and Mcfield into the stress tolerance of clades of zooxanthellae, symbionts of *Montastrea*, larval dispersion, and mariculture. Kramer and Kramer (2000) note serious declines in reef-builders including *Montastrea spp*. and suggest the following topics for further study:

- Recovery of tissue of selected tagged coral colonies
- Coral populations (species diversity, coral size)
- Coral recruitment
- Recent mortality
- Coral disease
- Macroalgal overgrowth
- Reef architectural complexity & loss of reef structure
- Fish populations (spawning aggregators)
- Physical characteristics (temperature, current, turbidity)
- Rate of change of habitat.

Heyman et al. (2006) offer several suggested topics for research into spags connectivity.

1. identify and characterize important nursery habitats
2. characterize multi-species spawning aggregations

3. track initial trajectory and dispersal of eggs from spawning areas
4. map adult migration routes
5. map genetic distributions of various species and taxa and identify barriers to and corridors that enhance connectivity
6. collect detailed bathymetric data for spawning and nursery areas
7. collect oceanographic data with time series at spawning areas
8. increase the use of remote sensing data – altimeter and ocean color particularly
9. reduce grid size of biophysical models

Research permits are required by Fisheries. The Research Committee should have input to this process. Permits are $150 annually. All permits have a scope of work which is supposed to be followed. Rangers should be aware of these limitations also.

4.5.3: Monitoring Program

One of the main principles of scientific management is feedback: to follow indicators that will help management assess the health of ecosystems and their elements. Such monitoring can help management evaluate the efficacy of programs and point to ways of improvement. Other reasons for monitoring include routine data collection to provide context information for scientific research, e.g. climate data.

Rangers should collect basic climate data daily with rainfall, temp, cloud cover, etc. Because spawning is exquisitely sensitive to temperature, data loggers should be installed at both sites. In addition, Rangers should be trained in underwater visual assessments (UVAs) to monitor spawning fish. These UVAs should be taken monthly for at least 4 days around the full moon at both spawning sites. During snapper seasons in which special licenses are issued, all landings should be weighed and measured for size-class analysis. At other sites, UB students have collected landings data. These data should be made available to the Spawning Aggregation Working Group organized by Fisheries. The Group meets approximately every 6 weeks and has maintained a database of all the spags reserves since 2000. Reserve staff should attend those meetings. In year two, protocols should be established to monitor juvenile populations of commercial species in seagrass, in mangroves, in macro-algae, and in reef habitat.

All other commercial species – lobster & conch -- should be routinely monitored, at least twice annually. Seagrasses are already monitored routinely at Calabash through Seagrass Net, a program out of University of New Hampshire. AGGRA monitoring should be carried out every two years at both sites. In addition, the Meso American Barrier Reef Project has established a comprehensive monitoring protocol by site.

Management Actions					
Inform management decisions					
To establish routine monitoring systems					
Management Action		**Present Status**	**Desired Status**	**Yr**	**People & Budget**
	Daily patrol and visitor logs	None	Logs data entered & analyzed monthly for Fisheries	1 2	See Biodiversity PRotection
	Install temperature loggers	none	Data stream of temperature at spawning sites	2	2 loggers 3,000 Install 500
	Quarterly aerial and landsat analysis	None	Quarterly estimate of loss of mangrove & seagrass	2	$500 x 4/yr
	Monthly UVAs	Intermittent	Monthly @ both Reserves	1 2	480 days@ 100 1,800 gallons
	Landings in snapper season	None	Length & weight all landings	1 2	250 x 3 students x 3 months/yr
	Quarterly Nursery monitoring	None	Quarterly counts of main spawning fish	2	40 days x 100=4,000 150 gal. = 1,500
	AGGRA	2006 & 2007	Every two years	2	10 days x 200= 2,000 150 gal = 1,500
	Lobster & Conch	none	Surveyed 2 x yearly	1 2	16 days x 4 x 100=6,400 150 gallons=1,500

4.5.4: Community Participation Programme

Most fishermen interviewed agreed that all marine resources are in steep decline. However, they are men of the sea. Conservationists hope to engender a sense of stewardship amongst fishermen. For too long, they've had an adversarial relationship with Fisheries. Routine monitoring jobs should go to fishermen to the extent possible. After 2 or 3 years when procedures and staff are familiar with the protocol, some of the youth could take the dive-master class and carry out the UVAs. At least 10 divers could then be trained to carry out UVAs at the two sites. The Nature Conservancy has carried out many of these training sessions. Dive teams could have experienced monitors from other parts of the country dive with them for the first 6 months or more; several divers in the south have extensive experience with UVAs. Others can be trained to carry out juvenile monitoring.

One important aspect of monitoring is consistency. To be able to compare conditions now with conditions before, the indicator must be measured exactly the same way every time. In fact, even if data are not accurate, if they are consistent in their error, they are still useful. A cadre of fishermen should be trained and charged with carrying out all routine monitoring of commercial species. Besides the additional income, fishermen will develop a stronger sense of conservation. As they themselves watch populations fluctuate, they will take ownership of the stocks.

Not all fishermen wan to be scientists. The Reserves should facilitate other trainings. In tourism, tour guiding and fly fishing. The divemaster training is included here. At the same time, a survey of fishermen could reveal other attractive professions that could be facilitated. For example, many fishermen do construction work during closed seasons. Training in finish work or cabinetry could improve incomes. Notice that trainings can be targeted by village after our analysis of age-class.

Management Actions					
To reduce pressure on fish stocks					
By 2012, 33% of fishermen will have developed alternative livelihoods					
Management Action		**Present Status**	**Desired Status**	**Yr**	**People & Budget**
	Divemaster training	none	25 fishermen trained to dive	1	2 Week Workshop 60,000
	Training for spags monitoring: UVAs	none	10 fishermen trained for UVAs	1	Trainer 4,000 Per diem 2,000 Gear 3,000
	Training for nursery monitors	none	10 fishermen trained to monitor nursery grounds	2	Trainer 5,000 Per Diem 1,500 Fuel 1,500 Gear 3,000
	Tour guide training	none	25 fishers trained	2	Tuition @500 Per diem @ 500
	Fly fishing training	none	10 fishers trained	2	Trainers 2,000 Perdiem 1,400 Fuel 1,500 Gear 2,000
	Survey for other trainings	none	Priorities for other alternative livelihoods	2	Consultant 2,000 Expenses 3,000

4.5.5: Public Use Program

Up to now, public use is not yet an issue at Dog Flea Caye Marine Reserve. However, the Elbow at Caye Bokel is one of the most popular dive destinations in th country. Most groups carry out drift dives . Many dive sites are located at the edges of the Reserve as well. For the first year, Rangers should meet all dive groups, gather basic data, and monitor where they dive. This monitoring will also include visitor satisfaction surveys to establish Limits of Acceptable Change for diving at the Elbow. One specific task for the Rangers is to maintain the mooring buoy that was placed by the Sun Dancer live-aboard. That buoy is used by many of the dive boats. Rangers should note optimum position for additional buoys while they observe dive tours.

