7. The Effects of Coral Bleaching in the Northern Caribbean and Western Atlantic

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Summary

- The effects of bleaching and hurricanes on coral reefs in 2005 varied across the region and within countries.
- Some countries experienced intense widespread coral bleaching down to 35 m, while the effects of increased water temperatures were moderate to low in others.
- Coral mortality rates were low on average; most corals recovered quickly when water temperatures dropped.
- Greater human and financial resources are needed to monitor and effectively combat the effects of natural disasters.
- Regular monitoring and analysis of data are essential components of sound management strategies for sustainable environmental management and economic growth.

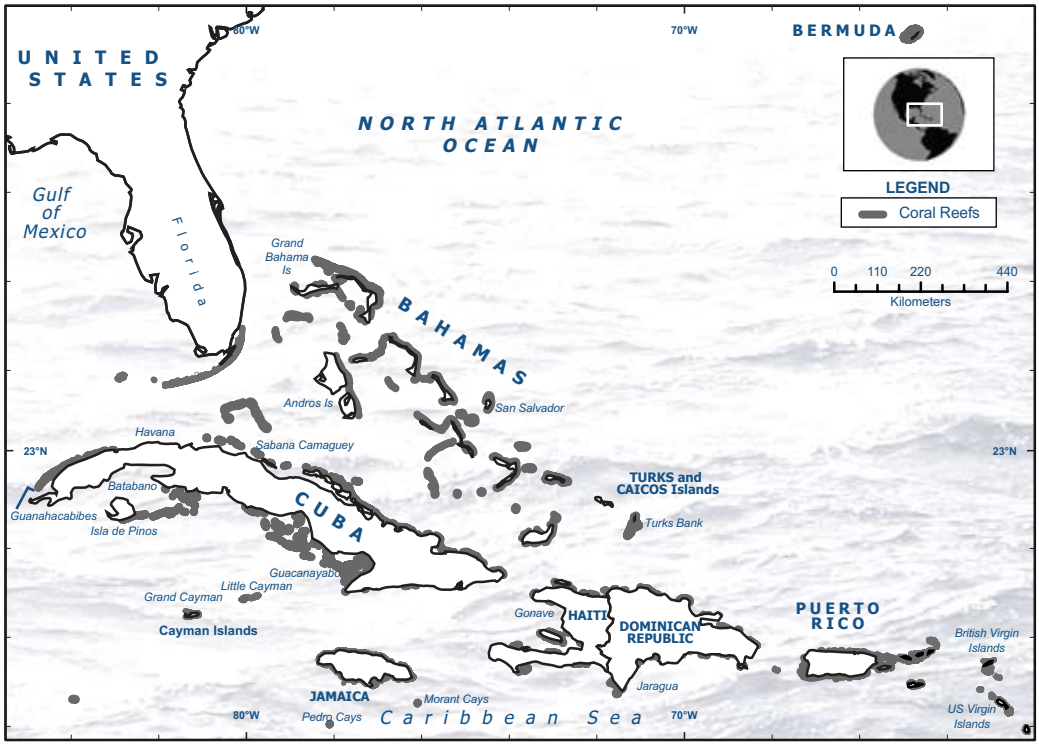
Introduction

Coral bleaching during the hot summer of 2005 hit the reefs of the Northern Caribbean (Bahamas, Bermuda, Cayman Islands, Cuba, Dominican Republic, Haiti, Jamaica, Turks and Caicos) just as they were recovering from many damaging stresses of the past 30 years. In the 1970s, the coral reefs generally had more than 50% coral cover, with large stands of branching corals; *Acropora palmata* on the reef crest, and *A. cervicornis* on the shallow fore-reef slopes. The first signs of over-fishing of groupers and large parrotfish were evident, but the reefs were predominantly healthy.

