17. Status of Coral Reefs in the Northern Caribbean and Western Atlantic GCRMN Node in 2008

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Abstract

- The Node is a mix of islands. Some with well developed economies like Bermuda, Cayman Islands and Turks and Caicos, where reef conservation is strong or improving; and developing or exceedingly poor economies (like Haiti) where reef monitoring and conservation needs to expand;
- All northern Caribbean coral reefs except Bermuda were affected during the 2005 major coral bleaching and hurricane year in 2005;
- Reefs were severely damaged, e.g. 34% of corals around Jamaica bleached and half of these died; there is evidence of coral resilience on the north coast;
- The Bahamas, Dominican Republic and Jamaica signed the Caribbean Challenge to conserve 20% of their coastal (including coral reef) resources by 2010, along with other Caribbean states; and
- The invasive Indo-Pacific lionfish (*Pterois volitans*) now occurs in several countries including Bermuda, Cuba, Jamaica, and Turks and Caicos and poses a significant risk to native species.

Introduction

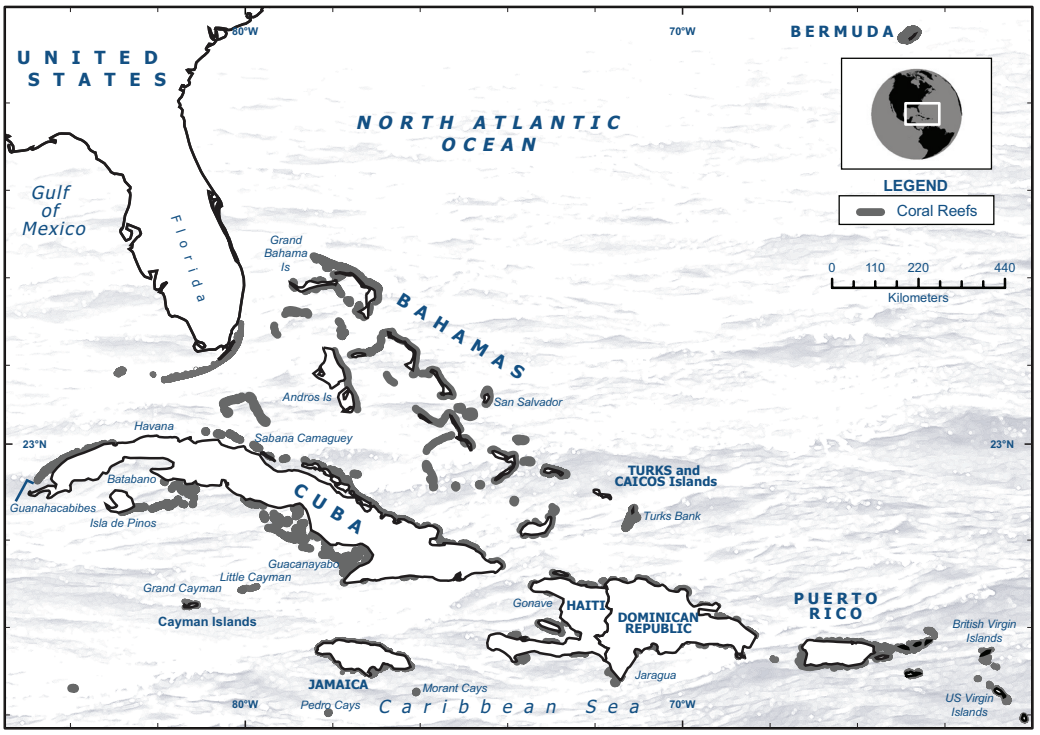
This report updates the status of the coral reefs of the Northern Caribbean and Western Atlantic since 2004 and includes the following: The Bahamas; Bermuda; Cayman Islands; Cuba; Dominican Republic; Haiti; Jamaica; and the Turks and Caicos Islands. The reefs in the northern Caribbean have suffered significant declines since the 1970s from mass mortality due to the grazing sea urchin *Diadema*, new coral diseases, over-fishing and other human stresses, such as nutrient and sediment pollution and habitat destruction. Since 2004 the northern Caribbean has suffered from 12 hurricanes and 8 tropical storms in addition to coral bleaching resulting from elevated sea surface temperatures in 2005. More details and reference material are contained on the attached CD with this printed report.