Most dives drift the west wall. The specific spawning site lies on the East side of the Elbow, and divers might disturb the aggregations. Management could consider closing the East side of the elbow to tourism.

One of the major issues with dive operators is ticket sales. Fisheries mandates a standard fee of $10US. How will this fee be collected? Many tour operators complain about having to purchase blocks of tickets and tying up their cash. But the reserve can't maintain ticket offices on San Pedro, Caye Caulker, Turneffe, and Belize City. Nor should the Rangers be handling large amounts of cash. More to the point, what benefit will divers receive for the fee? At this stage, the reserve has little to offer dive groups, so the Reserve should hold off on charging the Entrance Fee. First, we need to find out how to make the experience better, safer, and more sustainable. Rangers should survey dive groups to determine whether and where additional mooring buoys should be placed. The Reserve should contact the chamber on San Pedro and establish an emergency system in case of accident with divers. The Reserve should also consider giving a patch of other souvenir from the Reserve. Until then, no fee should be charged.

Management Actions					
Provide excellent recreation without degrading resources					
Management Action		**Present Status**	**Desired Status**	**Yr**	**People & Budget**
	Establish patrol data	None	Daily visitor log	1 2	See biodiversity Protection
	Survey users	None	Acceptable change defined	1	Materials Fuel 2,500
	Install mooring in Northwest corner of reserve	None	Safer dive put-in	2	Mooring buoy and cables 10,000 Install 3,000

4.5.6: Infrastructure Management Programme

UB is growing and still establishing its programs. The Institute of Marine Sciences will have its own director. Right now, the Provost is covering that position. University of Belize will hire a Project Manager to provide administrative and policy-level oversight. The Field Station now has a station manger who has a variety of excellent skills for running a field station. Calabash Caye has dock, two 30' Columbian boats and engines, power system (soon to be upgraded to renewable), dry lab, wet lab, and dive center. In short it's a fully equipped field station. Dorms and cabanas provide living space.

Current infrastructure consists of a small Ranger Station on the beach at the field station and one of the 30-foot Columbian skiffs with 2 200hp outboard engines. Because the Reserves are far apart, logistics are even more difficult than normal for a remote field station. A satellite camp should be set up at Tony Leslie's camp on Big Caye Bokel. Rangers can use it a headquarters. They can also stay over to run occasional night patrols. At Dog Flea Caye, a camp in Cockroach Bay would provide excellent surveillance of the site because it's the only nearby cut in the reef. All skiffs fishing the site would have to pass through that cut. For the first year, monitoring crews will work the site for 4-5 days monthly and can assist with surveillance during those critical times. As development continues, a more permanent camp will need to be built. Turneffe Flats has also offered to house Rangers (and maybe monitors).

Safety is a major concern. All boats should be equipped with GPS, radio, flares, life jackets, fire extinguishers, and other safety gear. Right now, Rangers have use of only one boat, but need more with two reserves in opposite directions. Monitoring teams will need a boat as well. On top of that, monitoring teams need dive gear, cast nets, fish traps, and other gear. Particularly important are scales that will accurately measure catch across a broad range. All of the equipment needs care, so maintenance logs should be created for all gear with routine tasks scheduled. Pins for demarcation buoys have been placed at both Reserves.

<table>
<tr><th colspan="6">Management Actions</th></tr>
<tr><td colspan="6">Ensure safe and efficient environment for management</td></tr>
<tr><td colspan="6">Support infrastructure and services</td></tr>
<tr><th colspan="2">Management Action</th><th>Present Status</th><th>Desired Status</th><th>Yr</th><th>People & Budget</th></tr>
<tr><td></td><td>Purchase Second boat</td><td>1 boat 2 Reserves</td><td>2 boats 2 Reserves</td><td>1</td><td>28'skiff, 2 100hp 66K</td></tr>
<tr><td></td><td>Build Satellite camp</td><td>none</td><td>Improved security</td><td>1</td><td>10K with solar</td></tr>
<tr><td></td><td>Set up Maintenance program</td><td>None</td><td>Efficient, well kept gear</td><td>1</td><td>Proj Man. & head Ranger 2 weeks</td></tr>
<tr><td></td><td>Develop hurricane plan</td><td>none</td><td>Prepared for emergency</td><td>1</td><td>2 weeks</td></tr>
<tr><td></td><td>Food and other Supplies to Ranger station</td><td>Intermittent</td><td>Routine Supplies</td><td>1
2</td><td>7.2K/y</td></tr>
<tr><td></td><td>Upgrade Ranger station</td><td>Minimal shelter</td><td>Expand
More furniture
Better power</td><td>2</td><td>Construction 6,000
Beds & desks 2,000
More panels 3,000</td></tr>
</table>

Since global warming is certainly one of the major factors behind coral bleaching, management of a marine protected area must maintain a low carbon footprint. Reserve staff will use four-stroke engines, and the Rangers field station will be powered with renewable energy.

4.5.7: Administrative Program

The co-managers – Fisheries and the University of Belize -- have ultimate responsibility for the resources in these Reserves. Management of the Calabash Caye has been problematic for UB; staff turnover has been high. The University's bureaucracy has created many obstacles. A new program called the Environmental Learning and Research Center is proposed to free research initiatives from such obstacles; ELRC would be established in August 2008. Marine Science and Reserve management would be an integral part of the academic component of the ELRC.