The Northern Caribbean reefs were degraded during the 1980s by outbreaks of coral diseases (especially white band disease of *Acropora*), mass mortality of the main algal grazer *Diadema*, nutrient and sediment pollution from activities on land, and severe coral bleaching and damaging hurricanes. Coral cover in most places dropped to 5-10%, and was replaced by fleshy and calcareous macro-algae, with cover often 50-80%. Since then, these Caribbean reefs have

been slowly recovering, however, coral cover was still low and the threats from increasing human populations and economic pressures continued to grow.

The first warning of problems came from NOAA in late May 2005 that indicated 'HotSpots' developing in the Northern Caribbean, especially around the Virgin Islands. These warnings alerted the scientists and NGOs in the region to examine their reefs in more detail. The results of subsequent surveys of bleaching and mortality in each country are summarized below.



Map of the Northern Caribbean region.

Ecological and Socioeconomic Impacts of Coral Bleaching and Hurricanes in 2005

Bahamas

Geographic Distribution and Extent of Coral Reefs: The Bahamas contain 13 major islands and more than 2000 smaller islands or cays, distributed over 260,000 km^2 on 2 large, shallow banks (Great Bahama Bank and Little Bahama Bank) separated by depths exceeding 4000 m. They are aligned northwest to southeast for more than 1400 km, from near Florida almost to Haiti. Coral reefs fringe most of the north and east windward coasts and bank edges and cover 1832 km^2 of the Great Bahama Bank and 324 km^2 of the Little Bahama Bank. Andros Island is the largest island with the third longest barrier reef system in the world (229 km). Reef development in the Bahamas is limited by hurricanes in exposed regions, cold winters in the northern Bahamas and by turbid, hypersaline waters on the leeward bank margins.

Status of coral reefs prior to 2005: Prior to 2005, live coral cover in the Bahamas was highly variable between sites, with cover ranging between 1% at Lindsay Reef at 4 m depth to 47% at Strip Reef at 10 m.

Impacts of Coral Bleaching in 2005: Reef Check conducted one survey at Turtle Rocks in August 2005 during the coral bleaching episode. This survey determined that live coral cover was 14%; 17% of coral colonies were affected by bleaching; and bleached colonies exhibited bleaching over 25-50% of their surface. No recently killed coral was recorded during the survey and a subsequent survey conducted in August 2006 recorded live hard coral cover of 18%, indicating that the 2005 bleaching event caused little or no coral mortality in the Bahamas.

Bermuda

Geographic Distribution and Extent of Coral Reefs: Bermuda is an isolated island chain 920 km off the coast of North Carolina on the Bermuda Platform. Together with the Challenger and Argus Banks, they occupy about 900 km^2. The fringing, bank-barrier and lagoonal patch reefs form the most northerly coral reef system in the Atlantic and are supported by warm water eddies from the nearby Gulf Stream. Coral diversity is, however, limited by cool winters.

Status of coral reefs prior to 2005: There has been little change in these coral reefs, which are the most northerly reefs of the region (Latitude 32°20'N), during the 10 years to 2005. Coral cover remained at 20% around the rim, 10-15% on lagoon patch reefs, and 45-50% on terrace reefs. There are healthy herbivorous fish populations, and the reefs escaped serious impacts caused by coral bleaching that damaged reefs to the south in 2005. A comparison with the first surveys 25 years ago illustrates the stability: hard coral cover on the terraces - 52.4% in 1981 vs 54.0% in 2005; and 22.5% in 1981 on outer rim coral-algal reefs vs 24% in 2005. Much of the stability on Bermudan reefs could be the result of a predominance of slow growing massive growth forms *(Diploria, Montastraea* and *Porites* species) and few branching and bleaching sensitive corals like *Acropora*.

