# 5. Status of the Mesoamerican Reef after the 2005 Coral Bleaching Event

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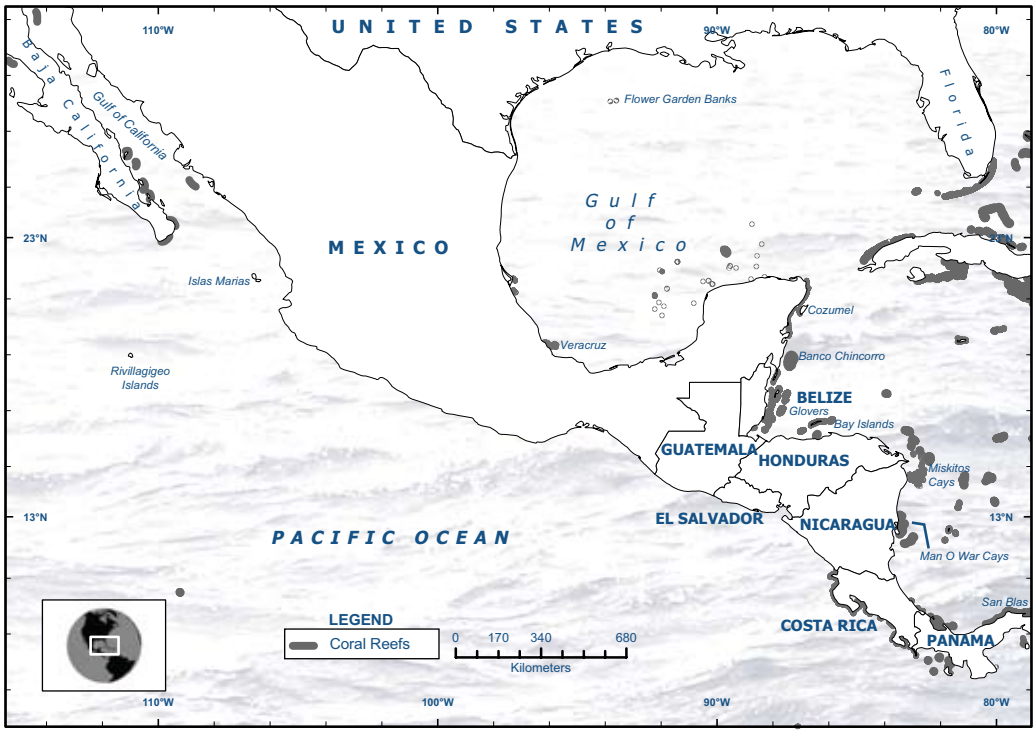
**Summary**

- Mass bleaching events in 1995, 1998 and 2005 have affected the reefs in the Mesoamerican Reef (MAR), although the 2005 bleaching resulted in little to no coral mortality;
- The 1995 event caused widespread bleaching, but minimal mortality (~10% of colonies had partial mortality in Belize);
- 1998 was the most significant bleaching event for the MAR, combined with a catastrophic hurricane that culminated in about 50% reduction in coral cover in Belize, with somewhat less in the other countries;
- Large-scale bleaching in late 2005 affected most reefs within the MAR, however, coral mortality was lower than in previous years;
- The active 2005 storm season may have contributed to greater mixing of oceanic waters and minimized 'doldrum conditions' that were associated with the previous, more severe bleaching events in the MAR;
- Reefs in Mexico were damaged by Hurricanes Wilma and Emily, but most of the other 2005 storms passed through the Yucatan channel into the Gulf of Mexico without causing substantial damage to reefs;
- The devastating coral bleaching and hurricanes of 1998 initiated the planning for potential adaptation and mitigation strategies into reef management efforts;
- The bleaching and hurricanes in 2005 may have further delayed potential recovery from the bleaching-related losses in 1995 and 1998; and
- Coral cover throughout the region remains moderately low, with little to no overall recovery from the 1998 losses.

## Introduction

The 1000 km long Mesoamerican reef system (MAR) is recognized as a global conservation priority owing to its biodiversity, cultural and socioeconomic values. The Caribbean coast and cayes of Mexico, Belize, Guatemala, and Honduras contain an abundance of diverse and productive ecosystems including coral reefs, seagrass beds and mangrove forests that provide critical habitats for commercial fish stocks and many threatened species. However, the ecological integrity of the MAR continues to be threatened by various anthropogenic and natural factors, ranging from pollution, tourism and unsustainable fishing activities to recent global climate change.




***Map of Mesoamerican Reef Ecoregion***

Bleaching and storm damage in the MAR is similar to what has happened in most reef regions of the world. This has changed the regulatory and management perspective, because large-scale coral bleaching events are beyond a local manager's capacity to control. Identifying practical and effective management responses for MAR has proven very difficult; current efforts are focused on restoring and maintaining reef ecosystem resilience.

Since the first mass bleaching in 1995, the MAR has suffered similar widespread bleaching events in 1998 and 2005. Although the 1995 mass bleaching event caused some coral mortality, the damage from the 1998 bleaching, combined with damage from 1998 Hurricane Mitch, was far more severe, resulting in a 50% average decline in live coral cover. In 2005, six sites in Belize were re-surveyed with the same methods, and no signs of recovery were found. There was no comprehensive assessment of reef recovery (or not) throughout the MAR region prior to the 2005 bleaching event. The limited data that are available suggest there had been little change from 1999 to 2005.