Fisheries and UB also lead the Advisory Board which consists of 13 members representing the following constituencies:

- Fisheries Department
- Forestry Department
- University of Belize
- World Wildlife Fund
- The Nature Conservancy
- Belize Fishermen's Cooperatives Association
- Northern Fishermen Cooperative
- Department of Lands, Ministry of Natural Resources
- Belize Tourism Board
- Belize Tourism Industry Association
- Smithsonian Institute
- Oceanic Society
- Belize Association of Private Protected Areas (BAPPA)/ Turneffe Flats Resort

With Advisors:

- Wildlife Conservation Society
- Association of Protected Areas Management Organizations

The Board will advise on operation of the two Reserves in the short and medium term. A second major activity of the Board is to lobby for protection and management of other habitats that are used by other life stages of reef fish – the mangroves, seagrass beds, and grouper nursery grounds on Turneffe Atoll (see full Terms of Reference – Appendix 5).

The Board will hire and work with a Project Coordinator who will oversee day-to-day operations of the reserves. The Coordinator will directly supervise the Rangers and the technical /Biology staff. All employees will fall under UB.

The ELRC provides for research funding to remain independent of the General Fund; outside donors often require separate accounts. This allows for true accountability. Reserves funds will be handled by a separate accountant and will receive professional audits annually. Transparency is also needed. During interviews, stakeholders brought up this point over and over. Management should consider a short, quarterly, transparency report that outlines use of funds as well as programs being developed.

Management Actions					
Establish framework for good management					
Capacity building					
Management Action		**Present Status**	**Desired Status**	**Yr**	**People & Budget**
	Advisory board	unformed	Regular meetings and advice	1 2	1,000/mtg/month
	Board training		Effective board	1 2	q 2 mo x 1,500
	Sign co-mgmt agreement	draft	Signed and implemented	1	Publicity 2,000 Ceremony 3,000
	Staff development	competent	better	1 2	3,500 x 2= 7,000/yr

Management Actions					
Maintain transparency and accountability					
Financial procedures and policies					
Management Action		**Present Status**	**Desired Status**	**Yr**	**People & Budget**
	Annual audits	None	Verified accounts	1 2	4,000/yr
	Quarterly public reports	None	Stakeholders informed	2	Printing and postage 500 x 4/yr
	Monthly Accounts	None	Up-to-date books	1 2	400/mo

4.5.8: Evaluation Program

The management team should also monitor itself. One of the first tasks of the Project Manager will be to establish the first or baseline measurement of management effectiveness. A management effectiveness survey is recommended annually by the NPASPS. Personnel evaluations should be carried out routinely. Stakeholders should also be asked to offer comments on management effectiveness.

Management Actions
To ensure excellent management of the Reserves' resources
Monitor management

Management Action		Present Status	Desired Status	Yr	People & Budget
	Carry out annual management effectiveness evaluation	None	Feedback to management	1 2	One day workshop 1,500
	Carry out annual personnel evaluations	None	Feedback to personnel	1 2	ToRs managers
	Carry out stakeholder satisfaction surveys	None	Feedback to management; unity	1 2	Consultant 2,000 Travel & expenses 1,500

4.5.9: Financial Program

The programs outlined in this management plan are expensive. The budget is approximately $600,000 Bz per year. The Oak Foundation is funding the current work which is providing basic infrastructure and covering salaries for a set of Rangers and the Project Manager. In the long term, UB will take responsibility for finding funds for the full range of programs outlined in this plan. In the short term, however, the field station at Calabash Caye is still poorly staffed, and the ELRC is not fully established. In order to get started, a preliminary budget is presented which covers very basic costs for the first year of operations. Once UB's resources are in place, a more comprehensive budget details costs for all programs (see Appendix 7).

Budget: Spags Reserves at Turneffe (Year 1 - $Bz)`
Note: This budget is tentative & will probably change.

Budget Item	Univ Belize	Fisheries	Total
Personnel			
Project Coordinator (2,500/mo.)	30,000		30,000
4 Rangers @ 1,000/mo	36,000	12,000	48,000
Watchman @ 400/mo	4,800		4,800
Social Security (ca 10%)	6,300	2,100	8,400
Insurance	2,500		2,500
Accounting (400/mo)	4,800		4,800
Operating Expenses			
Fuel 4,000 gal @ 11.00	44,000		44,000
Engine and Boat Maintenance (300/mo)		3,600	3,600
Food and Lodging for Rangers (300/mo)	3,600		3,600
Uniforms (4 @ 100)	400		400
Office Supplies (200/mo)	2,400		2,400
Telephone (200/mo)	2,400		2,400
Office Equipment Maintenance (100/mo)	1,200		1,200
Train Rangers as Fisheries Officers		1,000	1,000

Projects and Equipment			
30' Columbia skiff with 2 200 hp engines	60,000		60,000
Cables and Buoys to Demarcate Reserves		10,000	10,000
Install Buoys (2 divers, 3 days)	1,500		1,500
Furniture for Ranger Station (beds, desks)	2,000		2,000
Monitoring			
Snapper Landings (If special licenses awarded)	2,250		2,250
Dive Gear	7,000		7,000
Dive Certification (2 @ 350)	700		700
Training UVAs			9,000
Fuel UVAs (1,500 gallons @ $11)	16,500		16,500
Experienced UVA Monitors (2 @ 200/day x 5 days x12mo)	24,000		24,000
MBRS Synoptic Monitoring (2 diversx200 x 6 days)	2,400		2,400
Miscellaneous			
Advisory Board Meetings (monthly at Calabash) Transport, meals, materials 12 x 1,200	14,400		14,400
Totals.	**269,150**	**28700**	**306,850**

Funding will have to come from a variety of sources.

- User fees: ca. 4,000 visitors per year at the Elbow @ $10US. But Fisheries will allow about 50% for direct costs of management. So the Reserves would see 40,000 BZ, only about 7% of the protected area's complete budget.
- Local and International funders

  PACT

  GEF COMPACT

  Oak

  TNC/WWF

  Other funders

The Lodges (Turneffe Island Lodge, Blackbird Caye, and Turneffe Flats) represent an excellent opportunity for fund-raising. Wealthy clientele who are already partially invested in the Turneffe Atoll because they pay a lot of money to be there patronize them. Management should make weekly presentations in season to patrons, requesting financial help for specific programs. A great mailing list could be developed. The Reserves could also offer special Spags dives at a very high premium -- $1,000 US for example – during the spectacular seasons. Monitor spags fish behavior with video. Indeed, management could also expand the idea to offer a conservation tour of Turneffe – tour the biological wonderland and donate to the Reserves.