Impacts of Coral Bleaching in 2005: Some coral bleaching was observed on Bermudan reefs in 1988, 1991, 1992, 1995, 1998 and 2003, however, only the 1988 and 2003 events were recorded in detail. In 2005, seawater temperatures peaked at 30.3°C in mid to late August at most locations, except at 10-15 m depth on the terrace reef sites, which peaked at 28.7°C in early September. All sites cooled with the passage of tropical storm Philippe. Thus, seawater temperatures during 2005 were not unusual compared with previous summers and no widespread bleaching or disease of corals was observed. Hard coral cover was 22.7% in 2005; the same as 2004 and a slight increase on the 14 year mean (20.8%). Black-band disease and white plague on *Diploria, Montastraea* and *Porites astreoides* are the most common diseases in Bermuda, and occur mostly on the outer rim and lagoonal patch reefs. Yellow blotch disease is also relatively common in *Montastraea franksii*.

Impacts of Hurricanes in 2005: In 2005, there were 3 tropical storms ('Franklin', 'Harvey' and 'Philippe') and 2 hurricanes ('Nate' and 'Wilma') near Bermuda. However, peak wind speeds did not exceed 90 km/h (i.e. generally less than regular winter storms). The major effects of these storms were to temporarily lower seawater temperatures by 1-2°C, with no significant damage to the coral reefs.

Cayman Islands

Geographic Distribution and Extent of Coral Reefs: The Cayman Islands contain 3 individual islands (Grand Cayman, Little Cayman and Cayman Brac) on the Cayman Ridge, which extends from southeast Cuba to the Bay of Honduras. They are flanked to the south by the 6000 m deep Cayman Trench. These low-lying limestone platforms with narrow island shelves support prolific coral reefs. There is little obvious human impact on the coral reefs surrounding Little Cayman, which is the smallest and least developed of the 3 Cayman Islands. Thus, Little Cayman could provide a reference site for coral research in the central Caribbean.

Status of coral reefs prior to 2005: On Grand Cayman, mean coral cover declined from 25.7% in 1997 to 15.4% in 2001, probably because of bleaching events, lethal coral diseases and algal overgrowth. Increases in the abundance of algae in coastal waters near the more populated parts of the islands appear to have resulted from nutrient pollution leaching from resorts and residential areas. Atlantic and Gulf Rapid Reef Assessment (AGRRA) surveys of 18 fore-reef sites around Little Cayman showed a major loss in coral cover of nearly 40% (declining from 26.3% to 15.8%) from 1999 to 2004. There has been no further decline since.

The reefs continue to support relatively diverse and abundant fish assemblages. Previous conservation regulations did not prevent over-fishing of high value species such as conch, lobster and grouper, and there was little protection of grouper spawning grounds and turtle nesting sites from coastal development. The relevant regulations have been recently amended.

Impacts of Coral Bleaching in 2005: In August 2005, corals at all sites around Little Cayman showed signs of bleaching and there were also colonies infected with coral disease at 6 of the 8 study sites. Coral cover ranged between 9% and 22% (avg. 12.9%), and the amount of bleached coral in 2005 was the highest ever recorded. *Dichocoenia stoksii* was totally bleached, and partial bleaching was recorded in most colonies of *Montastraea faveolata, M. annularis, M. franksii, Agaricia agaricites, Siderastrea siderea, Diploria strigosa*, and *Porites porites*. Live hard coral cover did not decline in 2006, indicating that most corals had recovered from bleaching stress and there was little coral mortality.

Five coral genera, *Montastraea*, *Agaricia, Diploria, Porites*, and *Siderastrea* dominate Cayman Island reefs, and comprise more than 90% of all corals found. Between 1999 and 2005, *Montastraea* decreased in density by 30% (from 46% to 32%), *Porites* increased by 50% (11.8% to 17.7%) and *Agaricia* rose by 15% (22% to 25.4%). Average mortality rose from 29.0% to 42.7% for *Montastraea*, which was much greater than the average for all genera over those years (23.4% to 28.3%). The main cause of *Montastraea* loss appears to be white plague disease; this is serious because the massive frame-builder *Montastraea* usually dominates fore-reef spur and groove formations in the Caribbean. Despite these declines, coral recruitment on Little Cayman reefs has not declined, which demonstrates that these reefs have the capacity to recover; offering some hope for the future.

