16. Status of Coral Reefs of Northern Central America: Mexico, Belize, Guatemala, Honduras, Nicaragua and El Salvador

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Abstract

Recent large scale climatic events have had a tremendous impact on coral reefs of this region. The isolated, less-developed reefs of the Mexican Pacific suffered 40-50% coral mortality during the La Niña related cold-water events, following the 1998 El Niño bleaching event. The extensive, well-developed reefs on the Atlantic coast experienced unprecedented mass coral bleaching and mortality in 1995 and again in 1998, followed by

widespread damage from the intense Hurricane Mitch, also in 1998. These events heavily impacted reefs from the Mexican Yucatan to Honduras, causing losses in coral cover of 15-20% across the region with some losses as high as 75% in parts of Belize. Throughout large parts of the region there are intense fishing pressures and major threats to reefs from poor land-use practices and unregulated coastal development. Capacity to monitor and manage coral reefs varies enormously in the region, from advanced to virtually non-existent. Now, countries of the Mesoamerican region (Mexico, Belize, Guatemala, Honduras) are cooperating to conserve and manage their reefs and resolve cross-boundary management issues.

Introduction

Most striking about the coral reefs along the Pacific and Caribbean coasts of Northern Central America (NCA) is the dramatic difference in reef abundance, development and diversity. Fewer reefs exist on the Pacific coast, mostly in central Mexico, and these are usually small, less diverse, and isolated or patchy in distribution. These reefs are subject to frequent cold, nutrient-rich upwellings and El Niño events, and are sensitive to extreme disturbances and susceptible to local extinction due to their limited distribution and isolation. Numerous rivers flow onto the narrow steep shelf from southern Mexico south to Gulf of Fonseca, and Nicaragua further inhibiting coral reef development, while favouring the growth of mangroves. The next major reef area along the Pacific coast is to the south in Costa Rica.

In contrast, the well-developed reefs on the Caribbean side are extensive and contain the Mesoamerican Barrier Reef System (MBRS) which is the longest barrier reef system in the Western Hemisphere and the second longest in the world, extending over 1000km from the northernmost part in Yucatan, Mexico through Belize and east to the Bay Islands of Honduras. As well as the barrier reef, there are numerous patch, fringing, and atoll-like reefs, which are habitats for a high biodiversity of fishes, invertebrates, birds, plants, sea turtles, and mammals. Reefs along the Caribbean coast can be divided into several distinctive areas: SW Gulf of Mexico; extensive fringing and barrier reefs along the Yucatan and Belize coast; 4 unique atolls (Banco Chinchorro, Turneffe Island, Lighthouse, and Glover's Reef); small coral communities along mainland Guatemala and Honduras, and the Bay Islands; and extensive reef complexes in Nicaragua. Composed of luxuriant patch, fringing, and barrier reefs and four unique offshore atolls. These reefs are influenced by continental land masses and are also impacted to varying degrees by human pressures; coastal development, over-fishing, agricultural and industrial run-off, deforestation, land-use, and sewage pollution. In addition to these stresses, two major events in 1998 (El Niño mass bleaching and Hurricane Mitch) caused severe damage to reefs along the Mesoamerican Corridor (Yucatan, Belize, Guatemala, Honduras).

Although coastal communities depend heavily on the marine resources, the coastal zone is only a small part of the land area. Hence, national focus, priority and awareness of problems facing the coral reefs is much lower than other island nations where reefs dominate the resource base. This is also evident in the small amount of information available about the status of these reefs, except for a few well-studied reefs in Yucatan, Belize, and the Bay Islands. Large information gaps exist for the extensive reefs of Nicaragua, coastal coral communities along the mainland of Honduras and Guatemala, offshore islands and banks like Swan Islands and the Mysteriosa banks in Honduras, parts of the Belize reef

Country	Population x 1000 (growth)	Land area (km²)	Water (km²)	Coastline (km²)	Mangrove Coast (km²)*
Mexico	100,294 (1.73)	1,972,550	49,510	6760 P + 2900 C	5,246-14,202
Belize	235.8 (2.42)	22,690	160	386	730-783
Guatemala	12,335 (2.68)	108,890	460	400	160
Honduras	5,997 (2.24)	112,090	200	820	1,170- 1,213
Nicaragua	4,717 (2.84)	129,494	9,240	307	600
El Salvador	5,839 (1.53)	21,040	320	307	352 -450

Demographic and geographic summaries for the region. Population growth rate is given in parentheses after the total, with P the Pacific coast and C, Caribbean and low and high estimates for mangrove coast.

complex, and other reefs in the eastern Pacific coast. The following provides an overview of reef descriptions for each country, listed in order from north to south.

Reef Descriptions

Mexico

There are 3 distinct coral reef areas in Mexico: 1) the Pacific mainland coast and Baja California; 2) Southwest Gulf of Mexico (Veracruz and Campeche Bank); and 3) the Yucatan Peninsula. Reef development and diversity on the Pacific side is much less than the Caribbean and often restricted by cool temperatures (e.g. on the western side of Baja California). There are 12 hard coral species in the Gulf of California, 15 species further south on the Mexican mainland, and 18 on the Revillagigedo Islands. Most of these species are rare or have limited distribution, and coral communities are usually small and patchy with low abundances of other invertebrates, like soft corals, sponges, crustaceans, and echinoderms.

There are about 20 reefs off Veracruz, in the Gulf of Mexico, which have adapted to high turbidity from coastal runoff. The coral diversity is low for the Caribbean with only 45 reef-building species. On the eastern side of the Yucatan peninsula, there is an extensive fringing reef along nearly 350km of coastline from Isla Contoy south to Xcalak, including the offshore islands and the Banco Chinchorro atoll. The southern part continues as the Belize barrier reef. At least 56 reef-building species are reported. Reef development along Quintana Roo varies considerably, is often discontinuous and can be divided into 3 zones, north, central, and southern. Those in the north area have overall low living cover (17%), are mostly denuded bare rock, with a few patches of high cover, and are dominated by stands of dead *Acropora palmata*. The central and southern areas contain more continuous shallow reefs and better developed platform reefs. Banco Chinchorro is a large (46km x 14km) atoll with well-developed reefs on both the broad windward shelf and narrow leeward shelf.

The largest populations and longest coastlines occur in Mexico. Coral reefs provide commercial, recreational and tourism value for coastal communities, mainly Mestizo (Amerindian-Spanish), Amerindian, and some white. The main towns are near La Paz, Huatulco and Puerto Vallarta (Pacific) and Veracruz, Cancun and Cozumel (Atlantic). Tourism, concentrated in Huatulco, Puerto Vallarta and the northern portion of Quintana Roo, is the major economic activity and is expanding rapidly both to the north and south of Quintana Roo.

Belize

The second longest barrier reef in the world extends for 250km and covers 22,800km^2, as a unique assemblage of lagoon patch reefs, fringing reefs, and offshore atolls. Like Mexico there are three distinctive areas, northern, central, and southern barrier reefs. The Northern reefs are well developed and continuous from the Mexican border to Caye Chapel, while discontinuous and less developed south to St. Georges Caye. The Central Reefs are continuous and are considered to be the best developed. Southern reefs are discontinuous and less well developed. Numerous patch reefs, dominated by *Montastraea annularis*, are found throughout Belize and the unique rhomboidal-shaped shoals and reefs occur towards the south of the central barrier. Located 7-45km off the barrier reef, the three atolls (Lighthouse, Turneffe, and Glovers) have very different reefs on the leeward versus windward sides. Lighthouse and Glovers atolls are structurally similar having deep lagoons with numerous patch reefs, whereas the protected Turneffe Island has extensive mangroves in its shallow lagoon.

This is the most sparsely populated nation in Central America (about 9 people km^2), and coastal resources are important for commercial and artisanal fishing, tourism (e.g. snorkeling, diving, fishing), aquaculture, cultural resources, and limited shipping. Tourism and the export of marine products have increased significantly in the last few years. Belize has a diverse mixture of ethnic cultures (Mestizo, Creole, Maya, Garifuna, as well as Asian, European and Mennonites). Less than 50% of the population occurs in the coastal zone and it has actually decreased in the last few years.