Management Actions					
Sustain management of Reserves					
To raise funds					
Management Action		**Present Status**	**Desired Status**	**Yr**	**People & Budget**
	Develop strategic & financial plan	None	Carrying out fin plan effective management	1	Consultant: 25 days @ 250
	Produce proposals	Minimal funding	Funding for all budget lines	1 2	Consultant 60 days. @ 250
	Weekly presentations at Lodges	None	Database for mail contact	1 2	Fuel 2000 Projector 3,000

4.6: Conclusion:

The plan's overall goal is to maintain spawning aggregations and other biodiversity within Dog Flea Caye and Caye Bokel Marine Reserves while still providing benefits to fishermen. The focus must be on the fishermen and their growing predicament. Integrating fishing expertise with research techniques could yield powerful synergies. However, developing such programs requires strong leadership and management.

The benefits of the programs outlined here are enormous. UB will promote research opportunities within academia especially those studying marine connectivity. UB will also develop courses -- both theoretical and practical – around marine protected areas management. Fisheries will also benefit from its partnership with a research institution. The path is laid out here.

Glossary

Algal symbiont: A single-cell marine plant that lives inside a marine invertebrate thereby increasing chance for survival of both species.

Clade: A taxonomic group (such as one of organisms) comprising a single common ancestor and all the descendants of that ancestor.

Connectivity: larval dispersal from one population to another. This exchange of individuals among geographically separated subpopulations is a key process for population replenishment and genetic enrichment.

Conservation Targets: An ecosystem or species chosen as representative of the biodiversity of the protected area, then selected for conservation planning.

Coral: An invertebrate marine animal that often lives in sheet-like colonies. Corals have an alga living in their body tissue that provides energy through photosynthesis.

Coral Bleaching: A phenomenon associated with high sea-surface temperatures in which the coral expels its symbiotic and pigmented alga and so loses its color – 'bleaches'.

Crustose coralline algae: red algae of the division Rhodophyta. They are very important members of a reef community because they cement and bind the reef together. They are particularly common in high wave energy areas but can also be found throughout all reef zones.

Coral reef: Many corals secrete a calcium carbonate substrate to dwell in. Over time, these grow to form rocks and accrete to form reefs.

Critical List for Belize: The National List of Critical Species (http://biological-diverisity.info/Downloads/NPAPSP/Critical Species.pdf) is built on the IUCN Red List but has more detail for the Belizean Situation and includes many species of specific Belizean concern that are not listed in the IUCN lists.

Dredging: The process of removing material, usually sand, from the sea bottom and transferring it to build up land.

the Elbow*:* Nickname for the area at the southern tip of Turneffe Atoll, just south of Caye Bokel.

Fleshy macro-algae: Macroalgae are larger (canopy height usually >10mm) erect algae often with anatomically complex forms. Most macroalgae possess some from of deterrent against herbivory, either through chemical deterrents or structural resistance. High macroalgal biomass can interfere with coral recruitment and reduce coral survival.

Global warming: A phenomenon of the Industrial Age that is causing a significant rise in the temperature of the earth; carbon dioxide is trapping infra-red rays in the atmosphere.

Herbivorous Fish: vegetable, plant, fruit, and algae feeders by nature. Herbivores are frequent feeders and have a long digestive system.

Invertebrate*:* A class of living animals that have no backbone, including worms, gastropods, insects, and corals.

IUCN Red List: The internationally recognized standard for identifying species of concern to conservationists.

Larvae: The newly hatched, immature form of many marine animals including spawning fish and corals.

Limestone: Rock made mainly of calcium carbonate and usually derived from corals.

Live Coral Cover: Percent area covered by live coral. It is commonly used as a measure of the health of coral reefs.

Macroalgae**:** large aquatic photosynthetic plants that can been seen without the aid of a microscope.

Marine Reserves: Areas of the sea, often coastal that contain natural resources that need protection. Zoning is an important tool of marine reserves.

Photosynthesis: The process by which *chlorophyll* contained cells in green plants use light as an energy source to synthesize sugar from carbon dioxide and water.

Propagule: A specialized reproductive feature of mangroves. The seed sprouts while still attached to the mother plant then drops in the water.

Resilience: The ability of corals to withstand stress, particularly increased temperature.

Self-recruitment: Larvae of spawning fish can survive up to 40 days meaning that offspring could grow up hundreds of kilometers away from spawning site. Self-recruitment refers to offspring that gow out close to the spawning site, often 50 km from the site.

S.I.(Statutory Instrument): Any of the Laws of Belize.

Spawning aggregation: A biological phenomenon that occurs when many individuals (up to 100,000s) come together to reproduce. Aggregations are usually timed by lunar cycles.

Spur and groove formation: a system of shallow ridges (spurs) separated by deep channels (grooves) oriented perpendicular to the reef crest and extending down the upper seaward slope

Symbiosis: The close association of two different kinds of living organisms where there is benefit to both or where both receive an advantage from the association.

Turf: Turf algae are an assemblage of diminutive, often filamentous, algae that attain a canopy height of only 1 to 10 mm. There is a high turnover of individual turf algal species seasonally and only a few species are able to persist or remain abundant throughout the year. Turfs are capable of trapping ambient sediment and kill corals by gradual encroachment.

Turneffe Islands Coastal Advisory Committee (TICAC): A committee organized by Coastal Zone mai. The committee met regularly and formulated the first detailed development plan for its region of the Belize Barrier Reef in 2002. The committee is now the Advisory Board for the Spags Reserves at Turneffe.

Windward reef promontories: Projections out to sea from the barrier reef that point to prevailing winds. Spawning fish migrate to and aggregate at these sites.

Zooxanthellae: Symbiotic single-celled plants which are related to free-living marine algae (dinoflagellates); they live in the tissues of many marine invertebrate animals particularly reef-forming corals.

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Appendices

1. S.I. #161 of 2003.
2. S.I. #162 of 2003
3. Vulnerability of Nassau Grouper to Overfishing
4. Memorandum of Understanding Between Fisheries Department and University of Belize
5. Conservation Target Viability Analyses
6. GPS Coordinates of Sampling Sites for WWF Baseline Monitoring
7. Comprehensive Budget

S.I. 161 and 162 – need digital versions.