Impacts of Hurricanes in 2005: Several hurricanes passed within 150 km of Little Cayman in the last 40 years: 'Allen' 1980; 'Gilbert' 1988; 'Mitch' 1998; and 'Ivan' 2004. Hurricane 'Dennis' in 2005 passed between Little Cayman and Cuba and caused minimal damage. However, Hurricane 'Ivan' passed south of Little Cayman and made a direct landfall on Grand Cayman

on 12 September, 2004. Large masses of sand piled up on back-reef corals and in lagoons on the south side of Little Cayman. By November 2004, there was little obvious damage on the fore-reef slopes.

Cuba

Geographic Distribution and Extent of Coral Reefs: The main island of Cuba, the Isle of Youth and 4195 cays and islets are distributed over 110,860 km^2. The islands are at the entrance of the Gulf of Mexico, between the Atlantic Ocean and the Caribbean Sea. Numerous fringing and bank-barrier reefs border more than 98% of Cuba's 3200 km shelf margin, although more than 50% are separated from the mainland by cays or by broad, shallow lagoons with many patch reefs. This separation has provided the outer reefs with protection from anthropogenic influences, except for fishing and, in some places, tourist diving. Reef crests in Cuba tend to be more abundant at the edge of the 4 broad sections of the Cuban shelf: the Golfo de Guanahacabibes (Northwest Cuba); Archipiélago Sabana-Camagüey (central north); Golfo de Ana María-Guacanayabo (southeast); and Golfo de Batabanó (southwest). The narrow shelf of the Northeast also has well developed reef crests. Inshore patch reefs are dispersed on the northwest (Golfo of Guanahacabibes), southwest (Golfo de Batabanó) and southeast (Golfo de Ana María-Guacanayabo) where there are unique reefs on muddy substrata. There are 2 barrier reefs: Archipiélago Los Colorados (NW Cuba); and Archipiélago Jardines de la Reina.

Status of coral reefs prior to 2005: Live coral cover averaged 21% on Cuban reef crests and shallow reefs and 18% on fore-reefs. The corals have been stressed by organic and chemical pollution around populated areas, diseases, the *Diadema* die-off and resultant competition with algae, and some earlier bleaching. The reefs were recovering from these stresses until 2005, when bleaching and hurricanes resulted in coral mortality.

Impacts of Coral Bleaching in 2005: In summer 2005, coral bleaching was widespread and intense. Assessments conducted by the Early Warning Coral Reef Volunteer Monitoring Network showed that coral bleaching around Cuba varied from 1-10% to 75-100% of colonies, predominantly between categories 50-75% and 75-100% (at 89% of reported sites). Only one site, Punta Francés (SW of Isla de la Juventud), suffered lower intensity bleaching (1-30%). Most anecdotal reports refer to a high degree of recovery by May 2006.

Impacts of Coral Bleaching in 2006: Coral bleaching in 2006 was widespread but with varying intensities, increasing after mid-September. The volunteer monitoring network reported that coral bleaching did not exceed 10% and was generally not higher than 5%. María la Gorda was an exception with 10-30% colonies bleached at 20-25 m depth, but much less in shallower areas. Warming increased in mid-September, and moderate bleaching (10-30%) was recorded at Havana City and Jardines de la Reina Archipelago, and intense bleaching (75-100%) at Punta Francés (SW Isla de la Juventud). Bleaching was low in the Sabana-Camagüey Archipelago and Bahía de Cochinos. No information is available from Santiago de Cuba and Granma provinces, to the east.

Impacts of Hurricanes in 2005: Hurricane Denis, which made landfall in July, 2005 near Punta del Inglés, caused only minor damage at Cabo Cruz and Pilón (Nacional Park Desembarco del Granma, south-eastern Cuba), despite wind velocities reaching 310 km/h.

The reef was not exposed to the direct force of the wind and waves and only a few colonies of *Acropora palmata* (<10%) were fragmented. However, at Pilón (to the east), the impact was much greater because of its windward position. Many sponges and gorgonians were damaged, corals suffered fewer losses and sand was removed from the beaches.