Bahamas

The 13 major islands and 700 smaller islands and cays lie on a limestone platform covering 13 880 km^2 area comprised of two large, shallow carbonate banks. The largest is the Great Bahama Bank with Andros Island while the smaller forms a chain extending from the Straits of Florida to the Caicos Islands. The islands are low-lying and comprised mostly of very porous limestone so there is no surface water and therefore corals can grow close to the shore. Coral reefs occur mostly fringing the bank margins, with some small patch reefs on the banks in areas with high tidal circulation and with a few bank barrier reefs.

Bermuda

The Bermuda islands are a 53 km^2 chain of aeolian limestone islands in the North Atlantic at 32°N, 1050 km off the coast of USA and 1660 km north-east of Florida. The 7 main islands are connected by bridges and have a maximum elevation of 79 m. The climate is sub-tropical and sea surface temperatures range from 16°–30°C. Bermuda's reefs are geographically isolated; there is no land with reef corals nearer to Bermuda than the Bahamas, 1350 km to the southwest. These are the most northerly reefs in the Atlantic and amongst the most northerly in the world. The Bermuda platform of about 990 km^2 (maximum 200 m depth) has an atoll-like reef tract, unique in the Caribbean, and includes patch and terrace reefs covering 550 km^2. Bermuda has about 22 species of hard corals, but branching *Acropora* species have never been recorded in Bermuda. The shallow outer lagoon, rim and fore-reefs are dominated by massive high relief species such as *Diploria strigosa* and *D. labyrinthiformis*, *Montastraea franksi*, *M. cavernosa* and *Porites astreoides*. Nearshore reefs and deep fore-reef habitats are dominated by branching *Madracis decactis*, *Madracis auretenra* and *Oculina* species.



Cayman Islands

The Cayman Islands are in the middle of the Caribbean Sea, and consist of 3 small low-lying, limestone islands: Little Cayman; Grand Cayman; and Cayman Brac. The islands are a centre for banking, insurance and legal services as well as tourism, especially the cruise line industry and dive tourism. Fishing pressure is low, supplying only the local markets and the last known grouper spawning site is on Little Cayman. Fishing remains an important cultural tradition in Cayman Brac following activities of the original residents. On Grand Cayman there are numerous large resort hotels, condominiums, private homes and corporate development; whereas the population on the other islands is small. The islands are surrounded by shallow-sloping terraces: the first ends at 8–15 m depth and the lower terrace stops at 15–20 m, before the shelf-edge 'walls' that are diver favourites. In many locations there are shallow boulder ramparts formed from the once dominant *Acropora palmata* stands. Most reefs have low to medium relief (1–3 m) spur and groove formations.

Cuba

This large (110 000 km^2) high island has 3966 km of coral reefs along 98% of the long shelf edge. More than 50% of these reefs are separated from the mainland by cays or broad shallow lagoons with many patch reefs. This separation has provided protection for the outer reefs from human pressures, except for fishing and some tourist diving. Important reef areas, clockwise from the north-west, include: the Archipielago de los Colorados; the Archipielago de Sabana and the Archipielago de Camaguey on the north coast; and the Golfo de Guacanayabo, the Golfo de Ana Maria, the Archipielago de los Jardines de la Reina, the Archipielago de los Canarreos and the Isla de Juventad on the south coast.