## The 2005 Bleaching Event

The coral bleaching events of 1995, 1998 and 2005 coincided with unusually high sea surface temperatures and calm seas (although fewer data are available on wind speeds). The period between July and November, 2005 was the warmest for the Caribbean in 100 years; however MAR reefs were less damaged in 2005 than many other reefs in the wider Caribbean. Coral bleaching within the MAR was first observed in mid-July, and apparently peaked in late October to early November, with up to 40% of corals being affected.

The Mesoamerican reef will likely continue to be affected by future bleaching events as sea temperatures are predicted to increase. However, environmental and intrinsic characteristics of each reef may alter the extent of resulting coral mortality or other impacts on reef resilience. The amount of heat stress on a specific reef is highly variable and can be influenced by local environmental factors (e.g. currents, wave exposure, and light penetration). Intrinsic factors, such as genetic make-up or heat resistance of symbiotic zooxanthellae, can also alter the heat-tolerance of different coral species or reefs. These inherent resiliency factors will also have a strong influence on which reefs are likely to survive into the future. Reef managers will need to apply precautionary management principles to control other stressors on the reefs, such as dredging operations, mangrove clearance and high density coastal developments. Mass bleaching has highlighted the critical need to integrate these stresses into management efforts.

### REEF CHECK MONITORING IN THE CARIBBEAN

As threats to reefs continue to grow, Reef Check's community-based monitoring program is becoming increasingly important to document the status of the world's coral reefs. Hurricanes, El Niño events, disease outbreaks, bleaching and other stresses caused by human activities have increased coral mortality throughout the world in the past 25 years. Coral bleaching brought about by abnormal increases in sea temperatures is now considered the greatest threat to coral reefs. The most severe bleaching event to date occurred in 1998 and affected the entire Indo-West Pacific region. Subsequent coral mortality often reached 50% and, in some places, more than 90% of the hard corals were killed. The Caribbean region was also affected in 1998, but average mortality generally ranged between 5-10%. During 2005, another massive bleaching event occurred as sea temperatures in the Caribbean matched or even surpassed those recorded in 1998.

Reef Check teams conducted more than 185 benthic surveys in 16 countries throughout the Caribbean between January 2005 and June 2006 to determine the extent of coral bleaching and subsequent mortality at local to regional scales. On a Caribbean-wide scale, the percent cover of bleached coral ranged between 2% and 62%, and bleaching-related mortality ranged between 0% and 27%. There was little difference in the extent of bleaching between shallow and deep reefs and the average percent cover of live hard coral did not change significantly as a result of coral bleaching.

Substantial coral bleaching was recorded in Belize, Jamaica, St. Lucia and the British Virgin Islands. In Belize, St. Lucia and the British Virgin Islands, there was little subsequent mortality and no reduction in coral cover. In Jamaica, a large proportion of the corals that bleached subsequently died, but because the coral cover was generally low, the mortality did not reduce the coral cover significantly (see p 79).

If the 1998 and 2005 large-scale bleaching events are representative of a general pattern, then abnormally high sea temperatures within the Caribbean seem to cause extensive bleaching but little subsequent mortality. This is possibly a result of the recent domination of massive corals, which are more resilient than branching corals, within Caribbean coral communities, and/or because Caribbean corals are frequently exposed to larger fluctuations in sea temperature, allowing them to better adapt.

With greater investments in a strengthened monitoring network, the standardized survey methods employed by Reef Check enable the size of impacts resulting from large-scale environmental stresses, such as El Niño and climate change, to be quantified at local to global scales. Data resulting from large-scale standardized surveys are increasingly important in tracking reef responses to impacts from a variety of sources and are an extremely useful tool for coral reef management and conservation (from Cori Kane, ckane@reefcheck.org and Gregor Hodgson, gregorh@reefcheck.org).

***Summary of results of Reef Check surveys conducted during the 2005 bleaching event and in the following months to June 2006, to determine the percentage cover of bleached coral and levels of subsequent mortality on coral reefs throughout the Wider Caribbean (- indicates no data).***

| Country | Mean % Bleaching | Mean % Mortality |
|---|---|---|
| Bahamas | 16.8 | - |
| Belize | 27.9 | 6.5 |
| Brazil | 5.7 | - |
| British Virgin Islands | 55.0 | 2.1 |
| Colombia | 1.0 | - |
| Dominica | 4.6 | 0 |
| Dominican Republic | 26.8 | - |
| Honduras | - | 14.4 |
| Jamaica | 33.7 | 12.5 |
| Mexico | 25.2 | 8.5 |
| Netherlands Antilles | - | 4.2 |
| St Lucia | 43.8 | 4.3 |
| St Vincent | 75.0 | - |
| US Virgin Islands | 100 | 34.3 |

## *Belize*

The longest continuous barrier reef system in the western hemisphere extends approximately 260 km along the Belize coast, and along with the diverse assemblage of lagoonal patch reefs, fringing reefs, faroes and offshore atolls, covers about 1400 km$^2$. The reefs were once considered to be amongst the most flourishing reefs of the Caribbean, although now the current status is generally comparable with the rest of the Caribbean.

**Status of coral reefs prior to 2005:** The combination of disturbance events and chronic stresses has caused a decline in live coral cover and parallel increases in macroalgae on many reefs. The Acropora species have suffered a dramatic reduction in live cover since the late 1970s as a result of white band disease, and the region-wide die-off of the long-spined sea urchin grazer *(Diadema antillarum)*. In 1998, the most severe coral bleaching event on record occurred, along with the catastrophic impacts of Hurricane Mitch that produced torrential rains, flooding, and destructive waves that caused considerable mechanical damage to reefs. The combination of bleaching, hurricane damage, and increasing chronic local stresses, has resulted in dramatic reductions in coral cover: 62% in southern Belize; 55% in the north; 45% on the atolls; and 36% on central reefs.