In October, 2005, Hurricane Wilma produced wind velocities of 70-90 km/h, with gusts to 110-120 km/h, and 4-5 m waves at La Bajada-Uvero Quemado-María la Gorda (Ensenada de Corrientes, western Cuba). Many hard coral colonies and gorgonians in shallow water (<6 m) were removed. Damage was significantly less in the spur and groove zone (10-12 m), with only a few hard coral colonies fragmented or overturned. The sea-urchin *Diadema antillarum* disappeared in places where it had been abundant. Approximately 10-15% of hard coral colonies were bleached after the hurricane.

Wilma caused damage to coral reefs near Havana City, down to depths of 15 m; many sponges and gorgonians were deposited onshore and a few *Acropora palmata* colonies were overturned or fragmented. Massive corals were less affected; but the recovering *Diadema* population was devastated. However, seagrass beds and mangroves behind reef crests suffered only minor damage.

Socioeconomic impacts and management responses: In spite of current economical constraints, Cuba is still devoting much effort to coral reef assessment, research and monitoring, through different research projects and scientific-technical services. Since 1995, tertiary treatment for sewage generated by all tourist developments has been compulsory. These requirements are implemented and enforced through recently established EIA and licensing processes (Resolution No. 168/95 of Environmental Impact Assessment). Recent water quality assessments show that pollution from tourist resorts is negligible. In addition, destruction of coastal areas has been prohibited through the establishment Decree-Law 212 (year 2000) of Coastal Zone Management. Since then, there has been no additional anthropogenic destruction of the largely undisturbed mangroves.

Dominican Republic

Geographic Distribution and Extent of Coral Reefs: The Dominican Republic has 1576 km of coast including the islands of Saona, Catalina, Beata and the Cayos Siete Hermanos, with coral reefs along 166 km and mangroves along 377 km. The longest reef (64.2 km) is to the northwest of Montecristi. Most of these are fringing reefs, but there are also 2 barrier reefs, numerous patch reefs, and 4 large offshore banks. On the east and northwest coasts, there are broad coastal shallow platforms with barrier reefs. In most other places, high turbidity prevents reefs from forming.

Status of coral reefs prior to 2005: CARICOMP data show that coral cover rose from 8.2% in 2000 to 11.5% in 2001 and Reef Check surveys showed mean coral cover of 19.4% at Bayahibe in 2004.

Impacts of Coral Bleaching in 2005: Reef Check surveys recorded significant bleaching at all sites surveyed during September/October 2005. Bleaching affected as much as 68% of live corals, with the majority of colonies being entirely bleached. The average mortality was 11% across all sites surveyed, but there was great variation between sites with mortality ranging

between 0% and 38%. Significant bleaching also occurred between late May and the end of August 2006, with bleaching affecting between 66% and 85% of living coral cover and individual colonies exhibiting bleaching over 50-95% of their surface areas.

Jamaica

Geographic Distribution and Extent of Coral Reefs: Jamaica is the 3rd largest Caribbean island; 230 km long by 80 km wide with 891 km of coastline and a coral reef area of 1240 km^2. Well developed fringing reefs occur along most of the north and east coasts, while patchy fringing reefs grow on the broader shelf of the south coast. Reefs and corals also grow on the neighboring banks of the Pedro Cays, 70 km to the south, and the Morant Cays, 50 km to the southwest.