Dominican Republic

The eastern part (48 500 km^2) of the large island of Hispaniola is mountainous and large rivers drain extensive watersheds that carry sediments to limit nearby reef growth. Only 27% of the 1400 km shore (average shelf width 8 km) is fringed by mangroves and 12% by coral reefs. Important reef areas on the north (Atlantic) coast include the Montecristi barrier reef in the north-west (the widest shelf), narrow high-energy reefs in the central region and the Bávaro-El Macao-Punta Cana barrier reef system at the eastern end. In the north Samaná Bay receives many rivers and is the largest estuary on the Caribbean island, therefore nearby reefs are poorly developed. The Navidad Shoals and Silver Banks are about 100 km to the north. To the south, on the Caribbean coast, are the well-studied reefs of Parque Nacional del Este and the adjacent Isla Saona. Westward, past Isla Catalina to beyond Santo Domingo, are uplifted carbonate terraces with reefs growing on narrow platforms e.g. Boca Chica and the Parque Nacional Submarino de Caleta. Conditions are not good for reefs in the south-west, except on the shallow sheltered shelf east of Cabo Beata at Parque Nacional Jaragua.

Haiti

This is the western part (27 600 km^2) of Hispaniola with coral reefs in the south near Ile a Vache; all around Ile de la Gonave in the central bay of Port-au-Prince; on the Rochelois Bank and at Les Iles Cayemites; off the northern coast of the southern peninsula; and in the north from the border with the Dominican Republic in the east to the Baie de l'Acul just west of Cap Haitien. These reefs experience probably the greatest human pressures of any Caribbean island with serious land degradation resulting in major sediment and nutrient pollution, and severe over-fishing. This was particularly evident with 3 major hurricanes in the summer of 2008.

Jamaica

Jamaica is the third largest Caribbean island, 230 km long by 80 km wide, with 891 km of coastline and 1240 km^2 of coral reefs. 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 neighbouring banks of the Pedro Cays, 70 km to the south, the Morant Cays, 50 km to the south-west and the Formigas Banks to the north-east. Human pressures are great with over-fishing and pollution from the land affecting nearshore reefs.

Turks and Caicos Islands (TCI)

The Turks and Caicos consist of 8 islands and approximately 40 low-lying cays on the Turks Bank and Caicos Bank, adjacent to the submerged Mouchoir Bank. More than 300 km of coral reefs surround the islands, and the prevailing easterly trade winds create a clear differentiation on the banks with a windward eastern side and a calmer leeward western side. The banks have narrow discontinuous shelf-edge reefs of variable depth, relief, and hard coral abundance. The shallow fringing reefs along the western Caicos and Turks Banks are well developed near the shore. Shallow patch reefs occur around many islands and cays, and water visibility is considered good everywhere. These islands are a major tourist destination, especially for divers and yachts.

Status of Coral Reefs: 2008

The most significant event to affect the coral reefs in this node occurred during the major climate-change related events of 2005, which was probably the warmest year on record in the Northern Hemisphere and rivalled 1997–1998. Warm water bleaching and waves from numerous strong hurricanes resulted in major losses of corals in many of the countries, as well as significant damage on the land that resulted in sediment and other pollution flowing onto the reefs. Bleaching was compounded by major outbreaks of coral diseases in 2005 and 2006.