Guatemala

Most of the coastline borders the Pacific, with only a narrow coast in the Caribbean, which contains many mangroves, seagrass beds and coastal lagoons. Large flows from the Motagua, Sarstun and Dulce Rivers limit reef development to a few isolated corals and small patch reefs in the Gulf of Honduras. Few if any reefs occur on the Pacific. The local coastal communities of Mestizo (or Ladino) and Amerindian use the coastal resources for food and transport and on the Caribbean, they also rely on obtaining fish from adjacent Belize waters.

Honduras

Coral development is restricted on Caribbean coastal areas by elevated runoff from high rainfall running off the mountainous terrain, with only few scattered, poorly developed coral communities only around Puerto Cortes, La Ceiba and Trujillo. The only real reef development is around the offshore Bay Islands which consist of 60 small islands and several large islands that form 4 main groups: Roatan, Utila, Guanaja, and Cayos Cochinos. Most of these reefs fringe the drop-off and grow seaward down to 9-12m depth, and then drop sharply to 75m. Discontinuous well-developed reef buttresses are dominated by rich growth of *M. annularis* on most of the Bay Islands. There is also a discontinuous shallow fringing barrier reef of *A. palmata* and *Agaricia tenuifolia* on the northern sides of Roatan, Guanaja, and parts of Cayos Cochinos and southeastern Utila. These are sometimes exposed at low tides and much of the coral is dead and covered with dense turf algae. The Swan Islands, an isolated group of small islands to the far northeast, are surrounded by a fringing reef, and small fringing and patch reefs occur near the Mosquitia Cays and Banks. There are no reefs on the Pacific coast. Indigenous Mestizo, Garifuna and Miskito communities rely heavily on subsistence fishing, especially those living in coastal villages on the Caribbean. The Bay Islands are a well known tourist destination for scuba diving.

Nicaragua

Very little is known on the distribution and condition of the extensive reefs growing on the broad carbonate bank extending out from the Caribbean coast. Close to the coast (out to 10km), coral reef development is limited due to high sedimentation with less than 10% coral cover. The greatest reef development occurs in four main areas: Miskito Bank; Man O'War Cays; Crawl, Taira, Pearl, and Set Net Cays; and Little and Big Corn Islands, and is generally classified into nearshore (to 25km), mid or central shelf, and shelf edge. Miskito Cays, 50km offshore, are mangrove islands surrounded by fringing coral reefs, and extensive seagrass beds, with the most abundant coral on seaward edges. Complex reef development includes patch reefs, large pinnacles and fringing reefs, but little is known about these reefs, especially the Man O'War Cays. The Pearl Cays are shallow reefs with thickets of *A. palmata* on the windward coast, and the Corn Islands are the largest islands, with a series of three fringing reefs on the northeast side and numerous patch reefs. *Acropora palmata* and *M. annularis* are the major reef building corals, averaging 25% coral cover. Reef development is limited on the leeward side of the islands. On the Pacific, there are virtually no corals, except for a few isolated patches of individual Pocilloporid corals and scattered gorgonians.

The country is mostly agricultural with a small manufacturing industry, thus the coral reefs are largely ignored. Only 10% of the population lives along the Caribbean coasts, primarily indigenous Miskitos, Creole and some Garifuna. These people are closely tied to their marine resources and harvesting is restricted within their traditional land and sea territories. The largest coastal communities are on the mainland near the myriad of coral cays and fishing grounds around the Miskito Reefs. The Miskito Indians are the primary users of the Miskito Coast Marine Reserve (MCMR) surviving mainly through subsistence fishing.

El Salvador

There are few natural resources because it is small with only 307km of coast on the Pacific. Some coral communities have been reported at Los Cobanos, but little is known about the extent and current status. The smallest country in Central America has a population of almost 6 million (primarily Mestizo), and is one of the most densely populated countries in the whole Caribbean region.

Status of the Coral Reefs

The coral reefs of this region have experienced an increasing frequency and intensity of disturbances in recent years, with a few areas receiving recurring or coinciding disturbances. Prior to 1998, the principal disturbances were hurricanes, coral diseases, and recent mass coral bleaching (1995 and 1997). A history of moderate to severe hurricanes has impacted localised areas in Mexico and Belize and recovery from these storms has been variable. White band disease probably devastated *Acropora* populations since the early 1980s including many areas in Belize where they used to be the primary shallow reef builder. The 1983 die-off of the grazing sea urchin *Diadema antillarum* also damaged the region. Mass bleaching was first reported in 1995, with variable, but limited effects, followed by the major bleaching event and hurricane of 1998, which had profound impacts. Prior to 1998, most of the reefs were routinely described as being in good condition.

1998 Coral Bleaching in the Mesoamerican Barrier Reef System (MBRS)

There were few large-scale bleaching events in the north Central American region compared to other areas in the Western Atlantic because high temperature stresses were infrequent and other environmental stresses were relatively minor. For example, coral bleaching was reported for much of the Caribbean during 1983 and 1987, and the first well-documented mass bleaching event in Belize occurred in 1995 where 52% of coral colonies bleached, although only 10% of the corals suffered subsequent partial mortality (10-13% loss of coral cover). These impacts in 1995 were also observed in Cayos Cochinos, Honduras, where 73% of scleractinian corals and 92% of hydrocorals bleached and slightly higher mortality was reported. A less severe bleaching event was reported in 1997, although the extent of damage is not known.

Then there were major disturbances during 1998. First high sea-surface temperatures appeared during August and intensified during September. Reports of intense bleaching (>50% of colonies) started in the Yucatan in August/September, followed by reports in Belize (September) and Honduras (September/October). Coral mortality was first reported in the Yucatan in early October, particularly on Agaricia tenuifolia colonies. Reports of massive bleaching and mortality of A. tenuifolia and Millepora spp. in the central and southern Belize barrier soon followed. Then severe Hurricane Mitch passed over in October; sea surface temperatures decreased and recovery of some branching corals was reported while massive corals continued to remain bleached into 1999. Extensive surveys conducted indicated that the 1998 bleaching event affected the entire MBRS region, and was possibly more severe than mass bleaching in 1995. Shallow reef corals tended to either die immediately or recover more rapidly from bleaching compared to deeper depths, where coral recovery from bleaching proceeded more slowly. The magnitude of the bleaching was evident in deep fore reef sites where significant remnant bleaching was observed up to 10 months after the initial bleaching. Specific findings from this study showed:

- Regional average of 18% recent coral mortality on shallow reefs, 14% on fore reefs;
- Up to 75% recent coral mortality on localised patch and barrier reefs in southern Belize;
- Highest mortality observed for A. tenuifolia (>35%), M. complanata (28%), and Montastraea annularis complex (25-50%);
- Regionally high recent mortality and disease on Montastraea annularis complex;
- Low to moderate levels of recent mortality in Acropora palmata from bleaching;
- Remnant bleaching still evident on fore reefs 10 months later (up to 44% of corals still bleached); and
- High incidence of coral disease following the bleaching event on Belize shallow reefs (black band) and Honduras and Belize fore reefs (white plague).

In 1998, a sequence of catastrophic disturbance events impacted the region: unprecedented coral bleaching was documented throughout the region as well as elevated incidences of disease and in late October 1998, Hurricane Mitch impacted much of the coast from Nicaragua northwards to Yucatan. The synergistic effects of these events are expected to have long-term ecological consequences for the coral reefs.

Mexico

These reefs are among the best studied in the region. The main disturbances to Pacific reefs are strong El Niño events and extremely low winter water temperatures. Since most Pacific corals are found as small isolated communities, they are susceptible to disturbance and local extinctions can result, i.e. *Leptoseris papyracea* is probably extinct along the Mexican mainland and the distribution of *Porites sverdrupi* has been reduced to only 500km. Atlantic reefs of the SW Gulf, particularly the nearshore reefs near Veracruz receive intense anthropogenic impacts from agricultural, industrial, and urban wastes, over-fishing, oil spills, and ship groundings. Extensive mortality of *Acropora* has been documented at Isla de Sacrificios, whereas the offshore reefs of Campeche Bank are remote from direct human impacts, although occasional oil leaks and damage from the oil facility have some impacts. Coral cover ranged from 2 to 28% in 1981, but was 1 to 6% in 1993 at the CARICOMP monitoring site of Puerto Morelos. Much of the loss was due to Hurricane Gilbert in 1988 and the mass coal bleaching in 1995, although this was not measured. The largest decline in coral cover was on the back reef, from 28 to 5%, and the reef crest 27 to 6%. Despite these losses prior to 1998, these reefs showed evidence of recovery with little extreme bleaching or algal overgrowth, and some signs of re-establishing *Diadema* populations. AGRRA surveys (1999) in Veracruz found 17% average coral cover, low recent mortality, low coral disease and bleaching, evidence of coral recruits, few *Diadema*, and low macroalgae.