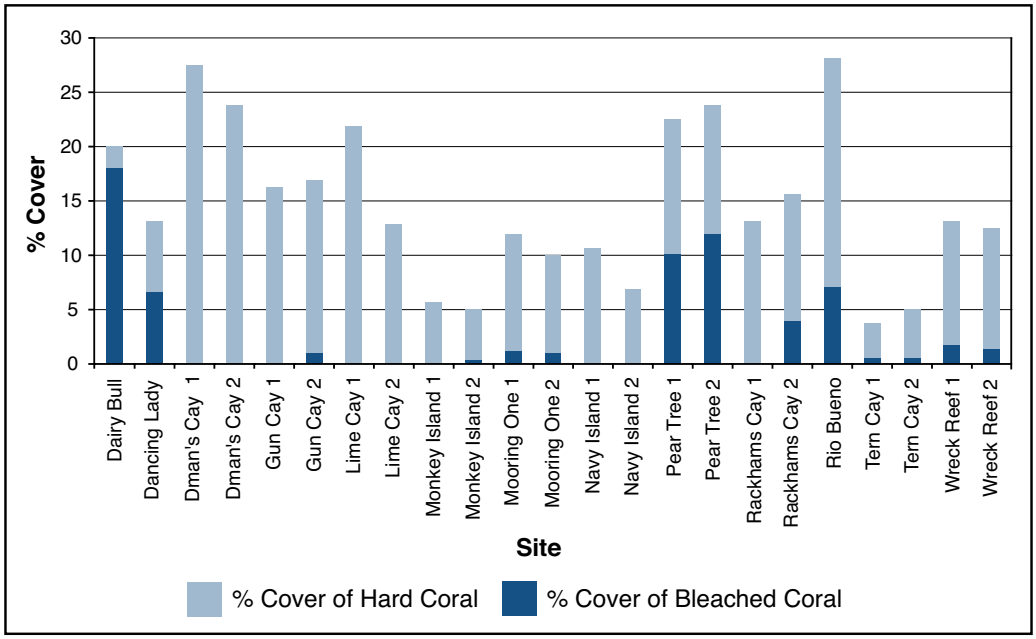
Status of coral reefs prior to 2005: Hard coral cover declined from 50% in the 1970s to less than 5% by the early 1990s as a result of hurricanes, *Diadema* die-off, coral diseases, and over-fishing. Coral cover has risen to 10-15% recently, with some sites having coral cover of 34-46%. Fish populations in Jamaica have been declining for decades because of poor fishing practices. Reef Check surveys at 35 sites between 2001 and 2006 reported an average density of 9.8 fish per 100 m^2.

Impacts of Coral Bleaching in 2005: Between August and October 2005, there were prolonged high sea surface temperatures around Jamaica and nearby countries, with 5 to 6 weeks of greater than normal temperatures, which resulted in widespread bleaching. This was first observed on the north coast from late August to early September and on the south coast in late September to early October. Corals started recovering as early as February/March when sea temperatures began to cool.

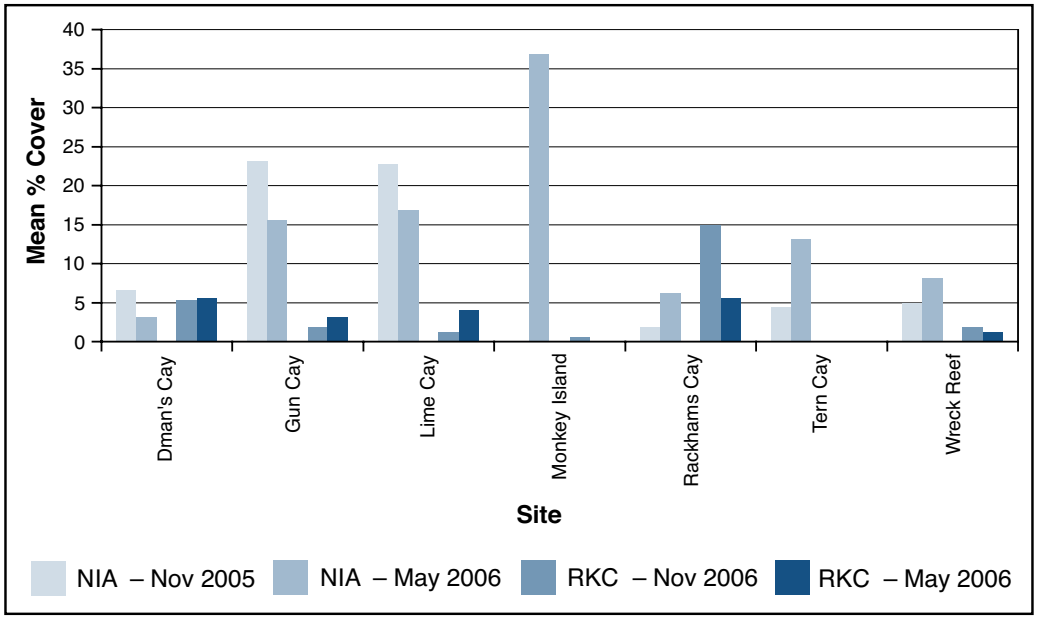
Bleaching was assessed 26 times at 16 sites. Variation in the proportion of corals bleached ranged from 10% to 95%, with *Montastraea annularis, M. faveolata, M. cavernosa, Siderastrea siderea, Diploria strigosa, Agaricia* spp.*, Millepora complanata* and *Porites porites* being most commonly affected. Within five months, about 50% of the bleached corals had recovered. There were however, increases in recently killed coral and fleshy algae, which usually indicate nutrient pollution.