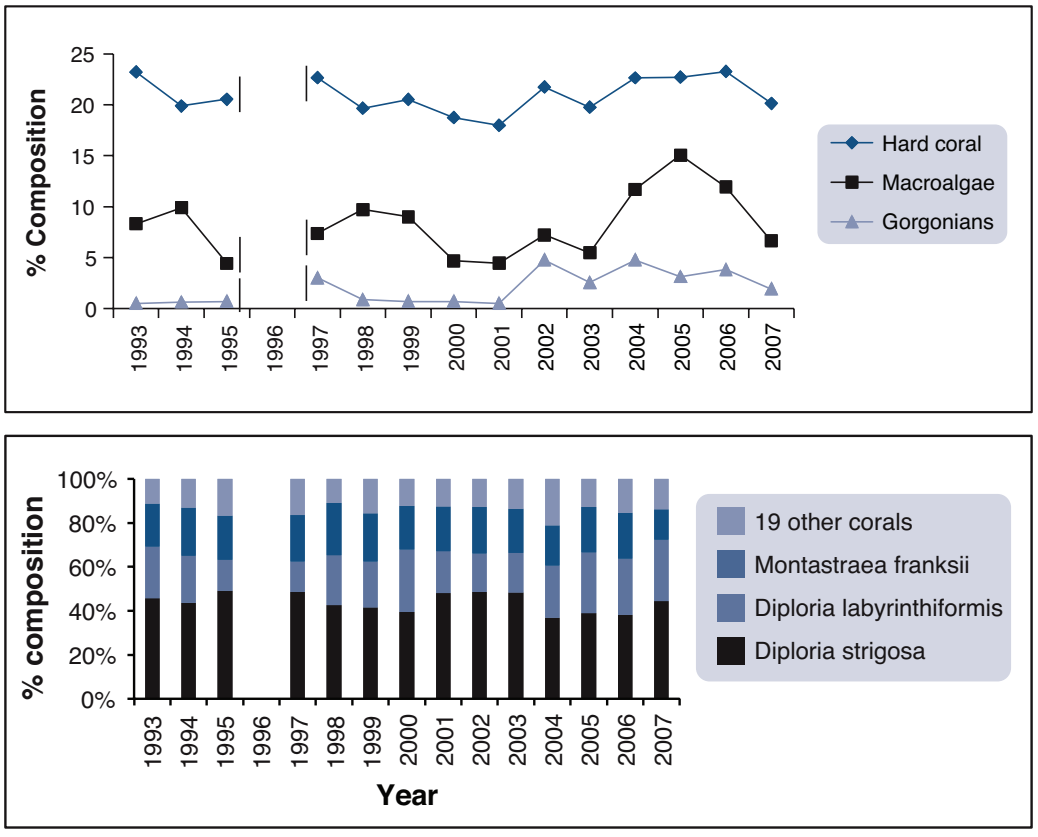
Bahamas

There are few long term data sets for Bahamian coral reefs, but one example stands out. There was a significant drop in live coral cover from 13% to 3% between 1991 and 2004 at Rainbow Gardens Reef (Iguana Cay, Exumas), as determined by comparing quantitative community descriptors. The number of coral colonies decreased from 295 to 240; thus the coral community was less rich and the resultant reef structure was more homogeneous. Most large *Montastraea annularis*, *Agaricia agaricites*, *Porites porites*, and *Porites astreoides* colonies were absent in 2004. Colonies were also more prone to stresses from algal smothering, excess sediment, and boring organisms; however no coral disease was recorded in 2004. The *M. annularis* skeletons were severely bio-eroded with a bright yellow skeletal band corresponding to an increase in bleaching and coral mortality; which probably resulted in the decline of corals. Thus it appears that a combination of bleaching, bio-erosion, and storm damage reduced the Rainbow Gardens discrete coral patches to rubble.

Bermuda

These northerly reefs have fared well over the last 25 years, compared with more tropical areas in the wider Caribbean. Although the reefs are adjacent to high human population densities, the economy is strong and considerable income is derived from reef-related tourism; thus there is a relatively strong conservation ethic. Recurrent bleaching events, hurricanes and

coral disease have had little effect on coral cover, which can approach 80–90% on the deeper main terrace reef. Coral cover at one site on the outer rim has not changed in 15 years (i.e. 20.5% in 1992 and 20.1% in 2007). The graphs below show that coral cover up to 2007 has virtually not changed since the 22.5% reported in surveys 25 years ago by Richard Dodge in 1982. Overall there appears to have been little appreciable change in coral cover on Bermuda's outer rim reef in the last quarter century.



These graphs show bottom cover at Hog Breaker reef (14 m depth) on the Bermuda outer rim since 1993, data collected during the Caribbean Coastal Marine Productivity Programme (CARICOMP). The coral cover line graph includes the hydrocoral Millepora alcicornis; and the bar graph shows that the coral composition is dominated by 3 coral species plus another 19 species (other corals).