Long-term data exist for a few sites in Belize; live coral cover on shallow patch reefs in Glovers Reef atoll has decreased from 80% in 1971, to 20% in 1996, and to 13% in 1999. The inner fore-reef region at Carrie Bow Caye had 30-35% coral cover in the 1970s, but declined to 12-21% in 1995. Similarly on the fore-reef at Channel Caye (3-15 m depth), an inner-shelf faroe, live coral declined from 85% in 1986 to 60% in 1996, primarily because of disease and loss of staghorn corals *(Acropora cervicornis)*, with partial replacement by thin leaf lettuce coral *(Agaricia tenuifolia)*. Subsequently, bleaching in 1998 devastated this reef, reducing coral cover to about 5% in 1999. In 1992, the coral cover on the barrier reef off Ambergris Caye and Gallows Reef (near Belize City) was 25% and 20% respectively. In 1993, the coral cover on the shallow Mexico Rocks patch reef off Ambergris Caye was 84%, but dropped to 66% in 1995 primarily as a result of the 1995 coral bleaching event. Prior to 1998, most impacts on reefs in Belize were from diseases and hurricanes, although regional increases in nutrient concentrations and sedimentation, loss of *Diadema*, moderate over-fishing, and bleaching were also likely contributors. The combined impacts of mass coral bleaching and Hurricane Mitch in 1998 exacerbated the rate of reef decline.

Major anthropogenic threats to Belize's reefs include coastal habitat alteration (mangrove clearance, dredging operations), sedimentation, agrochemical and domestic pollution (mainly associated with coastal development, and inadequate solid and liquid waste disposal), over-fishing, and direct impacts from tourists, boat anchors and groundings. The tourism industry is growing rapidly, providing the impetus for many of these growing pressures. Significant conservation efforts have been underway for over two decades to develop a system of marine protected areas (MPAs) to foster reef protection.

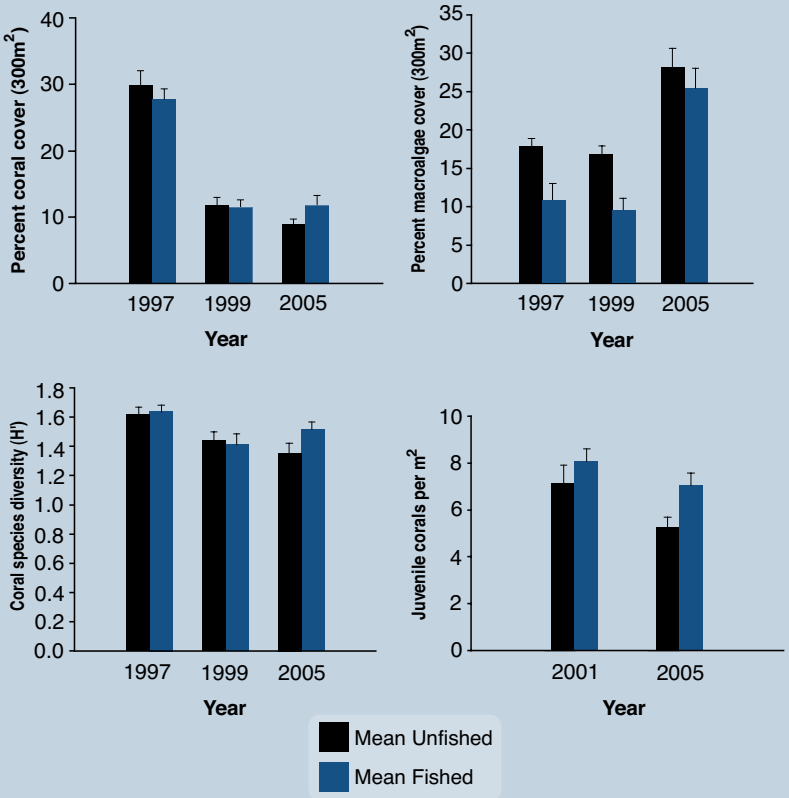
**Effects of the 2005 Bleaching Event:** The bleaching events in 1995 and 1998 caused some (mostly partial) coral mortality on most reefs in Belize. Sea surface temperatures (SSTs) surpassed the average summer maximum in both years beginning in late September in 1995 and early September in 1998. The bleaching event of 2005, while devastating to parts of the Eastern Caribbean, was less severe in Belize than the 1995 or 1998 events. No coral mortality in

## ASSESSING RECOVERY OF REEFS IN BELIZE

The recovery of Belize's reefs from the combined impacts of mass bleaching and Hurricane Mitch in 1998 were investigated in early 2005 to determine whether no-take protection status could accelerate potential recovery (i.e. increase resilience as defined by 4 indices: the abundance/diversity of benthic functional groups; hard coral diversity; coral recruitment; and herbivore abundance). Data were collected in 2005 at 3 highly protected sites and 3 reference sites and compared with data collected prior to or immediately after the 1998 event. There has been little recovery since 1998, with live coral cover at the 6 sites remaining less than 15%.

Because of the high level protection, it was predicted that the no-take reefs would exhibit significantly greater live coral cover and juvenile coral densities, and lower macroalgal cover than the fished reefs. However, there was no significant difference in mean live coral cover and coral diversity between fished and no-take reefs. Moreover, the density of juvenile corals was greater on fished reefs and the cover of macroalgae was significantly greater on unfished reefs.