In September 2006, black-band and white plague diseases were noted in the Port Royal Cays, especially Lime Cay and South-east Cay. White plague has been the most prevalent disease since January 2006, affecting the massive corals *Siderastrea, Montastraea*, and *Diploria* species.

Impacts of Hurricanes in 2005: Major hurricanes that have damaged Jamaica's reefs include 'Allen' in 1980, 'Gilbert' in 1988 and 'Ivan' in 2004. The hurricanes in 2004 and 2005 passed to the south of Jamaica causing most damage to south coast reefs. Hurricane Ivan passed parallel to the south coast in September 2004 causing damage to Port Royal and Portland Bight Cays, with large numbers of fractured and killed branching corals in shallow water (2-8 m). Other nearby corals were turned over, relocated, abraded and bleached. Some survived virtually undamaged or with only partial mortality. The lesions caused during the hurricane were quickly being overgrown by fast growing opportunistic algae; however, by February, 2005,



Live hard coral cover (light bars) ranged from 3.1% to 28.1% (average 13.4%). At some sites on Lime Cay, Drunkenman's Cay and Dairy Bull, more than 80% of the coral community bleached (dark bars).



Comparison of the percent cover of nutrient indicating algae (NIA) and recently killed coral (RKC) recorded during surveys in November 2005 and May 2006.

some of the corals displayed evidence of recovery and growth. In 2005, Hurricanes 'Dennis', 'Emily' and 'Wilma' passed close to the island bringing heavy rainfall and wind. Although the island was not affected directly by either of these systems, the southern parishes and the western town of Negril were hit by storm surge that toppled some corals.

Mangroves and seagrasses: The government, through the National Environment and Planning Agency (NEPA), has embarked on a process that will eventually lead to a no net loss policy for mangroves and seagrasses. Where development will result in loss or destruction, it is required that there is relocation/rehabilitation of an area roughly 120% the size that is lost or damaged.

Socioeconomic impacts and management responses: It is expected that the impacts of the damage associated with these events will ripple throughout the fabric of the socioeconomic environment in Jamaica as they have undoubtedly contributed to the continued decline in the landed fisheries resources of the island. Management responses have included cancelling the bird shooting season after hurricane Ivan to allow time for populations to recover (inclusive of mangrove areas).

NEPA has implemented a stricter permit and licensing system for activities that may damage coral reefs, and also ensured that assessments are conducted to feed into annual reports on resource status, with recommendations for management and improvement. A defined government policy on wetlands (inclusive of coral reefs, mangroves and seagrasses) is being planned.

The Government has implemented programs to increase the number of monitoring sites and the frequency of monitoring undertaken. This is facilitated by the University of the West Indies and the Jamaica Coral Reef Monitoring Network.

In an effort to improve conservation efforts by the Government and the general public, the importance of all coastal ecosystems is continually being emphasized by demonstrating the economic losses that occur as a direct result of ecosystem degradation.