The most common diseases of Bermudan corals are yellow blotch syndrome (YBS), on *Montastraea franksii* and *Diploria* species, and black band disease (BBD) and white plague on *Diploria* and *Montastraea* species and *Porites astreoides*. YBS has higher prevalence at deeper sites (greater than 5 m) and BBD at shallower sites (less than 5 m). The overall prevalence of disease was just over 3% in October 2005 (about 2.5% for YBS and about 1% for BBD) and this was lower than measurements from 1999 to 2001. However, octocoral diseases in 2005 were about 4 times more prevalent in Bermuda than diseases of hard corals. Bermuda has not experienced the long periods of high water temperatures associated with coral bleaching.

Cayman Islands

There were significant losses of live coral cover on shallow reefs surrounding Little Cayman between 1999 and 2004; but the trend in 2008 appears to have slowed indicating continued coral recruitment and decreased mortality. Average coral cover was 16% in 2004 and 17% in 2008, with no changes in the cover of fleshy macro-algae. AGRRA surveys reported no significant changes in recruitment from 1999 to 2007. For example, in 2005 marked juvenile corals showed that the total density of juveniles and the relative proportions of juvenile coral species did not change following the reduction of coral cover measured to 2004. Juvenile coral community structure was significantly different between and within reefs. In general, densities of brooding Agaricia and Porites species were higher than the spawning Montastraea and Siderastrea species but growth and survival of juvenile corals did not differ between species. Coral mortality varied from 23% to 27% and was largely attributed to white plague disease. The abundance of large reef builders (Montastraea) decreased while Agaricia and Porites increased.

Coral bleaching occurred in the Cayman Islands in the late 1980s, 1995, 1998, 2003, and 2005: the most severe bleaching was in 2005 but there was little mortality. Major hurricanes that have hit the Cayman Islands include Allen in 1980, Gilbert in 1988, Mitch in 1998, Ivan in 2004, and Dennis in 2005. Hurricane Ivan passed south of Little Cayman and Cayman Brac, but made 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 and Grand Cayman. Corals above 15 m were broken or totally displaced along both sides of the islands, but damage was patchy and recovery is occurring. Boulder ramparts on many beaches of all three islands and reef-crest zones provide historic evidence of the continuous impact by major storms.

Cuba

AGRRA assessments in 2007 reported live coral cover from 9–50% for reef crests in the south and east of the Golfo de Batabanó and from 6–21% for the fore-reef zones in areas affected by 6 hurricanes from 2001 to 2005. There have also been shifts in coral species dominance at most sites. Live coral cover along the Archiélago Jardines de la Reina, south-east Cuba was 7–19% (7–12% on reef crests, and 16–19% on fore-reefs). Previous AGRRA assessments in 2001 reported coral cover at 3–38% (mean 16%: 3–38% on reef crests, 10–23% on fore-reefs). The loss of coral cover at reef crests was presumably due to the category 4 Hurricane Dennis in 2005. Coral cover in 2002 was 20–39% at 12 sites between 3 m and 15 m depth, in eastern Bahía de Cochinos (south central Cuba). Similarly coral cover was 14–28% at 4 sites at 6 m and 40 m depth. In 2003 at Guajimico coral reef (east of Cienfuegos Bay, south central Cuba) coral cover was 20–25% at 14 sites (5–20 m deep). For 13 sites in north-western Cuba (Cayo Levisa; north Pinar del Río province) coral cover was 30–40% at the reef crest and 10–20% at the fore-reef in 2002 and 2003. Reef Check data collected from 13 stations in 2004 showed an average of 22.8% while for stations monitored in 2005 the average was 20.7%.

Dominican Republic: Areas favourable for reef growth are opposite dry areas and on the platforms of Montecristi, Macao–Punta Cana, Parque Nacional del Este, Parque Nacional Jaragua and the Silver Banks (170 km to the northwest of the island). There are 64 coral species identified in the Dominican Republic. Coral cover varies from 9–40% because of natural causes and human impacts. In 2004, mean coral cover was 11.4% at 6 sites (range 5.0–20.8%). Reef Check assessments in 2005 at 11 sites reported coral cover as 14.9% (range 1.9–30.6%). In 2006 at 8 sites the mean coral cover had increased to 21.9% (range 8.1–34.4%). Thus coral

cover has almost doubled from 2004 to 2007. This is good news after the damaging losses in the 1980s and 1990s and the big bleaching year of 2005. No data are available after the damaging hurricane season in 2008.