From: Nadia Bood (nbood@wwfca.org), Melanie McField (mcfield@healthyreefs.org) and Rich Aronson (raronson@disl.org).



Belize was attributed to this 2005 bleaching event, possibly because of the relatively late onset, the cooling effects of numerous tropical storms and hurricanes, and possibly because many of the corals susceptible to bleaching had died during earlier events. Despite the lack of apparent bleaching related mortality in 2005, coral bleaching remains the major threat to all reefs in Belize; including the most remote and most well-protected (in terms of MPA management). While all nearshore and some offshore reefs are threatened by a variety of chronic local stresses, mass coral bleaching events threaten all reefs and may inhibit the natural ability of bleaching-damaged reefs to recover from repeated bleaching events.

Data from the Mesoamerican Barrier Reef System (MBRS) Project between early July and late September 2005 showed the first bleaching on the Belize reefs in mid July with 25% of colonies affected. The proportion of bleached colonies increased through August and September. Although no data are available for Belize after September, bleaching was observed in Belize (Turneffe, Ambergris Caye, Glovers Reef, among others) through to mid-November. Not all corals bleached and most that did were only partially bleached. Bleaching occurred primarily in colonies of *Siderastrea siderea, Montastraea* spp., *Diploria* spp. and *Agaricia* spp.

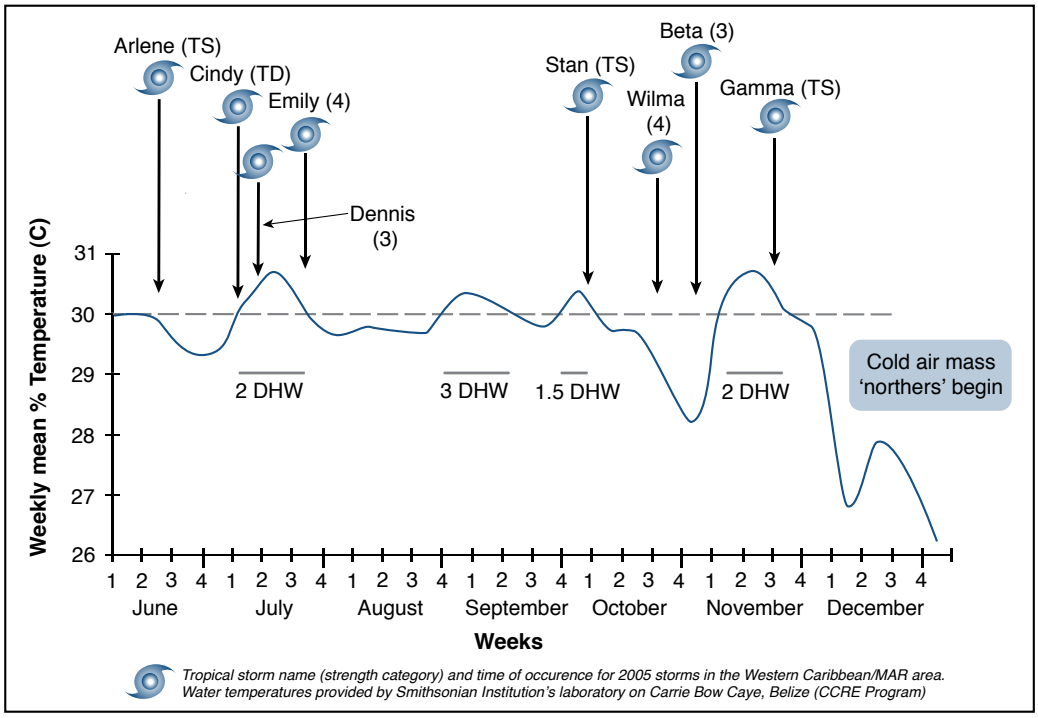
***The extent of bleaching in Belize in 2005 is seen as the number of coral colonies affected in the Northern Summer. Data provided by MBRS Synoptic Monitoring Program (www.mbrs.org.bz)***

| Location | Month assessed (n = number of colonies) | Colonies Affected by Bleaching (%) |
|---|---|---|
| Belize | July (n = 488) | 25 |
| | August (n = 505) | 19 |
| | September (n = 221) | 39 |

It may not be coincidental that 2005 was the most active storm season in the Western Atlantic in the past century. There were repetitive decreases in sea surface temperatures, which appear to coincide with the passage of intense storms that probably increased mixing and reduced SSTs. Thus, these storms may have contributed to the relatively low level of mortality of corals in Belize in 2005. A similar, but less dramatic, hurricane caused similar cooling during the 1995 bleaching event.

For four intervals between early July and mid November 2005, the average weekly SST in Belize exceeded the 30°C bleaching threshold for corals in the region, resulting in between 1.5 and 3 'Degree Heating Weeks' of temperature stress. On each occasion the stress was quickly reduced by rapid drops in temperature and coincident storm activity. By late November the regular cool winds, the 'northers', lowered sea temperatures.

**Impacts of Hurricanes in 2005:** Hurricanes have had a relatively regular impact on the reefs of Belize, but hurricanes Hattie (1961) and Mitch (1998) were exceptional. Hurricane Hattie reduced live coral cover on many reefs by 80%; however reefs subsequently recovered, at least to some extent. Hurricane Mitch in 1998 did not make landfall in Belize, but the pounding waves resulted in extensive physical damage throughout Belize, particularly on the Southern reefs. The heavy rainfall associated with this slow-moving storm also resulted in major flooding that damaged both inshore and offshore reefs of Belize and Honduras.