The ENSO event impacted reefs in the Gulf of California (18% coral mortality) and Bahia de Banderas (more than 70%). Oaxaca reefs were affected by the La Niña of late 1998 (more than 70% mortality). On the Atlantic coast, the 1998 bleaching and Hurricane Mitch impacts were lower in Mexico than in Belize or Honduras; only 4 of 27 reefs surveyed after the event had higher than normal recent mortality, averaging 11% on fore reefs and 7% on shallow reefs. The southern area was impacted by bleaching, disease, and minor hurricane impacts while the north and central region had low disturbance. In 1999 AGRRA surveys in the central and southern regions of the Mexican Caribbean, there was 12% average coral cover (10m depth), 37% total coral tissue mortality, greater average algal turf cover than macroalgae and crustose coralline algal cover, and evidence of coral recruitment, although there was an almost total absence of *Diadema*.

Belize

While there have been extensive studies on several select reefs in Belize, much of the barrier reef has not been studied. Some of the earliest disturbances reported were severe storms and hurricanes, such as Hurricane Hattie (1961) which reduced living coral cover by 80% and destroyed spur and groove structure along sections of the barrier reef. Prior to the mid-1980s, *A. cervicornis* was the dominant reef-builder on the fore-reef slope until populations were devastated, presumably by white band disease i.e. coral cover near Carrie Bow Cay shallow fore reef dropped from 30-35% in the late 1970s to 12-20% now. These losses were followed by increases (up to 60%) in fleshy macroalgal cover, primarily

Lobophora. *Agaricia tenuifolia* colonized dead *A. cervicornis* rubble and replaced it as the dominant coral species. Similar transitions between coral and algal communities have been seen in other areas of the Belize barrier reef. Patch reefs on remote Glovers Reef also changed during the last 25 years suffering a 75% loss of coral cover, 99% loss of *A. palmata* and *A. cervicornis*, and over 300% increase in macroalgae. These changes are probably linked to the reduction in herbivores (especially the urchin *Diadema*), and death of corals by white band disease. Although the acroporids were almost wiped out on the patch reefs, massive corals showed little mortality. A study of 12 deep fore reef sites throughout the barrier reef and atolls found the mean live coral cover to be 28% in 1997. The first mass coral bleaching event documented in Belize was in 1995 and resulted in about 10% of corals suffering mortality from bleaching and disease. Another bleaching event in 1997 affected the Snake Keys area, but details are lacking and it may have been salinity, not temperature-induced.

Belize experienced major impacts from the 1998 bleaching and hurricane events, with the majority of reefs (72 of 80 surveyed) showing significant damage: 46 with moderate disturbance; 26 had severe damage; and only 8 had low damage. Some of the highest mortality in the region was found on shallow reefs in the south with coral tissue losses twice as high (24%) on shallow reefs than fore-reefs (12%). Damage was less in the north, but some shallow reefs were affected, while deep fore-reef sites had mainly bleaching damage. The central area had moderate to severe disturbance at most exposed shallow sites, especially from the hurricane, while protected sites had more disease. Pre- and post 1998 disturbance studies on Glovers Reef found a reduction in coral recruitment on windward fore reefs and shallow patch reefs. Signs of recovery on reefs were seen in AGRRA surveys of 35 sites in July 2000, with increased recruitment on shallow reefs, including *Acropora*, more *Diadema* urchins, and little disease, bleaching or recent mortality. Two back reefs in the north, however, had high incidences of black band disease and mortality of *M. annularis*, particularly at Cay Chapel, a privately owned island under intense tourism development including a jet airstrip and 18-hole golf course. The 12 deep fore reef sites surveyed in 1997 were resurveyed in 1999 finding an average of 49% decrease in live coral cover (from 28% to 14%). The loss in live coral was greatest in the south (62%), followed by the North (55%), atolls (45%) and Central (36%), which were probably somewhat protected from the hurricane by the presence of the atolls.

Guatemala

There have been no surveys of the distribution and condition of coral communities. The reefs were probably heavily impacted by Hurricane Mitch, especially from storm run-off and the 1998-bleaching event.

Honduras

Disturbance to reefs in the Bay Islands has been caused by hurricanes, bleaching, coral diseases, over-fishing, and extensive coastal development. In Roatan, coral cover varies with reef zone: 8% on the reef crest; 18% on the shallow fore reef; 28% on the deep fore-reef; and 17% on spur and grooves (average of 21%). Coral cover in Sandy Bay West End Marine Reserve ranges from 24-53%, although macroalgal cover varies from 19-57%, and the sites with high algal cover (>50%) were near outfalls of sewage and sediment. Utila and Guanaja have low coral cover (5-20%). Cayos Cochinos has many small patch reefs

Coral Disease in the MBRS

Past information on the extent of disease incidence in the region is incomplete. A few well-documented studies suggest that the extensive mass mortality in the early 1980s of Acropora cervicornis was attributed to white band disease in Belize. In Mexico, Acropora palmata ramparts along the coastline apparently died in the early 1980s, possibly from white band disease. White band disease was also reported in Roatan and Cayos Cochinos although the extent was not determined. Black band disease increased in Cayos Cochinos after the 1995 bleaching event, with 34% of M. faveolata colonies infected; many bleached corals (particularly *M. annularis* complex) in Belize also became infected with black band after the 1995 bleaching event. Results from a large-scale survey of the MBRS found a high incidence of disease following the 1998 bleaching event; higher than reported for other areas of the Caribbean. The survey also documented:

- Black band was the most common disease on shallow reefs, white plague most common on fore reefs, low to rare occurrences of yellow band or other diseases;
- Fore reefs in Honduras (10% of colonies) had more disease than Belize (5%) and Mexico (3%);
- Belize shallow reefs (6%) had more disease than Mexico (3%) or Honduras (2%).
- 12 shallow and 11 fore reef corals were infected with disease - M. annularis complex most affected (10-22%)
- Very few acroporids were found with active diseases

The large proportion of *M. annularis* complex colonies in the MBRS infected and dying from disease is of particular concern, especially in Belize shallow reefs and deep fore reefs in the Bay Islands. AGRRA surveys conducted at 35 sites in 2000 suggest the overall incidence of disease has decreased compared to 1999, yet localised shallow sites had high levels of black band disease (especially Cay Chapel). Although disease incidence was lower, the high mortality this year suggests infections of white plague and black band in 1999 were responsible for much of the observed mortality.

with low coral cover, small colonies and signs of significant past disturbance, although deep reefs have higher cover (14 to 40%) and abundant macroalgae (*Lobophora variegata* and *Dictyota cervicornis*). Surveys in 1985 reported that all reefs in Roatan but one, were healthy, but white band disease was present. White band disease was reported on *A. cervicornis* in Cayos Cochinos probably triggered by the 1995 bleaching event where 34% of *M. annularis* and *M. faveolata* colonies were infected with black band disease.

Most reefs surveyed in Honduras (38 of 44) were damaged from the 1998 disturbance events; 25 had moderate disturbance, 13 had severe disturbance, and 6 had low disturbance. Recent mortality was similar on shallow (16% average) and forereefs (17%).

Localised shallow reefs, primarily in Guanaja, were damaged by the hurricane, while bleaching and disease affected deep reefs in the Bay Islands. Coral cover at 9 sites in Utila, Roatan, and Guanaja ranged from 13 to 33%, with 50 to 80% of coral colonies showing some partial mortality between 34 to 73% of the surface. Algae covered ranged between 52 and 85%.