Turks and Caicos Islands

Geographic Distribution and Extent of Coral Reefs: There are 8 low-lying limestone islands and 40 small sand cays distributed over 1736 km^2 in the Turks and Caicos, which is on an extension of the southeastern Bahamas Platform. All the islands and cays are fringed by narrow, discontinuous, shelf-edge reefs dominated by corals, algae and gorgonians growing down to 40 m, on hard substrata.

Status of coral reefs prior to 2005: Reef condition across the islands was quite similar, although human pressures from fishing, boat grounding, diving/snorkeling, sediments and nutrient flows from coastal development, varied between islands. Live coral cover on Providenciales ranged from 6–36%, with extremely low macro-algal cover. The near shore patch reefs had many isolated coral heads of *Montastraea* and *Diploria*, and a high cover of gorgonians. *Montastraea, Siderastrea* and *Porites* were the dominant corals on South Caicos. The cover of macro-algae at South Caicos was generally higher and this is probably related to

greater fishing activity and localized eutrophication. The Grand Turk reefs were generally in good condition, with 24% average coral cover (range 17-33%) and high coral diversity that was dominated by *Montastraea annularis, M. cavernosa, Siderastrea siderea* and *Agaricia agaricites*, with many gorgonians and low algal cover (1-20%). However, the average coral cover at 5 major dive sites decreased from 32.4% in 1995 to 21.9% in 2004.

There were active domestic and export fisheries, especially for queen conch *(Strombus gigas)*, spiny lobster *(Panulirus argus)*, grouper, hogfish and snappers. Herbivores, such as parrotfish and surgeonfish, are usually not kept. Most fishing is done with hand lines but there were a few traps. Generally, fishing pressure was relatively low and fish communities were relatively intact on both the Turks and Caicos Banks, with potential yields assessed by AGRRA of 70–140 kg per km^2 with an average fish density of 2-14 fish per 100 m^2 for selected families (Pomacanthidae, Cheatodontidae, Balistidae, Acanthuridae, Haemulidae, Lutjanidae, Serranidae and Scaridae). Fishermen have reported little change in the past 5 years.

Impacts of Coral Bleaching in 2005: The first coral bleaching occurred on South Caicos between September and December 2005. Of 166 coral colonies at The Warhead, The Fishbowl and Tuckers Reefs, only 3 colonies (1 *Montastraea annularis* and 2 *Agaricia agaricites*) were completely bleached, and 87 colonies showed partial bleaching. In shallow water (<6 m), bleaching was seen in colonies of *Acropora cervicornis M. annularis, Stephanocoenia intersepta, A. agaricites, Montastraea cavernosa* and *Diploria labyrinthiformis*. At 10 m, colonies of *M. annularis, A. agaricites, Porites porites*, and *Porites astreoides* were bleached, while at 15 m there was bleaching in colonies of *M. annularis, A. agaricites* and *Siderastrea siderea*.

Coral colonies appeared to be recovering in December 2006, with little evidence of coral mortality. The Department for Environmental and Coastal Resources initiated coral bleaching surveys to follow progress as some black-band disease was evident on South Caicos, similar to previous years.

Conclusions and Recommendations

The increased frequency and incidence of intense hurricanes coupled with abnormal rising sea temperatures are now common annual dilemmas facing the Node countries. Coastal ecosystems are now stressed more frequently and as such have less time to recover before the next catastrophe.

All countries continue to face similar problems of infrastructure related to funding and human resources. In the face of these difficulties, they are still committed to achieving environmental health by implementing monitoring and conservation exercises. All are still trying to achieve a balance between conservation and economic growth and have employed several measures to achieve this, such as integrated coastal zone management. The process is still being hampered in some cases by outdated laws and fines, and because some governments are still sacrificing the environment in their bid to achieve economic growth. To halt the continued degradation of the region's natural resources, outdated legislation and fines need to be revised. More monitoring is also required, but to achieve this, the lack of trained personnel available to conduct assessments needs to be addressed.

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