***Water temperatures in 2005 reached the bleaching threshold (around 30°C) on several occasions, however the passage of tropical storms in the Gulf of Mexico and Western Caribbean between June and December may have contributed to the series of sharp temperature declines noted in the graph above.***

The numerous tropical storms and hurricanes by-passing Belize in 2005 may have benefited the reefs of Belize by lowering SSTs, truncating the cumulative thermal stress, and thereby reducing the eventual extent of coral mortality.

**Status of Reefs in 2006:** A comprehensive reef assessment was conducted by WWF and partners in summer 2006 using the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol. This survey found negligible bleaching and minimal recent mortality on 141 reefs that were selected based on geomorphology and a randomized design using the millennium coral reef maps for the region. Only 207 of the 5614 colonies assessed (3.7%) showed any signs of coral bleaching. Interestingly, bleaching incidence was higher among fore-reef sites compared with other reef habitats. Disease infestation was also low overall, with less than 2% of colonies affected by any disease. Mean recent mortality for the 140 reefs (5614 coral colonies) was less than 1.5%, with no significant differences among habitats. Although the 2005 bleaching event did not cause significant damage to Belize's reefs, overall live coral cover remains relatively low, averaging about 10% and the bleaching may have slowed recovery by 1 to 2 years.

Fore- and pinnacle reefs were dominated by colonies of *Agaricia*, while *Porites* dominated patch reefs and reef flats. Mean fleshy macroalgae cover was 16% on fore-reefs, 18% on patch reefs, 15% on reef flats and 14% on pinnacle reefs. Coral recruitment was greatest on pinnacle reefs (7 per $m^2$) followed by reef flats (4/$m^2$), patch reefs (3/$m^2$) and fore-reefs (3/$m^2$). Herbivorous

fish (parrotfish and surgeonfish) biomass was 2.7 kg/100m$^2$, 1.8 kg/100m$^2$, 1.6 kg/100m$^2$, and 1.3 kg/100m$^2$ on pinnacle reefs, fore-reefs, reef flats and patch reefs respectively.

***A summary of reef status in Belize in 2006 shows that the 2005 bleaching event resulted in only low levels of prolonged coral bleaching, disease and mortality. Data provided by WWF.***

| Reef Habitat (n = number of colonies assessed) | Mean Coral Cover (%) (± S.D) | Colonies Affected by Bleaching (%) | Colonies Affected by Disease (%) | Recent Colony Mortality (%) |
|---|---|---|---|---|
| Fore-Reef (n = 2295) | 11 (± 4.8) | 5.7 | 1.6 | 0.9 |
| Patch Reef (n = 1348) | 11.5 (± 5) | 1.9 | 1.3 | 2.1 |
| Pinnacle Reef (n = 156) | 15.2 | 1.9 | 0.6 | 0.6 |
| Reef Flat (n = 1815) | 11.3 (± 7.1) | 2.7 | 1.3 | 1.0 |

**Socioeconomic impacts and management responses:** The lives of many Belizeans are inextricably linked to the health of their coral reefs through their dependence on the tourism and fishing industries, and their need for coastal protection (low-lying coastlines). For centuries, the reefs have provided cultural, ecological and economic benefits as well as physical protection during storms and hurricanes. Belize's growing tourism industry accounts for about 23% of the GDP (based on 2002 figures) with a total annual value of US$194 million. The fishing industry remains an important contributor with export earnings of US$67.16 million in 2005 (3.8% of GDP in 2005). Based on Caribbean averages, the value of shoreline protection in Belize is roughly estimated at US$35 to US$100 million per annum. The estimated total value of goods and services provided is roughly US$150 million per year (based on Belize's proportion of Caribbean reefs as calculated by Reefs at Risk Caribbean). A full economic evaluation of Belize's reefs will be conducted in 2007 by World Resources Institute (WRI) and WWF.

The reefs in Belize have declined during the last decade from a generally healthy condition to currently having lower coral and fish abundances than other areas of the Caribbean. There are now many marine conservation and monitoring programs in Belize, and 18 MPAs encompassing about 250,000 ha. Furthermore, the increased global significance of Belize and the wider Mesoamerican Reef is demonstrated by the establishment of regionally focused projects and initiatives, including: the Mesoamerican Barrier Reef System Project, a Global Environment Facility (GEF)/World Bank project that is now poised to enter its second 5-year phase; WWF's Mesoamerican Reef Ecoregional Program; the Nature Conservancy's Mesoamerican Reef Program; the Wildlife Conservation Society's marine program in Belize; the International Coral Reef Action Network (ICRAN) Mesoamerican Reef Alliance; and the Healthy Mesoamerican Reef Ecosystem Initiative. Since late 2003, however, national reef management efforts in Belize have suffered from the loss of funding and capacity within the Belize Coastal Zone Management Authority and Institute.

## *Mexico*

Reefs border the state of Quintana Roo on the east coast of the Yucatan Peninsula. The coastline is noted for its lack of surface rivers, although there are abundant subsurface flows within the limestone terrain. Coral reefs along the Mexican Caribbean coast consist of partially submerged

fringing reefs on the northern Yucatan coast and fully developed fringing reefs, with well developed and extensive spur and groove systems from Xcalak to Belize. The presence of the Xcalak trench has fostered the development of twin reef crests and fore-reefs in this area. A wide carbonate shelf, influence from coastal upwelling, and scattered patch reefs characterize the northern section. Offshore are three banks/islands: Arrowsmith Bank, along a submerged platform (ranging from 25-400 m in depth) with patch reefs on its southern section; Cozumel Island, with reefs on the windward and leeward side; and the Banco Chinchorro atoll with highly developed reefs on the windward side and well developed spur and groove systems.