Nicaragua

The coast is fairly remote with limited access, therefore it has not received intensive human use or scientific attention. Increased deforestation has resulted in higher sediment loads which are

Impacts of Hurricane Mitch on the MBRS

This region has a long history of hurricanes damaging the coral reefs; some major, some minor. Hurricane Gilbert (1988) caused severe damage to shallow reefs along the Yucatan peninsula; Hurricane Haiti (1961) and Greta (1978) were two of the most significant storms to hit the central coast of Belize; and Hurricane Fifi (1974) devastated the coast of Honduras. But then came Hurricane Mitch; a Category 5 hurricane with sustained wind speeds over 250km per hour, which battered the Caribbean coast and parts of Honduras, Nicaragua, El Salvador, and Guatemala between Oct. 27 - Nov. 1, 1998. It killed over 11,000 people and destroyed more than 50% of the infrastructure in Honduras. Hurricane Mitch is considered one of the largest and deadliest tropical cyclones in the Caribbean this century. Moreover, it stalled for over 48 hours over the Bay Island of Guanaja, and hurricane force winds destroyed houses and denuded pine and mangrove forests. Large storm swells smashed on the Belize barrier and southern Yucatan. The extent and type of damage to coral reefs varied depending on location, species present, and architectural complexity. Results from a large-scale survey to assess Hurricane Mitch's impact on barrier and fore reefs at 151 sites found:

- Greatest damage on Belize barrier (29% of shallow corals and 5% of fore reef corals damaged);
- Guanaja (22%) had more damage than Roatan (13%), Utila (8%), and Cayos Cochinos (5%);
- Southern Yucatan (11% shallow, <1% fore reef) had minimal damage;
- Almost 80% of corals damaged at NE Glovers Reef, the highest in the region;
- Localised shallow reefs in Belize and Honduras had 50-70% of corals damaged;
- Acropora tenuifolia and M. complanata were affected the most; and
- There was major reduction of reef structure on many shallow reefs.

Secondary impacts were likely from extensive runoff of low salinity, high nutrient, sediment-laden water into the Gulf of Honduras as far north as Glovers Reef, and possible contamination from high quantities of pesticides and fertilisers in runoff. Decreased water temperatures in Honduras and southern Belize were reported after the hurricane. Loss of revenue in fishery and tourism industries was also reported.

seriously degrading nearshore reefs, and over-fishing and damaging fishing practices also contribute to the degradation. Most shallow reefs around the populated Corn Islands are degraded due to discharge of untreated sewage i.e. on 5 CARICOMP transects at 12-15m in 1994-96, bottom cover was dominated by algae (44% - mostly *Dictyota* and *Padina*); live coral (25% - mostly *M. annularis, Agaricia, Porites*, and *Millepora alcicornis*); and minimal sponge and soft corals (5%). There was no evidence of coral bleaching or gorgonian diseases and *Diadema* urchins were seen. In the Miskito Reserve, coral recruitment was high, coral disease and bleaching were low, algal diversity was high but macroalgal overgrowth was low, probably due to urchin grazing. Nothing is known of the status of the well-developed *A. palmata* reefs on the windward eastern edge of the Pearl Cays, which are subject to coastal runoff. Little is known of damage from Hurricane Mitch, but high damage is anticipated because it went over the Bay Islands and resulted in massive runoff of sediments. Anchor damage is minimal because the fishing boats are small. Overall, the reefs of Nicaragua have probably lost about 10% of coral cover over the last 10 years, but coral cover of 25% is comparable to other areas of the Caribbean.

El Salvador

Little is known about the coral communities at Los Cobanos.

Potential Climate Change Effects on Coral Reefs

Perhaps the greatest future threats to the reefs in this region are from bleaching events. The 1990s decade was the warmest on record with the most extreme El Niño events. Models for the next 100 years predict that warming will continue and coral bleaching will become more frequent and severe, probably becoming an annual occurrence over much of the region by 2015 and seriously damaging these coral reefs. Continued Hurricane impacts are also expected. Thus, increased management efforts will be needed to protect the coral reefs from additional anthropogenic stress which would compound these global effects, prevent recovery from acute disturbances, and further increase the probability that these reefs will experience significant shifts in community structure, including continued losses of live coral.

Status of Coral Reef Fisheries and Fisheries

Northern Central American reefs have traditionally been an important source for food, but the intensity and frequency of fishing is increasing at an alarming rate. Marine fish captures are largest in Mexico, are steadily increasing in Nicaragua (259mt in 1992) and Guatemala (92mt in 1993), while there is an overall decline in landings in Belize and Honduras between 1996-1998. These declines are attributed to lowered populations, over-fishing, changing economic circumstances, illegal fishing, destructive fishing methods like gill nets, and lack of enforcement. While fisheries management is non-existent in some areas, there are several examples of effective management to use as models for other areas. Two of the most exploited reef species are lobsters and queen conch, which both rely on healthy reefs and are vulnerable to over-fishing.

Mexico

There are at least 245 reef fish in Atlantic Mexico: 68% of these in the Gulf of Mexico; and 92% along the Yucatan. Herbivores dominate on Gulf of Mexico reefs, carnivores are more

Status of Conchs and Lobsters

Throughout this region, queen conch *(Strombus gigas)* and spiny lobster *(Panulirus argus)* have important economic, social and cultural values. But over-exploitation, illegal fishing, poor enforcement, and lack of trans-boundary management over the last 30 years have resulted in declining populations and decreases in catches. The Mexican Atlantic has the greatest conch catches, while the largest lobster catches are from Nicaragua. Management of these fisheries varies throughout the region, although illegal fishing is common and trans-boundary issues are largely ignored.

Mexico: Extensive over-exploitation in the late 1970s caused conch stocks to collapse, leading to fishery closures in Yucatan (1988) and seasonal closures in Quintana Roo (1991). Shallow water conch and lobster populations have declined and deeper water populations are at risk since collection using scuba and hookah is permitted. Larger lobster populations are found in Bahia de la Ascencíon, Espirtu Santo Bay and Banco Chinchorro. Lobster regulations include minimum size (145mm) restrictions, 4 month closure, and a ban on collecting berried females.

Belize: Lobster is the biggest, most important fishery and years of over-fishing have altered both lobster and conch populations. The populations are skewed towards smaller lobsters, while many conch are legal size but not sexually mature; yet the overall status of lobster and conch is not known. Regulations include closed seasons for lobster (Feb 15-June 15) and conch (July-Sept), gear restrictions (no scuba), prohibited take of egg-bearing lobsters, and minimum size restrictions for lobster and conch (18cm). There is extensive illegal fishing and the use of baited gill nets to harvest lobsters damages reefs.

Honduras: Lobster and conch are important commercial and artisanal fisheries. Conch are collected by free or scuba diving and harvesting restrictions include a closed season (March-August) and minimum size (22cm); there are no regulations for the lobster fishery. Historically, Honduras had the largest lobster catches, but these have drastically declined. Few large lobsters exist and populations of conch and lobsters are only found in deeper waters. Lobster and conch collecting is prohibited in Cayos Cochinos Reserve, and they are overfished in the Bay Islands, whereas the status on the offshore banks is unknown.

Nicaragua: Lobster is the most important fishery by Miskito artisanal, industrial, and pirate industrial fishermen. Fishing effort has doubled in the last 10 years, yet lobster populations are not considered to be heavily over-fished by the locals. Little is known about conch. There are no regulations to conserve lobster or conch and illegal fishing by foreign vessels (Honduras) is the greatest threat.

Management recommendations include closed seasons, size and weight restrictions consistent with size or sexual maturity, gear restrictions, protection of nursery and spawning grounds, establishment of no-take zones, limited entry or quotas, gathering more information on status and distribution, alternatives to fishing, and measures to

improve trans-boundary management of larger, regional fisheries, including greater enforcement and harmonisation of regional regulations.