Appendix 3

Side Bar 3 from Caye Glory Paper

Vulnerability of Nassau Grouper to Overfishing

The scientific literature abounds with documentation of the vulnerability to overfishing of the Nassau grouper. Nassau grouper stocks are below sustainable levels and have even been eliminated from much of their historic range (Dahlgren 2001, Sadovy and Eklund 1999). Their vulnerability has been ascribed to the following life history traits, in addition to their desirability as seafood and therefore relatively high price:

- Slow growth and a high age at maturity
- Increasing reproductive rate with age
- Increasing number of eggs per reproductive event with age
- Change sex from female to male
- Reproductive failure at low density
- Long life and low adult mortality
- Reproduction through spawning aggregations. (Gascoigne 2002).

The Nassau grouper's long life span (it is not unusual to find groupers aged 15 or 20 years, or more), slow growth rate and late sexual maturation mean that populations are typically slow to replace themselves or to recover from overfishing (Gascoigne 2002; Sadovy 2001). Overfishing is reached at a low level of fishing mortality in a species with naturally low mortality (Coleman *et al.* 2000). Sex change from female to male late in life renders Nassau grouper vulnerable to *selective* fishing pressure since the fisherman's target is likely to be the larger individuals—who are also the older and male individuals—thus males are reduced disproportionately. Worse yet,

populations with low natural mortality, long life and increased reproductive output with age tend to depend on older individuals for reproduction. As mortality increases, the probability of an individual's surviving to a given age declines exponentially, meaning that even small increases in fishing mortality have a large impact on life span because the number of older individuals declines much faster than the total population figure. Therefore the reproductive output declines faster than the overall population size. This is even worse if fishing targets older (larger) individuals specifically. [The combination of such factors renders it] easy to reach the situation where very few individuals even survive to reproduce. A population that contains a large proportion of immature individuals is not likely to be in good reproductive health. (Gascoigne 2002).

However, the greatest threat to the survival of the Nassau grouper stems from its reproduction through spawning aggregations, defined as a group of conspecific fish, gathered at a specific site and time, for the purpose of spawning, with fish densities or numbers significantly higher (at least three times) than those found during the non-reproductive period (Domeier and Colin 1997; *cf*. Claydon 2004). These aggregations, the only known reproductive opportunities for many species of reef fishes (Sadovy and Domeier 2003), may draw individuals from both a wide area and the immediate vicinity (Bolden 2000; Green Reef Environmental Institute 2002). For groupers, spawning generally occurs over only one to three days during two to four consecutive months. During each month, individuals congregate to build up in numbers to a peak, until spawning occurs often over several consecutive evenings. The fish usually disperse immediately after the spawning event. Thus, the total annual reproductive output for the population of a region occurs in a tight window of time and space (Dahlgren 2001, Sadovy and Eklund 1999, Heyman and Requena 2003).

Some evidence exists to indicate that "social learning" plays a role in the development and repeated formation of a spawning aggregation, suggesting that location of spawning sites and/or routes thereto are passed from older and experienced individuals to the next generation (Starr et al. 2007, Sadovy and Domeier 2005, Coleman et al. 2000, Bolden 2000, *cf*. Carter 1989). Thus the reduction of older individuals might endanger the aggregation's future. In addition, since those older individuals tend to be male, their reduction below some critical threshold could cause a rapid decline of the population and disappearance of the spawning aggregation from its historic site (Carter et al. 1994). Moreover, if too few individuals congregate for spawning, no spawning will occur (Starr et al. 2007, Sala 2001). No evidence exists to indicate that a spawning aggregation, once collapsed, will recover (Starr et al. 2007), even if closed to fishing (Sadovy and Eklund 1999).

In many areas, the majority of annual landings (up to 90%) of Nassau grouper, is, or once was, taken from spawning aggregations (Sadovy and Eklund 1999). Overall, an estimated one-third of known Nassau grouper spawning aggregations have either disappeared or decreased to negligible numbers (Sadovy and Eklund 1999, Heyman & Requena 2003). However, a global database compiled by the Society for the Conservation of Reef Fish Aggregations (SCRFA) shows that within exploited aggregations of known history over 60% show evidence of declines, almost 20% may have ceased to form, while the remaining 20% show stability or, in a few cases, may increase (http://www.SCRFA.org). Not coincidentally, Nassau grouper, once the most commonly landed species within the Caribbean and tropical western Atlantic, is in decline or collapse throughout the region (Claydon 2004), including in Belize (Paz and Grimshaw 2001). The Nassau grouper has been listed as an endangered species by the US federal government, red listed as an endangered species by the International Union for the Conservation of Nature, and classified as threatened by the American Fisheries Society (Sadovy and Domeier 2005 citing Musick et al. 2000).

While fishing a spawning aggregation can have a huge effect on the Nassau grouper population of a region and the ecology over a broad area (Claydon 2004), fishing outside the spawning aggregation—during other times of the year and/or at other locations—can reduce the size of the spawning aggregation itself (Sadovy and Domeier 2005). Most obviously, fishing near an aggregation site to catch fish moving toward the aggregation will deplete the aggregation (Aguilar-Perera and Aguilar-Dávila 1996). Highly efficient gear, such as fish pots and spear guns, can diminish a spawning aggregation by rapidly depleting the population that might otherwise join the aggregation. However, year-round fishing by hand line and spear can remove as much as 14% of the adults from a local population per year. Fisheries models developed with data gathered at Glover's Reef indicate that such a level of fishing is unsustainable, and if continued, will cause the Nassau grouper population to disappear in the near future. (Sala et al. 2001). Moreover, tag studies indicate that only 3% of the Nassau groupers spawning at Glover's Reef actually leave the atoll after spawning, a finding which could explain apparent inability of a Nassau grouper spawning aggregation to reform after its collapse. (Starr et al. 2007).

Appendix 4

MEMORANDUM OF UNDERSTANDING

For Co-management of the CAYE BOKEL MARINE RESERVE and DOG FLEA MARINE RESERVE, TURNEFFE ATOLL

BETWEEN THE

FISHERIES DEPARTMENT, GOVERNMENT OF BELIZE

AND

UNIVERSITY OF BELIZE

THIS AGREEMENT is made the ___________day of April 2006, the Fisheries Department, Government of Belize of the first part and the University of Belize, a national, autonomous and multi-location institution committed to excellence in higher education, research and service for national development, of the second part.