**Status of coral reefs prior to 2005:** Puerto Morelos and nearby reefs suffered significant coral mortality from Hurricane Gilbert (1988) and the mass bleaching in 1995. Unlike the Belize reefs, the 1998 mass bleaching and Hurricane Mitch did not cause widespread coral mortality along the Yucatan coast. Patch reefs at Isla Mujeres and Cancun suffered some mechanical damage and fragmentation from Hurricane Ivan in 2004.

These reefs have suffered from intense fishing activities since the 1960s and increasing pressure from tourism since the mid 1970s. Reef patches at Punta Nizuc and El Garrafon at Isla Mujeres have already been affected by tourism-related activities and the damage appears to be spreading elsewhere to Akumal, Puerto Morelos, Mahahual and Cozumel. Shallow reefs at Cancun, Sian Ka'an and Chinchorro have been affected by boat-related damage. The reefs just off the northern tip of the Yucatan Peninsula and immediately westward (Punta Mosquito, Boca Nueva, Piedra Corrida) have very little (<2%) live hard coral cover.

**Effects of the 2005 Bleaching Event:** Coral bleaching was observed on Mahahual and Sian Ka'an reefs in late July by the Amigos de Sian Ka'an (Global Vision International) routine monitoring program. Although some bleaching was evident in almost twice as many colonies at Sian Ka'an compared with Mahahual, the number of colonies that were completely bleached at each site was low. Significant bleaching was observed during October by the Mesoamerican Barrier Reef System Project, with greater than 40% of colonies assessed on Xcalak reefs exhibiting some bleaching.

***There was significant coral bleaching along the Yucatan coast of Mexico in 2005, but subsequent mortality was low (from MBRS Synoptic Monitoring Program, Xcalak; Amigos de Sian Ka'an-Global Vision International Monitoring Program, Sian Ka'an; and UQROO, Mahahual).***

| Location | Monitoring Timeframe (n = number of colonies assessed) | Colonies Affected by Bleaching (%) |
|---|---|---|
| Mexico (Mahahual) | July-September (n = 1532) | 23 |
| Mexico (Sian Ka'an) | August-September (n = 825) | 42 |
| Mexico (Xcalak) | October (n = 248) | 45 |

**Impacts of Hurricanes in 2005:** The Yucatan Peninsula is frequently affected by storms and hurricanes. In the 20th century alone, 58 hurricanes (of varied strength) have passed along Mexico's Gulf and Caribbean coasts. These storms often resulted in significant reef damage from waves and the re-suspension of sediments. The reefs of Mexico suffered direct hurricane impacts

in 2005, with hurricanes Emily (17 July) and Wilma (21 October) hitting Cozumel, causing damage mainly to shallow coral reefs (< 8 m depth), including sponges and gorgonians.

There was a dramatic increase in bare rock substrata along Cozumel's west coast after hurricanes Emily and Wilma (July and October, 2005) increasing from 10% to 40% coverage, as a result of the removal of sand and benthic biota. Conversely, hard coral cover decreased after each hurricane from 24% to 17% and eventually down to 10%. After Emily, piles of broken coral colonies were seen scattered around the reefs, while after Wilma the coral rubble was removed from the reef areas, probably because of the long duration and high intensity of that hurricane.

Reefs off the northern Yucatan tip were also affected. Deeper reefs sustained little damage, with some sedimentation increases down to 15-20 m; although the sediments were usually removed by currents within a few weeks. In Cancún and Puerto Morelos, impacts were mainly on the reef crest and primarily to branching, boulder and mound hard corals. Restoration of fragmented pieces was carried out shortly after for reefs within Cancún and Puerto Morelos Marine Parks.

**Status of reefs in 2006:** Minimal bleaching was observed on Mahahual and Sian Ka'an reefs in 2006; about 5-6% of 1858 assessed colonies were affected. The reefs seem to have recovered from the 2005 bleaching event, and the disease and recent mortality values were very low; coral cover recorded at 121 sites (n = 3113 colonies) along the Mexican Caribbean (Amigos de Sian Ka'an and The Nature Conservancy /WWF 2006 Rapid Reef Assessment) was unusually low. However, this may be related to the representative sampling design, which included many marginal reef sites and only a few sites with coral cover values around 20-30%.

***Low levels of recently diseased or dead corals were assessed on the Quintana Roo reefs (from Isla Contoy to Xcalak, including Cozumel and Banco Chinchorro) in September 2005 – December 2006 during the Amigos de Sian Ka'an and TNC/WWF Rapid Reef Assessment.***

| Reef Habitat (n = number of colonies assessed) | Coral Cover (%) | Colonies Affected by Disease (%) | Recent Colony Mortality (%) |
|---|---|---|---|
| Fore-reef (n = 1886 colonies) | 8 | 0.9 | 1 |
| Reef flat (inter-tidal (n = 704 colonies) | 6 | 0.2 | 0.8 |
| Patch reef & others (n = 523 colonies) | 9 | 1.0 | 0.9 |

Sand beaches from Punta Cancun to Punta Nizuc were lost as a result of Hurricane Wilma in late 2005. In February 2006, the municipality implemented a project to restore the beaches; however, this project resulted in the die-off of 10 species of hard corals in Punta Nizuc owing to erosion of the reclaimed beach areas.