Haiti

There have been no comprehensive coral reef surveys since the 2003 Reef Check surveys of 5 sites north-west of Port-au-Prince, when the reefs appeared to be fairly healthy. There is no government involvement in coral reef monitoring or conservation in Haiti and only one small NGO monitors the reefs and provides education. But there is clear evidence of continuing degradation to reefs from eutrophication, sedimentation, coral harvesting, pollution, and over-fishing.

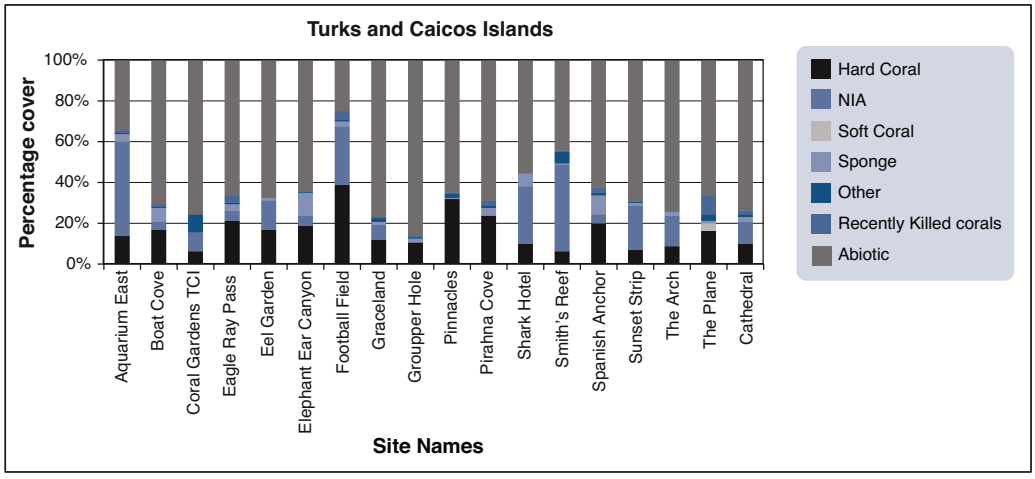
Jamaica

There has been a mix of reef decline and recovery between 2001 and 2007 which included periods of elevated sea surface temperatures and several major hurricanes. Average coral cover was 14.8% (range 2.2–37.5%): generally, very shallow reefs (3 m or less) have lower coral cover. Coral cover less than 10% was at 18 of 53 sites, showing continued severe stress, with Jamaican reefs continuing to be more degraded than the rest of the Caribbean. The good news is that Jamaican reefs have rebounded from the 5% average coral cover in the early 1990s, with mean estimates in 2008 being 15%, a threefold improvement. Moreover, some reefs have relatively high and stable coral cover exceeding the Caribbean average (12 sites above the regional average of 20%). On fringing reefs around Discovery Bay on the north coast coral colony size reduced for many species in 2006 after the mass bleaching of 2005, with subsequent increases in 2007 and 2008. Coral bleaching in 2005 was severe but with relatively little mortality unlike the nearby US Virgin Islands. At Dairy Bull Reef total coral cover and *Acropora* species (13% and 2% respectively in 2006) increased in both 2007 (20% and 10%) and 2008 (31% and 22%). These studies indicate strong resilience on the fringing reefs around Discovery Bay in Jamaica. The trend of algal dominated reefs is, however, still visible on reefs around the island with coverage by algae (indicating increased nutrients) ranging between 0–62.9% with an island-wide average of 24.2%.

Turks and Caicos Islands

About 50–75% of coral colonies suffered partial to total bleaching in 2005 on their reefs resulting in losses of live coral around most islands. Rapid assessments in 2006 and 2007 of 18 sites around the 3 major islands reported that live coral cover averaged 10%–20% with an approximate maximum of 40%. Coral cover at Providenciales ranged from 6–38% which was higher than 2004 estimates; algal cover ranged from 0–46%. There was lower coral cover on shallow inshore sites than on the deeper offshore reefs, possibly indicating a range of human stressors. Average coral cover in West Caicos was 17% with low algal cover while in South Caicos there was 9–16% coral cover and 15% macro-algal cover.