WHEREAS the Minister of Fisheries has the power to declare Marine Reserves under section 7 of the Fisheries (Amendment) Act of 1983, Chap. 174 of the Laws of Belize, and to do everything necessary for the sound management and administration of these Reserves;

AND WHEREAS the Fisheries Administrator of the Fisheries Department, Government of Belize, is responsible for the administration of the Marine Reserves, and is therefore joined as a party hereto;

AND WHEREAS the Fisheries Department, Government of Belize, is desirous of entering into an Agreement with the University of Belize in order that the parties hereto may continue the work of cooperating in the management of the Caye Bokel and Dog Flea Marine Reserves, declared under the Fisheries Order, 2002.

NOW THEREFORE IT IS HEREBY AGREED as follows:

1) The Fisheries Department, Government of Belize, and University of Belize shall jointly manage and further develop the Caye Bokel and Dog Flea Marine Reserves.

2) The parties hereto in keeping with the provisions of the Fisheries Act shall exercise such joint management.

3) The Fisheries Department, Government of Belize, in consultation with the University of Belize and the Turneffe Islands Coastal Advisory Committee (TICAC) may also put in place such other regulations by Statutory Instrument or otherwise as may be necessary in order to develop full implementation of this Agreement.

4) (i) The University of Belize, the Turneffe Islands Coastal Advisory Committee (TICAC) and The Fisheries Department, Government of Belize, along with the other agencies and NGOs as appropriate, shall together formulate and implement detailed Management Plans (hereinafter referred to as "the Plans") for the further development of the Caye Bokel and Dog Flea Marine Reserves to explicitly include goals, objectives, permitted activities, standards, methods of implementation and control, priorities, budget, personnel requirement, target dates and such other matters as shall be agreed.

   (ii) The Plans shall also specify the assessment methods to monitor accomplishments and shall provide the necessary periodic evaluations and refinements. Such Plans shall include provisions for methods of protection, enforcement, visitor usage, staffing, structures, monitoring, research and any other provisions as are appropriate to the Marine Reserve.

5) The staff of the Marine Reserves, under the directives of the University of Belize shall be responsible for the day-to-day management of the Caye Bokel and Dog Flea Marine Reserves with advice from the Fisheries Department and the Turneffe Island Coastal Advisory Committee. The Fisheries Department, Government of Belize, shall provide additional security and enforcement of the Marine Reserve. Notwithstanding the foregoing, the Fisheries Department, Government of Belize, shall retain all statutory rights and duties over the Marine Reserves which are not consistent with this Agreement.

6) (i) The reserve staff in consultation with the University of Belize and the Turneffe Island Costal Advisory Committee shall be responsible for the proper implementation of all aspects of recreation, for visitor use within the Marine Reserves and day-to-day maintenance of equipment provided for the Marine Reserves, as well as for pubic awareness campaigns and education with respect to the Marine Reserves.

   (ii) The University of Belize shall be permitted to conduct research within the Marine Reserves through permits issued by the Fisheries Administrator.

7) The reserve staff along with the University of Belize shall provide the Fisheries Administrator with quarterly financial statements, annual reports and reports on any major revision in operations regarding management of the Marine Reserves. For its part, Government, upon written request from the University of Belize, will provide the University of Belize with relevant financial information pertaining to the Marine Reserves.

8) The Fisheries Department shall, in accordance with the Fisheries Regulations, process all applications for scientific research after consultation with the University of Belize and the Turneffe Island Coastal Advisory Committee.

9) (i) The Fisheries Department after consultations with the University of Belize and the Turneffe Island Coastal Advisory Committee can refuse any recreational activities pertaining to the Marine Reserves. Such activities shall be decided jointly by the parties hereto pursuant to the Plans.

(ii) The Fisheries Department after consultation with the University of Belize has the right of refusal of extractive activities as outlined in the Plans.

10) (i) The Reserve Staff will collect fees such as entrance fees, program fees, and other fees associated with the management, development and use of the Marine Reserves.

(ii) All fees collected by the Marine Reserves shall be apportioned as follows:
(a) Marine Reserves Trust Fund – 100% of fees collected is to be used for the management and development of the Marine Reserves.

11) The Fisheries Department, Government of Belize, shall provide assistance to the University of Belize in the form of tax exemptions and other like benefits as are enjoyed by non-profit, non-governmental organizations for the carrying out of activities related to the Management Plan for the Marine Reserves.

12) Any endowment, trust fund, grant, loan, subsidy or any monies whatever obtained by the University of Belize for the co-management and development of the Marine Reserves under this Agreement shall be for the exclusive use of the University of Belize, providing these fall within the priorities as defined in the approved Management Plan for the Marine Reserves.

13) In the event of an infringement of any of the terms of this Agreement, the party making a complaint shall give notice thereof and the parties shall then use their best efforts to resolve the matter within three (3) months of the date of the infringement.

14) If no satisfactory resolution is reached, the complaint may be taken to an agreed –upon arbitrator.

15) If no satisfactory resolution is reached, the complaining party may, by further notice of at least thirty (30) days after the expiration of the period referred to above, terminate this Agreement. In the event of dissolution of this Agreement, the University of Belize nor the Fisheries Department, Government of Belize, shall incur any liabilities.

16) Either party may, wherever it deems necessary and after consultation with the other party, terminate this Agreement, provided that notice of a minimum of six (6) months is given to the other party.

17) This agreement shall be amended where such proposed amendment is reduced to writing and signed by both parties.

AS WITNESS the hands of the parties hereto the day and year first above mentioned,

SIGNED: WITNESS:

SIGNED:	WITNESS:
Hon. Michael Espat Minister of Agriculture, Fisheries & Cooperatives	Beverly Wade (Miss) Fisheries Administrator
President University of Belize	Vice-President University of Belize

Conservation Target Enter # of Target		Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Current Indicator Status	Current Rating	Desired Rating	Date of Current Rating	Date for Desired Rating
1	Community of Spawning Species	Landscape Context	Oceanographic regime -- health of site	# of species that spawn annually	50% of maximum	75% of Maximum	90% of maximum	Maximum	Unknown.For now, assume maximum to be same as Gladden Spit: 34 species.	poor	Good	Sep-07	Sep-12
1	Community of Spawning Species	Landscape Context	Connectivity among communities & ecosystems	Total area of mangrove and seagrass bed nursery grounds within a 50 Km radius from SPAG site	Aerial extent of mangroves and seagrass beds are below 50% of original coverage.	Aerial extent of mangroves and seagrass beds are 50% of original coverage.	***Aerial extent of mangroves and seagrass beds are 51%-84% of original coverage.***	Aerial extent of mangroves and seagrass beds are 85%-100% of original coverage.	Damage from Hurricane Keith & Mitch still evident. But forests are now regenerating	Good	Good	Sep-07	Sep-12
1	Community of Spawning Species	Landscape Context	Oceanographic regime	Presence of dominant current regimes that influence larval disbursement									
1	Community of Spawning Species	Condition	SPAG Population structure	Length-frequency distribution									
1	Community of Spawning Species	Size	Population abundance outside of the SPAG season	Resident population size									