**Socioeconomic impacts and management responses:** Mexico's Caribbean reefs function as critical fishing grounds for communities along the Quintana Roo coast. These reefs are also the center of tourism activities; 8 MPAs have been established to protect reefs, and there are new MPAs proposed, including Playa del Carmen, Akumal, Puerto Aventuras and Tulum and Cozumel.

## *Guatemala*

Guatemala has limited reef development along the Caribbean coast, with the best known being the carbonated banks of Punta Manabique, which are dominated by sediment resistant corals species such as *Siderastrea siderea*, and the isolated coral communities and diminutive patch reefs of the Gulf of Honduras.

**Status of coral reefs prior to 2005:** There has been significant degradation of Guatemalan reefs because of the combined effects of hurricanes, flooding and associated sedimentation, and increases in sea surface temperature. The major threat to the reefs of Punta Manabique is sedimentation resulting from deforestation and soil erosion, which bring elevated sediment loads and contaminants onto reefs, causing increased coral mortality and algal proliferation. A study conducted in 2000, recorded live coral cover of less than 9% and non-coralline macroalgal cover of 65%.

**Effects of the 2005 Bleaching Event:** The only monitoring data on the bleaching in 2005 were obtained in late November at Punta Manabique with 16% of 31 colonies being affected (data from the Mesoamerican Barrier Reef System Project, Synoptic Monitoring Program).

**Impacts of Hurricanes in 2005:** Like Belize, the reefs of Guatemala were not directly affected by the storms or hurricanes of 2005. However, increased sediment runoff associated with the torrential rains generated during the passage of Hurricane Beta near Honduras is likely to have had an impact.

**Status of reefs in 2006:** Based on a rapid assessment of 5 reef sites (145 colonies) in August 2006, the 2005 bleaching event did not appear to have made a significant impact on Guatemala's bank reefs. Recent mortality was less than 1%, while disease infestation was somewhat higher at 11%. Mean live coral cover was low overall, averaging 8.5% and similar to that found in 2000. Mean fleshy macroalgae cover was recorded at 7.3% and turf at 23.4%.

**Socioeconomic impacts and management responses:** River inputs of nutrients and sediments resulting from land erosion impede reef growth. Those reefs that do exist are subjected to intense fishing pressure and currently have minimal fish populations. Guatemalan fishermen are increasing fishing pressures on the southern reefs of Belize.

## *Honduras*

While only small coral reef communities occur on the Caribbean coast of Honduras (Puerto Cortes, La Ceiba and Tujillo), there are well developed reefs on the outer Bay Islands (Utila, Morat, Barbareta, Roatàn, and Guanaja) and Cayos Cochinos. Well developed fringing and patch reefs are also found eastward (Misquitu Cays and Banks) and further northeast of the mainland (Swan Island). The edge of the Honduran continental shelf is almost vertical and has high coral cover.

**Status of coral reefs prior to 2005:** *The Global Coral Reef Atlas* reports average coral cover of 28% on the fore-reefs of the Bay Islands in the early 1990s. A 2001 WWF survey found average fore-reef live coral cover in Roatan/Barbaretta of 12%, with 8% in Cayos Cochinos, somewhat lower than the MAR-wide average of 15%. This same study found the prevalence of

coral disease in Honduras was slightly higher than the MAR-wide average (4.4% versus 3.4%) as was recent partial mortality (1.8% versus 1.6%). The reefs of the Bay Islands were considered to be relatively healthy prior to the 1998 mass bleaching event and Hurricane Mitch. These events resulted in 18% coral mortality on shallow reefs and 14% on deep reefs, along with a high prevalence of coral diseases. Hurricane Mitch contributed to this damage via mechanical damage from waves and coral smothering from sediment-laden runoff. Hurricane Iris in 2001 also affected Honduran reefs through increased river runoff and sedimentation.

**Effects of the 2005 Bleaching Event:** No data on the extent of the 2005 bleaching event (during the event) were available to the authors. The MBRS Synoptic Monitoring Program reports data from one site (Utila) collected in February 2005 (before the bleaching season). The reef status indicators for 2006 show some signs of elevated disease and bleaching. However, without any data on the extent of bleaching during the 2005 bleaching season, no potential relationships can be considered.

**Impacts of Hurricanes in 2005:** The 2005 tropical storms probably reduced the temperature of overlying reef waters and decreased the severity of bleaching and associated mortality. However, some reefs may have been smothered by sediment plumes from runoff and mudslides originating from torrential rains, especially from those generated during the passage of Hurricane Beta.

**Status of reefs in 2006:** An assessment of 61 reef sites (1363 colonies) from early June to mid-August 2006 revealed some bleaching, but less than 11%. The prevalence of coral disease was rather high among the reef flat and patch reef sites, but recent mortality was less than 5%. Live coral cover was relatively low, averaging between 10% and 15%. Mean fleshy macroalgae cover was recorded at 15% on fore-reefs, 16% on patch reefs and 19% on reef flats.

***There were moderate levels of coral bleaching, disease and mortality on the reefs of Honduras, predominantly resulting from the effects of hurricanes and to a lesser extent to increased water temperatures.***

| Reef Habitat assessed (n = number of colonies) | Colonies Affected by Bleaching (%) | Colonies Affected by Disease (%) | Recent Colony Mortality (%) |
|---|---|---|---|
| Reef flat (n = 373 colonies) | 11 | 14 | 4 |
| Fore-reef (n = 868 colonies) | 4 | 9 | 2 |
| Patch reef (n = 122 colonies) | 8 | 18 | 2 |

**Socioeconomic impacts and management responses:** The Bay Islands' reefs are the center for both tourism and fishing activities. Fringing reefs have been heavily exploited and the continued high demand for fish products has resulted in a relocation of fishing efforts to the more remote offshore reef banks. The Reefs at Risk project has estimated that 34% of Honduran reefs are threatened by anthropogenic stress, with the most pervasive being over-fishing (30%), coastal developments (25%), sedimentation from agricultural practices (10%) and marine based activities (6%). Enforcement of regulations aimed at protecting coral reefs and resource management is generally weak. Twelve MPAs have been developed, although a number of these are not legally declared or fully managed.