The high abundance of algae and the zonation patterns of species in many shallow locations indicate probable land-based sources of nutrients. However, high levels of algae were also seen at many places with no land influences. The horizontal and vertical gradients of algae at these locations suggest that the nutrients come from upwelling of cold, deep, nutrient-rich water from offshore.



Coral cover at 8 sites around Providenciales in 2007 show comparable cover of hard and soft corals and variable but relatively high cover of turf or macro-algae.

Status of Mangroves, Seagrasses and Fisheries: 2008

Bermuda

Bermuda has a highly regulated fishery with relatively large seasonally protected areas, protected species, limited entry, gear restrictions and bag limits. Reef fish populations showed signs of over-fishing in the 1980s when the preferred target species were rare in fish traps. This decline and the ultimate ban on fish traps in 1990 resulted in a shift towards pelagic species, particularly wahoo (*Acanthocybium solandri*) and yellowfin tuna (*Thunnus albacares*). Now pelagic species account for about 50% of commercial finfish landings. Populations of critical herbivores (parrotfish) and the large black grouper (*Mycteroperca bonaci*) have increased. Landings of other high target grouper species, *Epinephelus guttatus* (red hind), and *Cephalopholis fulva* (coney) have been fairly stable but there has been little recovery of other large grouper populations. This is probably related to the reduced reproductive output of smaller fish and destruction of seagrass and mangrove nursery habitats. Harvests of target species of snapper (Lutjanidae), jacks (Carangidae) and spiny lobster (*Panulirus argus*) are variable with no trends over the last decade. Threats to the reef fisheries include a large, virtually unregulated recreational fishery; non-compliance with regulations; insufficient enforcement personnel and inadequate penalties. There are very few documented marine invasive species in Bermuda, however, the Indo-Pacific lionfish (*Pterois volitans*) has established populations since 2002 throughout Bermuda from the shallows to 80 m depth and threatens populations of small and juvenile fishes.

There have been considerable losses of seagrass habitat, possibly as high as 25% of the total; now there are few 'undisturbed' areas. Most losses are on the rim reef and lagoonal locations far removed from obvious human stressors. The reasons for these losses are unknown. Mangrove forests in Bermuda were never extensive but were probably more widespread than today: pre-settlement mangroves probably covered 0.25 km^2 and now the area is probably 0.18 km^2. One of the largest mangrove forests was severely damaged by Hurricane Fabian in 2003.

Cayman Islands

Herbivorous fish populations have not changed overall with similar size structures for each species, except parrotfish, since 1999. Parrotfish density has declined significantly, especially on the leeward (north) side of the island. However, parrotfish, groupers and snappers showed significant increases in size of individual fish between 1999 and 2007, which may reflect differential sampling of rare species. Parrotfish showed the greatest increase in size. Over-fishing of conch and lobster, and lack of protection of turtle nesting sites from coastal development are major issues. Residents (of at least 5 years) can obtain speargun and seine net licenses and permits to capture turtles if they can prove these activities are a cultural necessity. Now there are 500 speargun licenses in the Cayman Islands. The growth of the hotel industry with more workers from other Caribbean countries and the Philippines has increased exploitation of marine resources.

Studies of mangroves and seagrass beds began with the completion of the Little Cayman Research Centre in 2006. Mangroves are abundant around the major sound on the south side of Little Cayman and along the north and south coasts inland fringing brackish water ponds. Mangroves and seagrass beds are under intense threat, especially on the western coast of Grand Cayman. Results from the little Cayman mangrove and sea grass studies (2006–2007) indicate no change in productivity and biomass.