Conservation Target Enter # of Target		Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Current Indicator Status	Current Rating	Desired Rating	Date of Current Rating	Date for Desired Rating
2	Grouper Spawning Aggregation	Landscape Context	Dec to Mar reproductive cycle at Dog Flea Caye	SPAG peak abundance	<500 individuals	500 - 3,000	3,000-10,000	>10,000	Counts low; in 2006, 1 individual seen	poor	fair	Sep-07	Sep-12
2	Grouper Spawning Aggregation	Landscape Context	Connectivity among communities & ecosystems	Extent of rocky reef and soft coral within a 50 Km radius from SPAG site	Aerial extent of rocky reef and soft coral are below 50% of original coverage.	Aerial extent of rocky reef and soft coral are 50% of original coverage.	***Aerial extent of rocky reef and soft coral are 51%-84% of original coverage.***	Aerial extent of rocky reef and soft coral are 85%-100% of original coverage.	Rocky reef present but soft corals endangered in Belize	Fair	Good	Sep-07	Sep-12
2	Grouper Spawning Aggregation	Condition	Reproductive Output	Fecundity (eggs/gram of roe)	<1.0 egg/mg roe	1.0 to 2.5 eggs/mg	2.5 to 4.0 eggs/mg	>4.0 eggs/mg	Closely relate to size dist of females	Poor	Fair	Sep-07	Sep-12
2	Grouper Spawning Aggregation	Condition	SPAG Population structure	Length-frequency distribution	75%-100% of fish below reproductive size	50% to 75%% of fish below reproductive size	50% to 75%% of fish above reproductive size	75% to 100% of fish above reproductive size	mean=75 cm upper limit of reproductive size (from newsletter3)	Poor	Fair	Sep-07	Sep-12
2	Grouper Spawning Aggregation	Size	Population abundance	Population size at peak spawning period	<500 individuals	500 - 3,000	3,000-10,000	>10,000	Counts low; in 2006, 1 individual seen	Poor	Fair	Sep-07	Sep-12
2	Grouper Spawning Aggregation	Size	Density of juveniles	Fish Counts in Nursery					Not available			Sep-07	Sep-12

Conservation Target Enter # of Target	Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Current Indicator Status	Current Rating	Desired Rating	Date of Current Rating	D R

3	Snapper Spawning Aggregation	Landscape Context	Connectivity among communities & ecosystems	Total area of mangrove and seagrass bed nursery grounds within a 50 Km radius from SPAG site	Aerial extent of mangroves and seagrass beds are below 50% of original coverage.	Aerial extent of mangroves and seagrass beds are 50% of original coverage.	***Aerial extent of mangroves and seagrass beds are 51%-84% of original coverage.***	Aerial extent of mangroves and seagrass beds are 85%-100% of original coverage.	Damage from Hurricane Keith & Mitch still evident. But forests are now regenerating	Good	Good	Sep-07	S
3	Snapper Spawning Aggregation	Condition	Reproductive Output	Fecundity (eggs/gram of roe)	<1.0 egg/mg roe	1.0 to 2.5 eggs/mg	2.5 to 4.0 eggs/mg	>4.0 eggs/mg	Closely relate to size dist of females			Sep-07	S
3	Snapper Spawning Aggregation	Condition	SPAG Population structure	Length-frequency distribution	75%-100% of fish below reproductive size	50% to 75%% of fish below reproductive size	50% to 75%% of fish above reproductive size	75% to 100% of fish above reproductive size	mean=85cm near the maximum reproductive size	Good	Very Good	Sep-07	S
3	Snapper Spawning Aggregation	Size	Apr to Jun reproductive cycle at Caye Bokel	Population size at peak spawning period	<500 individuals	500 - 3,000	3,000-10,000	>10,000	Peak count 2003-2005 = 5,000	good	very good	Sep-07	S
3	Snapper Spawning Aggregation	Size	Population abundance of juveniles	Juvenile density					unknown			Sep-07	S

Conservation Target Enter # of Target		Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Current Indicator Status	Current Rating	Desired Rating	Date of Current Rating	Date for Desired Rating
4	*Montastrea spp.*	Condition	Purity of seawater	Salinity	<25	25-30	30-33	33-36	Both areas are outside the reef with little runoff 30-36	Very good	Very good	Sep-07	Sep-12
	Montastrea spp.	Condition	Nutrient levels	[N]	>200uM	100-200uM	30-100 uM	<30uMN	Eva's h20 quality	Good	Very good	Sep-07	Sep-12
	Montastrea spp.	Condition	Sedimentation	Sed Rate	?				Not an issue yet				
4	*Montastrea spp.*	Condition	Space to reproduce	% algal cover	>10%	5-10%	1-5%	<1 %	AGGRA 2006 site 1071 =45% site2073= 59%	Poor	Fair	Sep-07	Sep-12
4	*Montastrea spp.*	Size	Pop'n size	% M.spp.of coral cover	<10**%**	*10-20%*	20-30%	30-40%	AGGRA 2006 site 1071 Mont.spp=0% site 2073 =29%	Fair	Good	Sep-07	Sep-12