Country	Conch	Lobster	Fish
Belize	252	502	111
Guatemala	--	--	213
Honduras	490 (1996)	306	160
Mexico	3,293	613	93,291
Nicaragua	162	3,729	4,088

The harvest for the major marine resources - strombid conch, lobster, and fish 1998 in metric tons (mt)

abundant in the Caribbean, and important families include Scaridae, Pomacentridae, Labridae, Acanthuridae, Lutjanidae, Haemulidae and Serranidae. There is higher species diversity, more abundant herbivores, and 2-3 times higher predator biomass in the Sian Ka'an Biosphere Reserve, than on adjacent unprotected reefs. Mexico has an advanced fishing industry, concentrated mainly on the Pacific side. Coral reef fisheries concentrate on snappers, groupers and parrotfishes, but fisherman often avoid reef areas to prevent net damage and instead fish for larger fishes found near rocky points. Harvesting for reef invertebrates (e.g. sea cucumbers and molluscs) and aquarium fish (angelfish, butterflyfish) is high and the fishery is poorly regulated. Most reef fishing targets groupers, grunts, barracudas, snappers, snook, and Atlantic Spanish mackeral on reefs in the Gulf of Mexico and the Yucatan. Fishing regulations near Veracruz in the SW Gulf of Mexico have been fairly successful at limiting fishing to subsistence and recreational fishing, but fishing on the Campeche Bank is intense and the resources are heavily exploited, particularly lobsters and groupers. Six spawning aggregations on the Yucatan have been commercially fished for grouper (*Epinephelus* spp.) for over 50 years and catches continue to increase, yet these aggregations are considered to be over-fished. Regulations exist for the amount, size and depth of collection of black coral, but it is over-exploited and commercially threatened. A lack of enforced fishing regulations, increases in tourism, and lack of alternatives to fishing threaten the status of coral reef fishes in unprotected areas. Yet, awareness on the need to develop sustainable fisheries is increasing with actions underway to designate new protected areas (Xcalak), and implement tighter fishing regulations at existing ones (Banco Chinchorro, Sian Ka'an, Cozumel, Contoy Island).

Belize

There are more than 317 reef fish species with higher fish density on shallow reefs (primarily surgeonfish) versus deeper fore reefs (primarily parrotfish). Densities on shallow reefs are generally higher at Glovers, Lighthouse, and Central Barrier than Turneffe and the northern barrier. Abundance at deep sites is very similar, although Lighthouse has the lowest. Belize has a small but expanding commercial and subsistence fishing industry. Lobster is the most important fishery, followed by marine fishes, conchs, and *Penaeus* spp. shrimps. Now shrimp mariculture accounts for more than the value of all fisheries combined. At least 10 spawning aggregations are currently over-exploited, the largest one is at Gladden Spit with

at least 20 species. Little is known about black coral collection, sport fisheries (e.g. snook, bonefish), small scale harvesting of sponges and the alga *Euchema*, and collecting for the small aquarium trade. Fish are exploited throughout Belize, with Gladden Spit and Sapodilla Cayes being most vulnerable to over-fishing and substantial illegal foreign fishing. The Hol Chan Marine Reserve has effectively protected fish populations for over 13 years, with more species, higher abundance, and larger sizes of commercial species compared to non-protected areas. Belize has the infrastructure and legislation to implement effective marine fisheries regulations, but the challenge will be to enforce such regulations and reduce illegal fishing.

Guatemala

Commercial fishing is not well developed, although apparently, abundant resources exist. On the Pacific side there are small-scale local fisheries for fishes, sharks, rays, and skates, and the yellowleg and *Penaeus* shrimps. On the Caribbean side the main fish include manjua, shrimp, red snapper, mutton snapper, billfish, jack, tarpon, and snook. Very little is known about the fish resources and level of exploitation on the Caribbean coast. Some areas are believed to be over-exploited i.e. Amatique point and the coastline east to the Honduran border. Many local people rely heavily on fishing (legal and illegal) and buying from fisherman in southern Belize and Honduras.

Country	1980		1990		1997	
Belize	131	$141	183	$241	31	$191
El Salvador	246	$164	188	$252	119	$303
Guatemala	6	$7	347	$66	67	$391
Honduras	59	$65	281	$609	700	$1,405
Mexico	960	$1,995	27,272	$35,718	27,943	$52,646
Nicaragua	544	$735	234	$291	1,675	$6,625

Total marine fish exports in metric tons and the value in US$1000

Honduras

There are over 294 reef fish species with at least 226 in Cayos Cochinos Biological Reserve. Abundant fish include parrotfish, damselfish, surgeonfish, and wrasses, bar jack, and yellowtail snapper, but at least 34 species have been over-fished. The fishing industry consists of small-scale local fisherman and industrial fishing fleets. On the Pacific coast, marine fishes, crabs and *Penaeus* shrimps are important, while on the Caribbean, *Penaeus* shrimps, lobster, marine fish, and conch are the major fisheries. There is intense fishing along the mainland coast and gill nets are often used, yet the status of the coastal fisheries is unknown. There is a long history of large industrial fishing trawlers exploiting all reef fish around the Bay Islands resulting in a dramatic collapse of many fish populations. Fishing regulations at the Cayos Cochinos Reserve prohibit industrial fishing vessels and commercial vessels and limit fishing to the traditional Garifuna communities. Total fishing effort and landings decreased in 1998-1999, probably due to Hurricane Mitch. Fish are exploited along the north coast and Bay Islands (except Cayos Cochinos), but the status of fisheries on the offshore banks is not known. Despite hosting the largest commercial fleet of shrimp trawlers along the Caribbean coast of Central America, Honduras' capacity for fisheries management remains weak, and data collection on stocks and factors limiting productivity is unreliable or non-existent.

Nicaragua

There is little information on reef fish in the Caribbean, although the species composition is probably similar to other areas. Fish have always been an important local and domestic food source, but extensive fishing for shrimp and lobster in the 1980s threatens fish stocks. Lobsters are the most important fishery, as well as fish and shrimp. USAID reports from 1996 suggest there are few commercially important fish on shallow reefs, with the most abundant being small yellowtail snappers. Illegal fishing by foreign fisherman is a serious threat to the small artisanal fishery, which appears to be sustainable, but industrial fishery is not sustainable. There is a growing aquarium fish trade at Corn Island that may expand into other areas. Endangered green turtles are heavily fished for food (14,000 turtles/year are harvested) and immediate action is needed to conserve them. There is great opportunity to develop and implement fisheries regulations before extensive over-exploitation destroys stocks of lobster, shrimp, reef fish, and turtles. A first step would be to reduce the amount of illegal fishing by neighbouring countries.

El Salvador

There is no reef fishery, but there is a small offshore shrimp (*Penaeus* spp.) and marine finfish fishery.

Anthropogenic Threats to Coral Reef Biodiversity

These are the greatest threats to coral reef biodiversity, with the potential to reduce species diversity and richness, abundance, habitat quality and quantity, productivity, and critical habitats such as spawning, breeding or foraging sites. After the dramatic impacts from the 1998 mass bleaching event and Hurricane Mitch, the long-term recovery of reefs will not only depend on natural recovery processes, but also on the ability of governments and managers to reduce the level of cumulative anthropogenic disturbances. Continued human damage to reefs will have severe ecological and socioeconomic consequences.

As part of the Mesoamerican Barrier Reef System (MBRS) conservation initiative with Mexico, Belize, Guatemala, and Honduras, and preparation of a regional GEF/World Bank project to conserve and sustainably manage the MBRS, a 'Threat and Root Cause Analysis' was conducted to identify the main threats to the ecology of coral reefs as: 1) inappropriate coastal/island development and unsustainable tourism; 2) inappropriate inland resource and land use and industrial development; 3) over-fishing and inappropriate aquaculture development; 4) inappropriate port management, shipping and navigation practices; and 5) natural oceanographic and climate meteorological phenomena and how these interact with the other threats. These countries share many of the same resources, therefore many issues, problems and concerns about the use and management of these resources extend beyond country boundaries. These trans-boundary issues have demonstrated the need for mechanisms to address existing and emerging threats. The Threat and Root Cause Analysis identified several trans-boundary threats to coral reef resources including:

- Agricultural/Industrial Runoff (e.g. Aguan, Motagua, Dulce, New Rivers etc.);
- Country boundary (Honduras & Nicaragua, Belize & Guatemala);
- Land based pollution, contamination (Chetumal Bay etc.);

- Maritime Transport/Port, pollution (e.g. Gulf of Honduras);
- Migratory/Endangered species (e.g. sea turtles, manatees);
- Sedimentation, contamination (e.g. Gulf of Honduras);
- Tourism (regional);
- Unsustainable fishing (regional); and
- Illegal fishing (e.g. widespread illegal foreign fishing in Belize and Nicaragua)

In the Mexican Pacific, the main threats are excessive sedimentation from deforestation, anchor and other diver-related damages, and illegal fishing. The remoteness of the Caribbean coast of Nicaragua and history of civil unrest has limited development except by the indigenous communities. Specific threats to coral reefs include over-fishing, coral extraction, oil pollution, deforestation, soil erosion and sedimentation, and water pollution. Natural hazards such as earthquakes, volcanoes, landslides, and severe hurricanes also pose threats to reefs, although these are periodic rather than chronic sources of disturbance. Water quality around coastal communities and inhabited cays has declined due to untreated sewage, industrial activities, fish processing plants and maritime transport. Sedimentation and eutrophication from coastal deforestation along the Honduran coasts affect the Miskito Coast Marine Reserve downstream, in addition to local and intense foreign fishing of lobster, fish and turtles. Extensive poaching of Nicaragua's marine resources by Hondurans has been reported.