## Mesoamerican Reef Management and Conservation Efforts

A number of regional conservation and management initiatives are being implemented to monitor, track, and promote the sustainable use and conservation of the MAR including: the Healthy Mesoamerican Reef Ecosystem Initiative; the GEF/World Bank Mesoamerica Barrier Reef System Project; The Nature Conservancy Mesoamerica Reef Program; and the WWF Mesoamerican Reef Ecoregional Program, and the ICRAN Mesoamerican Reef Alliance. There is relatively good collaboration among these and the many local conservation programs aimed at reducing threats to reefs and improving reef management. In 2006, these regional groups joined forces with numerous local partner organizations to conduct the largest regional assessment of reef health ever conducted in the region. More than 320 reef sites were surveyed in Mexico, Belize, Guatemala and Honduras using the 2006 AGRRA (plus) protocol. These data are being used for regional, national and local planning, management, and reporting efforts by the partner organizations.

If large-scale bleaching events continue to increase in frequency and severity, the coral reefs are likely to suffer further degradation. Whether these reefs will be able to maintain their ecological integrity will depend largely on their resilience, as well as the effectiveness of management efforts aimed at reducing other anthropogenic stress. Current and proposed bleaching management actions within the MAR are focused on identifying and protecting reefs that may be naturally more resistant to bleaching, have higher bleaching tolerance, and/or a greater ability to recover from bleaching (resilience), as well as traditional approaches for reducing or eliminating other anthropogenic stresses.

The areas that appear to be intrinsically resistant or resilient to bleaching can then be integrated within a regional MPA, which includes about 64 marine and coastal protected areas. These more resistant or resilient reefs may exhibit environmental (e.g. strong current or wave exposure, shading, etc.) or intrinsic factors (e.g. abundant heat-tolerant species) that help protect them from rising sea temperatures and allow them to potentially 'reseed' other reefs that are more affected by future bleaching events.

While traditional reef management efforts have focused on the management of MPAs, recent emphasis has been on the development of private sector partnerships aimed at promoting better management practices to reduce environmental impacts, particularly in tourism, fishing, agriculture and aquaculture industries.

## Conclusions and Recommendations

Although the number and scope of marine conservation programs has grown tremendously in the last decade, continued degradation from mass coral bleaching and hurricanes has the potential to prevent reef recovery and even further accelerate reef damage. Climate-related stressors, in combination with many increasing chronic anthropogenic stressors, could lead to unprecedented collapse of the Mesoamerican reef ecosystem and the many livelihoods that depend upon it. It has been suggested that the degree to which mass bleaching will affect coral reefs over the long term may depend on the extent of additional environmental stressors (over-fishing, pollution, habitat destruction), the degree to which corals are able to acclimate or adapt to the rising temperatures, the frequency of these disturbances, and whether these repeated disturbances compound each other. The MAR reef management community needs to increase

the understanding of how different coral reefs will respond to continued ocean warming. Such information can be incorporated into preventative strategies and aid in adaptive responses and monitoring.

There was no organized and immediate bleaching monitoring response to the 2005 bleaching event. Most of the planned monitoring efforts (MBRS Synoptic Monitoring) occurred before the main effects of the bleaching event in late October. There is an urgent need to establish a MAR 'Bleach Watch' rapid response program.

A Coral Bleach Watch Rapid Response Contingency Plan for the MAR would: i) incorporate the NOAA 'HotSpot' system of forecasting bleaching events into the local managers networks; ii) make available early warnings of any major bleaching episode; iii) measure the spatial extent and severity of large scale bleaching events through all phases of the event; iv) assess ecological impacts of such events (8 – 10 months later); v) involve stakeholders in reef monitoring activities; vi) enhance communication and awareness on bleaching and the effects of climate change on the MAR; and vii) provide critical information necessary to evaluate implications of bleaching events for management, policies and strategies.

Finally, managers need to continue to reinforce efforts to improve watershed management and enforcement of fishing, tourism and coastal development regulations, to reduce the stress on coral reefs to provide them with a better chance to recover from bleaching events.

The *Healthy Mesoamerican Reef Ecosystem Initiative* is a multi-institutional effort that generates user-friendly tools to measure the health of the Mesoamerican Reef Ecosystem, and delivers scientifically credible reports to improve decision-making that effectively sustain social and ecosystem well-being. The Initiative focuses on three over-arching goals:

- Promoting the adoption and application of **eco-health and socioeconomic indicators** by managers, policy makers and other leaders concerned with the integrity of the Mesoamerican Reef Ecosystem;
- Providing **standardized analyses** of reliable scientific data to improve reef ecosystem management; and
- Serving as a **clearing house** for information and networking among science and conservation partners to improve environmental management and stewardship of reefs.

Annual Eco-health Report Cards and triennial State of the Reef Reports will be a mainstay of this growing Initiative, which recently published the seminal publication, *Guide to Indicators of Reef Health and Social Well-being in the Mesoamerican Reef Region*. This publication and other information on the Initiative are available from www.healthyreefs.org.

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