Conservation Target Enter # of Target		Category	Key Attribute	Indicator	Poor	Fair	Good	Very Good	Current Indicator Status	Current Rating	Desired Rating	Date of Current Rating	Date for Desired Rating
5	Permit	Landscape Context	Connectivity among communities & ecosystems	Total area of mangrove and seagrass bed nursery grounds within a 50 Km radius from SPAG site	Aerial extent of mangroves and seagrass beds are below 50% of original coverage.	Aerial extent of mangroves and seagrass beds are 50% of original coverage.	***Aerial extent of mangroves and seagrass beds are 51%-84% of original coverage.***	Aerial extent of mangroves and seagrass beds are 85%-100% of original coverage.	Damage from Hurricane Keith & Mitch still evident. But forests are now regenerating	Good	Good	Sep-07	Sep-12
5	Permit	Condition	Reproductive Output	Fecundity (eggs/gram of roe)	<1.0 egg/mg roe	1.0 to 2.5 eggs/mg	2.5 to 4.0 eggs/mg	>4.0 eggs/mg	Closely relate to size dist of females			Sep-07	Sep-12
5	Permit	Condition	SPAG Population structure	Length-frequency distribution	75%-100% of fish below reproductive size	50% to 75%% of fish below reproductive size	50% to 75%% of fish above reproductive size	75% to 100% of fish above reproductive size	mean=55 cm 50% reached reproductive size	Fair	Good	Sep-07	Sep-12
5	Permit	Size	Apr to Jun reproductive cycle at Caye Bokel	Population size at peak spawning period	<500 individuals	500 - 3,000	3,000-10,000	>10,000	Peak count 2003-2005 = 5,000	Fair	good	Sep-07	Sep-12
5	Permit	Size	Population abundance of juveniles	Juvenile density					unknown			Sep-07	Sep-12

Site Name	***Date of Survey***	***Coordinates (NAD 27)***	***Depth (feet)***	***Site Description (ForeReef / BackReef) (Inside Reserve / Outside Reserve)***
TUR NAD 01	March 6, 2007	N 17°09'51.2"	40	backreef
		W087°53'53.9"		OUTSIDE / CAYE BOKEL
TUR NAD 02	March 6, 2007	N 17°09'26.9"	20	forereef
		W087°54'32.7"		INSIDE / CAYE BOKEL
TUR NAD 03	7 March, 2007	N 17°09'26.1"	40	backreef
		W087°55'00.6"		OUTSIDE* / CAYE BOKEL
TUR NAD 04	7 March, 2007	N 17°09'49.3"	30	forereef
		W087°55'15.6"		OUTSIDE / CAYE BOKEL
* Actually on the boundary of Caye Bokel Marine Reserve				
TUR NAD 05	7 March, 2007	N 17°29'34.8"	40	backreef
		W087°46'05.3"		OUTSIDE / DOG FLEA
TUR NAD 06	8 March, 2007	N 17°31'02.0"	40	backreef
		W087°44'48.7"		INSIDE / DOG FLEA
TUR NAD 07	8 March, 2007	N 17°30'52.1"	26	forereef
		W087°44'56.3"		INSIDE / DOG FLEA
TUR NAD 08	8 March, 2007	N 17°29'33.4"	23	forereef
		W087°46'13.6"		OUTSIDE / DOG FLEA

Appendix 7: Comprehensive Budget

Turneffe Marine Reserves		
Full Budget ($BZ)		
CATEGORY	**Year One**	**Year Two**
Salaries and Benefits		
Project Coordinator	36,000	36,000
Technical Coordinator/Biologist	24,000	24,000
Accountant(400/mo)	4,800	4,800
Rangers (2 full-time)	24,000	24,000
Rangers (8 part-time)	48,000	48,000
Boat Captain (part-time)	6,000	6,000
Watchman	2,400	2,400
Social Security (ca 10%)	15,000	15,000
Sub-total (Salaries & Benefits)	**200,200**	**200,200**
Operating Expenses		
Fuel (6,000 gal@10)	60,000	60,000
Travel and Transportation	5,000	5,000
Joint patrols 8/yr	4,000	4,000
Telephone	2,400	2,400
Advisory Board Expenses(12 mtgs x 1,000	12,000	12,000
Quarterly public accounting		2,000
Insurance	2,500	2,500
Audit	4,000	4,000

Dues & Subscription	2,400	2,400
Bank Charges	1,000	1,000
Engine & Boat Maintenance	4,000	4,000
Building Maintenance	3,600	3,600
Office Equipment Maintenance	1,200	1,200
Sub-total	**102,100**	**104,100**
Expendable Supplies		
Office Supplies	1,200	1,200
Ranger Station Supplies 200/mo and Food 400/mo	7,200	7,200
Uniforms (24 @ 100)	2,400	
Cleaning Supplies	600	600
Sub-total (Expendable Supplies)	**11,400**	**9,000**
Contracts		
Consultant ISFP	6,250	
Consultant Development	15,000	15,000
Fund-raising -lodges	5,000	2,000
Sub-total (Contracts)	**26,250**	**17,000**
Monitoring		
Annual mgmt effectiveness	1,500	1,500
Stakeholder Satisfaction surveys	3,500	3,500
Water Quality		500

Survey LAC	2,500	
Community Researchers @100/day	48,000	58,400
Snapper landings	2,250	2,250
Temp Loggers		3,500
Aerial estimates		2,000
Fuel AGRRA		1,500
Fuel Nursery monitor		1,500
Fuel Lobster&conch	1,500	1,500
Fuel UVAs	18,000	18,000
Sub-total	**77,250**	**94,150**
Training and Education		
Adv. Board Training	9,000	9,000
Fisher Outreach	2,000	2,000
Dive Master Training25 students)	60,000	
UVA Training (1 week 10 people)	9,000	
Train Nursery Monitors		11,000
Tour Guide Training		25,000
Fly Fishing Training		6,900
Survey Fishers		5,000
Staff Training 8x $1,000	8,000	
Ranger Training (Practical)	4,000	
Fisheries Officers (4 x 500)	2,000	2,000
Brochures and Flyers	2,500	

Sub-total (Training)	**96,500**	**60,900**
Lobby & Recruit		
Research Committee		2,000
quarterly meetings Forestry	2,000	2,000
Recruit Scientists	1,000	5,000
Lobby developers	2,000	2,000
Sub-total (Lobby & Recruit)	**5,000**	**11,000**
Capital Expenses		
Computers (2 laptops)	5,000	
Software	3,000	
28 foot skiff	30,000	
Outboard Engines (2 100 HP 4 S)	36,000	18,000
Diving Equipment	8,000	4,000
Monitoring Equipment	6,000	
Communication Equipment	6,000	
Mooring & Demarcation buoys	11,500	10,000
Dive Tanks (20)	2,400	
Upgrade Ranger Station		11,000
Satellite Ranger Station	8,000	8,000
Sub-total (Capital Expenses)	**115,900**	**51,000**
	634,600	**547,350**
Administration (15%)	95,190	82,103
Total	**729,790**	**629,453**