In El Salvador current threats to the coastal zone include deforestation and soil erosion, water pollution, soil and water contamination from disposal of toxic wastes, and frequent and often destructive earthquakes and volcanic activity.

Coasts / Threats	AGM	CMX	CBL	CGU	CHO	CNI	PMX	PES	PNI
Agricultural runoff	+		+	+	+	+		+	+
Aquaculture development			+	+	+	+		+	
Coral extraction (curio trade)	+	+	+		+	+	+		
Deforestation	+	+	+	+	+	+	+	+	+
Destructive fishing	+	+	+	+	+				?
Diving activities	+	+	+		+		+		
Dredging	+	+	+						
Fish extraction	+	+	+	+	+	+	+	+	+
Garbage pollution	+	+					+		
Heavy metal pollution	+			+				+	?
Industrial activities	+	+	+	+	+	+			?
Maritime activities	+	+	+	+	+	+		+	?
Oil pollution	+		+	+	+			?	+
Over-fishing	+	+	+	+	+	+	+	?	?
Sedimentation/siltation	+	+	+	+	+	+	+	+	+
Sewage pollution	+	+	+		+	+		+	?
Tourism activities	+	+	+		+		+		?
Urban development	+	+	+	+	+			+	+

A listing of the anthropogenic threats to coral reef biodiversity affecting the coasts of this region: AGM: Atlantic Gulf of Mexico; CMX: Caribbean Mexico; CBL: Caribbean Belize; CGU: Caribbean Guatemala; CHO: Caribbean Honduras; CNI: Caribbean Nicaragua; PMX: Pacific Mexico; PSA: Pacific El Salvador; PNI: Pacific Nicaragua.

Current MPAs, Monitoring Programmes and Conservation Management Capacity

The conservation and sustainable use of marine resources is becoming a higher priority in countries of the region and programmes or regulations are being developed and implemented to address land use and development, fisheries exploitation, pollution control, and tourism. Mexico and Belize have several well-developed management programmes to conserve coral reef resources, while continuing progress is being made in Honduras, Guatemala, and Nicaragua. One of the most significant steps towards protecting coral reefs was the signing of the Tulum Declaration (1997) by the leaders of Mexico, Belize, Guatemala, and Honduras which was an agreement to work towards regional conservation to ensure the integrity and future management of the 'Mesoamerican Barrier Reef System' (MBRS). The objectives of the MBRS Project with Mexico, Belize, Guatemala, and Honduras, are to enhance protection of vulnerable and unique marine ecosystems of the second longest barrier reef in the world. The project, financed by the GEF with support from the World Bank, is to assist the countries involved to strengthen and coordinate national policies, regulations, and institutional arrangements for marine ecosystem conservation and sustainable use. Specific conservation targets identified by the governments include strengthening a regional system of protected areas, regional fisheries management and conservation of key species and habitats.

Current Marine Protected Areas

There are over 100 marine and coastal protected areas in North Central America providing protection for over 45,000km^2 of marine habitats and resources and most have been designed specifically to address issues from over-exploitation of fishery resources, protection of critical habitat, and pollution and degradation of resources related to excessive use. Identifying and limiting access to within limits of human carrying capacity is an important MPA conservation management tool. Mexico and Belize have both governmental and NGO managed MPAs, while Guatemala and Honduras have delegated more fully to NGO management.

The effectiveness and conservation approach varies with each MPA. There have been calls for assessments of the effectiveness of MPAs, and Belize has undertaken such a study. Overall, the effectiveness of their management was found to be 'moderately satisfactory' with the main problem being with administration. Although some MPAs have been relatively successful at reducing human impacts on coral reefs, many others remain as 'paper parks', mainly due to the lack of financing for management activities. Developing reliable funding mechanisms and building the human capacity to manage the resources remain the two greatest challenges for the region's MPAs. A frequently overlooked consideration in the design of marine protected areas is the 'regional perspective', including trans-boundary issues and threats, physical linkages between MPAs, and the lack of cooperation and coordination between countries. Strengthening mechanisms to promote trans-border coordination in the protection of system wide resources and ecological processes will be essential for protecting coral reefs in this region.

Conservation of the MBRS

The Mesoamerican Barrier Reef System (MBRS) has been recognised as one of WWF's Global 200 ecoregions with outstanding biodiversity, whose protection is vital for the conservation of global biodiversity. The MBRS also offers numerous benefits for coastal inhabitants and visitors including subsistence, recreational, and commercial fishing, tourism, snorkeling and diving, as well as providing structural protection against storms and erosion. Yet years of indiscriminate and unsustainable use, such as unregulated coastal development and over-exploitation of fishery resources, now threatens the balance of this unique ecosystem.

Recognising the ecological, aesthetic, cultural, and economic value of the MBRS, the Presidents of Mexico, Guatemala and Honduras and the Prime Minister of Belize, signed the Tulum Declaration in June 1997, launching the Mesoamerican Barrier Reef Initiative (MBRI). The primary objective is to promote the conservation and sustainable use of the MBRS and to ensure its continued contribution to the ecological health of the region and the livelihood of present and future generations. An Action Plan for the MBRS was developed at the formation of the Mesoamerican Barrier Reef Congress in November 1997, which was jointly organised by the Central American Commission for Environment and Development (CCAD), the World Bank, the World Wide Fund for Nature (WWF), and the International Union for the Conservation of Nature (IUCN). With support from Global Environment Facility and World Bank, a regional strategy to protect the MBRS is currently being prepared based on actions to:

- Integrate policies and legislation to strengthen coordination at the regional level;
- Promote conservation;
- Promote sustainable use;
- Broaden environmental education and awareness;
- Develop a regionally compatible ecosystem/biodiversity monitoring program and information

Since the signing of the Declaration in 1997, significant steps have been made towards developing a regional conservation strategy to ensure the integrity and future management of the MBRS including:

- 1st and 2nd MBRS Regional Project Preparation Workshops (July & September 1999 in Honduras and Belize)
- Status of the MBRS: Impacts of Hurricane Mitch and 1998 Bleaching on Coral Reefs Report
- Threat and Root Cause Analysis Report
- Guidelines for Developing a Regional Monitoring and Environmental Information System Report
- Sustainable Fisheries Management Report
- Establishment and Management of Marine Protected Areas Report

- Environmental Education and Public Awareness Report
- Harmonisation of Policies and Legislation and its Implications for the MBRS Report

AGRRA Capacity Building for Science and Management in the MBRS, Workshop 1999
WWF Report on Preliminary Meeting of Experts (June 1999, Belize City)
WWF/RSMAS- Development of a regional GIS database for MBRS
WWF/CCAD Workshop: Ecoregion Planning: Ecological vision & conservation priorities (April 2000)

Several other efforts are progressing at all levels (grassroots, national, regional, and international) to address the threats endangering the MBRS. Other organisations involved in the MBRS initiative and conservation in the entire NCA region include Food and Agricultural Health Organisation, World Wildlife Fund for Nature (Conservation of the MBRS Ecoregion), PROARCA-COSATAS/USAID (Regional Environmental Project for Central America), The Nature Conservancy, University of Rhode Island/Coastal Resource Center (URI/CRC), AGRRA, CARICOMP, UNEP, GCRMN, UNDP, GTZ, USAID, DANIDA, and Inter-American Development Bank. Contact: Marea Hatziolos The World Bank, Mhatziolos@worldbank.org.

Country	#of Marine Protected Areas	Approximate size of protected areas (km²)	Comments
Mexico	44 (marine & coastal)	>40,000	Most recent MPA is Xcalak, Yucatan- a community based marine reserve (2000) and Puerto Morelos (2000)
Belize	12 (marine)	>2117.5	Most recent MPA is Gladden Spit, one of the largest spawning aggregation areas for snappers, groupers (2000).
Guatemala	4	170	Established the first Manatee Protected Area.
Honduras	25	4300	Cayos Cochinos Biological Reserve (government and NGO support) and Sandy Bay Reserve (NGO based).
Nicaragua	4	1200	Miskito Cay Marine Reserve- community based MPA.
El Salvador	2	52	
Total	**91**	**>47,739**	

A summary of Marine and Coastal Protected areas in North Central America

Coral Reef Monitoring

Monitoring capacity and activities vary considerably across the region, with some regional monitoring programmes including GCRMN, AGRRA, REEF, Reef Keeper and Reef Check, and numerous local and national programmes. Most monitoring and research has been conducted recently at select locations in Belize and Mexico, and more recently in Cayos Cochinos and Roatan (limited), Honduras. Monitoring is almost non-existent in Guatemala and Nicaragua.

A recent review in the MBRS showed that a lack of a regional monitoring perspective, and poor coordination and data sharing among monitoring programmes were hindering conservation efforts. Monitoring capacity is often based in a NGO or academic sector with limited ties to decision making. Many government agencies lack the funding and capacity to implement extensive monitoring programmes to assist in policy formulation. Therefore MBRS Initiative focuses on improving monitoring capacity, developing an integrated regional perspective, and improving access to environmental information throughout the region. Only Mexico and Belize had national geo-referenced databases and an integrated environmental information system. But a new regional Geographical Information System (GIS) database has been created to develop a more comprehensive and regional approach to monitoring (RSMAS/WWF), and to include ecological, physical, and socioeconomic data as part of a distributed data based monitoring and information system.

Mexico

Regional monitoring programmes include CARICOMP, AGRRA, REEF, Reef Keeper and ReefCheck. Institutions involved with local monitoring include SEMARNAP, UNAM, ECOSUR, Amigos de Sian Ka'an, CINVESTAV, Universidad Quintana Roo, Centro Ukana I Akumal, EcoSur, University of Miami, INVESTAV, INVEMAR, University of Miami/RSMAS, University of Maine, University of Rhode Island/CRC, and Dauphin Island Sea Lab. On the Pacific coast, ongoing monitoring is done by the Universities: Baja California (La Paz), Guadalara (Puerto Vallarta) and del Mar (Puerto Angel). Several scientific studies are ongoing by Mexican and international academic institutions.

Belize

Regional monitoring programmes include CARICOMP, AGRRA, CPACC and REEF. Institutions involved with local monitoring include Coastal Zone Management Authority, Belize Dept. of Fisheries, Belize Audubon Society, University College of Belize, The Nature Conservancy/TIDE, Greenreef, University of South Florida (M. McField), CARICOM Fisheries Unit, CFRAMP, Wildlife Conservation Society, University of Miami/RSMAS. There are numerous scientific studies by foreign academic institutions.

Guatemala

With few coral reef resources, most monitoring revolves around forestry, ecotourism, environmental education, capacity building, and sustainable land development. Groups involved include Fundary (Fundacion mario Dary), Association for Research and Social Studies (ASIES), PROARCA/COSTAS, WWF, USAID, FUNDAECO Izabel, CONAP, CECON (Centro para Estudios Conservacionistas), Sierra de Sta. Cruz, and Sierra de las Minas.

Honduras

Groups involved with monitoring include Cayos Cochinos Marine Reserve, Bay Island Conservation Association, Biodiversity of Protected Areas Project (PROBAP), Wildlife Conservation Society, WWF, AGRRA, CARICOMP, Inter Development Bank (BID), REEF, USGS, and NOAA.

Nicaragua

Groups involved with monitoring/research include Mikupia, Miskito Reef Mapping Project, USAID, CARICOMP, and MARENA.

Government Policies, Laws and Legislation

Mexico has signed all major international agreements dealing with coastal and marine biodiversity, while the other countries are party to a number of international agreements. The most significant regional plan for increasing government capacity to protect coral reefs is the Declaration of Tulum. The Cartagena Convention is also important to protect and conserve fragile ecosystems, as countries agreed to prevent, reduce and control pollution from ships, dumping, sea-bed activities, airborne, and land-based sources and activities within the Wider Caribbean. National government capacity varies with each country, yet there is an overall lack of infrastructure and weak institutional framework that has lead to poor implementation of international agreements and a lack of enforcement of national environmental regulations.

Mexico

There is extensive legislation and a solid institutional capacity to manage natural resources. The Secretariat of the Environment, Natural Resources and Fisheries (Secretaria del Medio Ambiente, Recursos Naturales y Pesca - SEMARNAP) is the Federal Government agency responsible for managing natural resources and fisheries. SEMARNAP oversees the following administrative units that have jurisdiction over the management of coastal and marine ecosystems:

- Federal Attorney for Protection of Environment (PROFEPA) - Enforcement of environmental law;
- National Institute of Ecology (INE)- Protected areas, wildlife management, pollution control, environmental zoning and environmental impact assessment;
- National Institute of Fisheries (INP)- Fisheries research;
- National Water Commission (CNA)- Water management;
- Undersecretariat of Fisheries- Fisheries management, aquaculture and fisheries infrastructure; and
- Undersecretariat of Natural Resources- Federal marine-coastal zone, soil conservation, forestry.

Other Federal agencies with jurisdiction over coastal and marine ecosystem management include: the Navy Secretariat; the Transportation and Communications Secretariat; the Tourism Secretariat; the Governance Secretariat and the Health Secretariat. The Governance Secretariat administers federal islands and cays, including the management of island

ecosystems. The Health Secretariat has jurisdiction over issues affecting health and subsequently natural resources. There is extensive legislation including key regulations such as: Declaration of Tulum 1997; Ecology Law 1988; Fisheries Law 1992; National Waters Law 1992; Federal Ocean Law 1986; Port and Navigation Law; and National Properties Law. Mexico has an extensive and effective protected areas program, with numerous ecological zoning programmes responsible for regulating coastal activities.

Belize

There is the legal and institutional policy framework to manage coral reefs, but there is a lack of enforcement and monitoring capacity. The system of MPAs is not financially sustainable, and relies on international support. Administrative units involved with the conservation and sustainable use of coastal marine resources include:

- Fisheries Department - management of fisheries, responsibility for marine reserves; plans to delegate more to NGOs
- Forestry Department – responsibility for National Parks, most delegated to NGOs
- Coastal Zone Management Authority/Institute – monitoring and research, conservation and MPA planning, policy development, financing of many MPAs
- Marine Protected Areas Committee - promotes communication among MPAs;
- National Coral Reef Monitoring Group- proposed coordination for national reef monitoring efforts;
- Barrier Reef Committee - oversees MBRS project and World Heritage sites;
- Coastal Zone Advisory Committee - shares information and advice between governmental departments and NGOs
- Land Utilisation Authority - regulates land use;
- Department of Environment - enforces environmental regulations;
- NEAC (National Environmental Appraisal Committee) - approves/disapproves EIAs
- Belize Tourist Board - oversees tourism industry.

The pertinent laws include: the Fisheries Act 1948; Environmental Impact Assessment 1995; Environmental Protection Act 1992; Water and Sewerage Act 1971; Declaration of Tulum 1997; and Coastal Zone Management Act 1998.

Guatemala

There are few laws or regulations that pertain directly to coral reefs, although several may benefit reefs indirectly: Declaration of Tulum 1997; Decrees Issued by the Congress of the Republic on protected areas and reefs; Elimination and Disposal of Sewage and Residual Water; Law for the Rational Exploitation of the Fisheries Resources of the Country; Law of Protection and Improvement of the Environment; Regulatory Law of the Areas of Territorial Reserves of the State of Guatemala; and Rules Concerning an Environmental Impact Assessment.

Honduras

There are several laws and regulations affecting coral reef resources, although the enforcement of these is sometimes lacking. Important regulations includes Declaration of Tulum; Biodiversity Convention; Central American Component for the Protection of the Environment Convention, Environmental Protection; Climatic Change Convention;

Conservation of Biodiversity in Central America Convention; General Law of the Environment; Fisheries Law, Fisheries Resolutions; Law for Planning and Development of Tourism Zones; and Merchant Marine Law.

Nicaragua

There is no national legislation or institutional framework dedicated to conserving coral reefs. The Instituto Nicaraguense de Recurosos Naturales y del Ambiente (IRENA) is in charge of conservation and wildlife. In 1991, 23 coastal Miskito communities made an agreement with the Nicaraguan Ministry of Natural Resources and international conservation groups to establish the largest coastal marine protected area - the Miskito Coast Protected Area (MCPA). The agreement supports true community-based marine management where the local Miskito communities have the right and responsibility to manage their own marine resources. In addition, guidance from an advisory team, assistance to provide enforcement of the MPA, and national and international financing assistance is included. In 1993, a national integrated coastal zone management plan (PAA-NAC) was approved to promote the sustainable use of coastal resources, but implementation has been slow. Other existing regulations need updating and modification, while several proposed laws are waiting for approval (e.g. Fishery and Aquaculture Law). There are a few small NGOs, but few collaborative efforts between them or public/private partnerships to manage coastal resources.

El Salvador

There is no legislation for coral reefs probably due to the lack of reef resources.

Information Gaps, Monitoring and Research Needs

Significant information is lacking on key issues required to improve our understanding and ability to manage coral reefs and minimise human impacts. Based on existing information of the status and threats to coral reefs in the region, these are four target areas that require further focus:

1) Sustaining fishery resources

- Fishing activity (effort, catch)
- Status of fisheries resources (population, life history data)
- Location, size and exploitation of nursery and spawning areas
- Economic alternatives to fishing
- Larval dispersal, juvenile settlement, adult migration patterns

2) Conserving coral reefs

- Status and distribution of coral reefs
- Physical oceanography data (currents, wind, gyres)
- Water temperature trends and patterns
- Information on other coral benthos, particularly keystone species

3) Sustainable development

- Current and projected land use
- Land carrying capacity
- Tourism levels and potential sustainable expansion
- Agricultural development and impacts

4) Improving Water Quality

- Status of water quality
- Sources of contamination (point and non point)
- Water discharges and flows
- Measures to minimise water pollution and improve water quality

Conclusions

- Reefs are poorly developed on the Pacific compared to the well-developed reefs on the Atlantic coast which contain some of the most outstanding reefs in the Caribbean, including the second longest barrier reef in the world, luxuriant patch, fringing, and barrier reefs, 5 offshore atolls, and important habitat linkages to extensive adjacent mangroves, seagrasses, bays, and lagoons. Significant information gaps remain on the development and condition of reefs in Nicaragua, mainland Honduras and Guatemala, offshore areas like Swan Islands and Mysteriosa banks and other reefs in the eastern Pacific coast and more long-term monitoring is needed throughout the region.
- Major anthropogenic threats to regional reefs include: inappropriate and unsustainable land use; tourism, and industrial development; over-fishing and impacts from aquaculture farms; pollution from inappropriate sewage treatment, waste disposal, agricultural runoff, and other land-based sources; and absence of sound port management, shipping and navigation practices, in addition to global threat of climate change.
- Development along the coastlines varies from highly developed tourist hot spots in Huatulco and Puerto Vallarta (Pacific Mx) and Quintana Roo (Atlantic Mx) to small local indigenous fishing villages in the Miskito Cays, Nicaragua.
- The intensity and frequency of fishing pressure is increasing for important fishery species like conch, lobster and grouper which are over-exploited in much of the region. Failure to implement new (or enforce existing) fishery regulations, fragmented management of trans-boundary resources, and the absence of economic alternatives to fishing continues to impede the ability to properly conserve fishery resources.
- Coral reefs in the region have declined in the last 25 years due to coral diseases and mortality of the sea urchin *Diadema antillarum*; mass coral bleaching is a relatively recent event (1995, 1997, 1998), while hurricane impacts have a long history in the region. The distribution and status of many other coral reef resources is not well known at the regional scale.
- The 1998 coral bleaching event and Hurricane Mitch severely damaged many reefs in the MBRS, particularly shallow reefs in Belize. Extensive losses of individual coral species (e.g. *Agaricia tenuifolia*, *Millepora complanata*, *Montastraea annularis* complex, *Acropora* spp.) are of particular concern as they are major reef builders.
- The long-term ecological consequences of the 1998 bleaching and Hurricane Mitch will depend on recovery processes (ability of corals to recruit, adapt, persist, etc), future disturbance events (intensity, duration, and frequency), and the degree to which human impacts are minimised.
- Pacific reefs in Mexico suffered 18-70% coral mortality related to the 1998 El

Niño event and subsequent La Niña event.

- A variety of capable localised monitoring and research programmes exist especially in Mexico and Belize, but the lack of a regional monitoring capacity and poor data sharing among programmes has hindered a better understanding of these systems and conservation efforts. A regional monitoring program for the MBRS is currently being developed to address these deficiencies and preliminary efforts are currently underway.
- Overall management and conservation awareness is advanced in Belize and Mexico, while capacity continues to grow in the other countries. Yet, the ability to address and minimise anthropogenic threats is highly variable and completely absent in some areas. Few mechanisms are in place to promote trans-border coordination and cooperation to reduce the escalating scale of human impacts. Poor or inconsistent enforcement of existing regulations is a continuing problem.
- Over 90 marine and coastal protected areas encompass more than 45,000km^2 of marine resources, but many of these lack financial sustainability and trained personnel to be effective. Mexico and Belize have the legal and institutional framework to implement MPAs, while the other countries often lack legislation, and all are in need of financial sustainability.
- A significant step towards protecting coral reefs was the signing of the Tulum Declaration (1997) by 4 neighbouring countries; a conservation strategy for the Mesoamerican Barrier Reef. International efforts are underway to strengthen and coordinate national policies, management programmes, monitoring efforts, and other actions aimed at conservation and sustainable use.

Recommendations

- A lack of understanding of ecological processes contributing to reef health limits our ability to conserve them, thus it is important to improve knowledge of these processes. A high priority is to identify and characterise the extent and condition of coral reef habitat and associated organisms, especially in less known areas as Nicaragua, mainland Guatemala/Honduras, offshore islands and banks like Swan Islands and Mysteriosa banks, and reefs in the eastern Pacific. Other data gaps include physical oceanographic and climate meteorological phenomena and how these interact with anthropogenic threats, and the ecological connections between reefs and adjacent coastal ecosystems and watersheds.
- Coral reefs that warrant immediate protection need to be identified, particularly those with high biological production; biodiversity hot spots; endangered, imperilled, or rare species; nursery and breeding areas; sources of larval corals, fish and other important reef organisms; and those at risk of pollution or other human impacts.
- Unsustainable and unregulated development of coastal resources must be eliminated throughout the region by developing effective land use strategies, implementing/enforcing appropriate land use regulations, eliminating inappropriate uses of resource, and minimising unsustainable tourism and industrial development. Sources of land based pollution need to be identified and actions to reduce the impacts need to be developed. Mechanisms to

reduce inappropriate port management, shipping and navigation practices must be created. The importance of addressing trans-boundary threats is emphasised.

- Unsustainable fishing practices throughout the region must be reduced by: enforcing existing fishery regulations and improving compliance; designing new regulations that reflect an ecosystem approach to management and are harmonised regionally; designating marine fishery reserves; developing financial mechanisms to sustain marine protected areas; eliminating destructive fishing practices; developing economic alternatives to unsustainable fishing; and promoting economic incentives for conservation.
- The institutional infrastructure and financial sustainability for implementing and enforcing national and international government policies needs improvement in Mexico and Belize and full development in the other countries. Policies and legislation to strengthen cooperation and coordination on conservation and sustainable use of coral reefs at the regional level need to be developed.
- There is an immediate and attainable requirement to develop the infrastructure and capacity to carry out an interdisciplinary regional program for collecting, exchanging, and using important ecological and socioeconomic information as well as monitoring the regional status of coral reefs and their resources.
- Raising environmental consciousness on the importance of coral reefs and the need to conserve their resources is the highest priority that needs to be incorporated into all of the above recommendations. Local, national, and regional education/awareness programmes need to be developed along with incentives to promote conservation and to take action to use coral reefs in a sustainable manner.

Acknowledgements and Supporting Documentation

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Many exceptional resources were used to compile this report and full citations can be

found on the AGRRA website www.coral.aoml.noaa.gov/agra/. Other general resources include:

www.fao.org;
www.worldbank.org;
www.reef.org
www.odci.gov/cia/publications/factbook/;
www.ims.wcmc.org.uk; and
www.fao.WAICENT/FAOINFO/FISHERY/STATIST/FISOFT/fishplus.asp.

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