Cuba

Recently, the Ministry of Fishery Industry banned the use of set nets (Resolution 058/2004, Ban of set net deployment) and implemented a policy to reduce bottom trawling by 25% per year in the finfish fisheries. This ban was aimed at stopping seagrass bed degradation and to allow fish stock recovery: affected fishermen are given generous subsidies, alternative livelihoods or opportunities to participate in technical educational.

Mangrove forests cover is 4.8% (5569 km^2) of the Cuban Archipelago, placing it ninth in the world and third in tropical America. The forests contain *Rhizophora mangle*, *Avicennia germinans*, *Laguncularia racemosa* and *Conocarpus erectus*. The mangrove forest at Golfo de Batabanó is remote from coral reefs and decreasing due to harvesting of the red mangrove and exacerbated by coastline erosion from rising sea levels and storm surges. The main management difficulties include insufficient enforcement caused by limited personnel, vehicles, portable communication facilities, and rehabilitation capacity. This is resulting in local degradation of forests from fires, illegal felling, etc.

Dominican Republic

The main problems facing reefs are over-fishing of essential species such as conch, lobsters, groupers, snappers and parrotfish. Several non-official institutions, as well as the Secretaria de Medio Ambiente y Recursos Naturales have programs for conservation of marine and coastal habitats, communities and species.

Haiti

Lobster and conch exports have been suspended under CITES regulations because of over-exploitation and the absence of any form of management. However, illegal coral harvesting continues; mangroves continue to be exploited at an alarming rate for fuel wood, charcoal

production and construction; and seagrass beds continue to be threatened by sedimentation and pollution. A rapid socioeconomic study was made of fisheries along the southwest tip of Haiti by NOAA specifically to understand exploitation in the US National Wildlife Refuge at Navassa Island.

Jamaica

The un-sustainability of current fishing practices is evident in the depletion of the near-shore fishing stock and a change in the composition of fish communities. The overall mean densities of snappers, grunts and parrotfish were between 0 and 31.5 fish per 100 $m^{2,}$ averaging 1.4/100 m^2. High fishing effort, possibly combined with environmental factors, has resulted in significantly reduced fish stocks. Over-fishing remains a problem as the observed net size and pot density appear unsustainable. Low fish and *Diadema* densities have also contributed significantly to the prevalence of algae on the reefs, with *Diadema* densities (average 20.7/100 m^2) being too low to have any significant effect on algal cover. Despite the lack of herbivores some reefs have shown signs of stable coral cover. In the Portland Bight Protected Area preliminary indications are that the urchin *Echinometra viridis* is now controlling algal growth.

The lionfish *Pterois volitans*, an Indo-Pacific aquarium fish, now occurs in Jamaica and in other Caribbean countries. This invasive and poisonous fish may destabilise reef fish populations and coral health by feeding on grazing fish. The Ministries of Health and the Tourism have been advised of these potentially toxic fish in Jamaican waters.

Turks and Caicos Islands

Similarly, lionfish are now common at several locations in Turks and Caicos waters. Nearshore seagrass beds and mangroves continue to be in good health, however, there is inadequate monitoring of these systems.

Conclusions and Recommendations

The climate change-related threats of increased frequency and incidence of intense hurricanes coupled with rising sea temperatures that result in coral bleaching are now annual dilemmas facing the islands. Coastal ecosystems are stressed more frequently and therefore have less time to recover before the next damaging episode.

Bahamas

These results clearly demonstrate that their coral reefs are in a near crisis situation. Even shallow, and presumably stable, coral reefs in remote localities have undergone change. However, some patch reefs near Rainbow Gardens appear less degraded suggesting that local, small-scale differences may be important components of reef resilience (Pante, 2007).

Bermuda

Research and monitoring in Bermuda has increased in the last 4 years with large-scale and long-term programs established to assess corals; algae; fish communities; seagrass cover and seasonality; and water quality (temperature, nutrients, dissolved inorganic carbon, light attenuation). All marine habitats are being mapped into a GIS database to support research and management. Recent management developments include:

- The Protected Species Act (2003) which mandates active intervention to increase protection of all threatened and endemic species and develop recovery plans;
- The Fisheries (Protected Areas) Order which now includes recently discovered grouper spawning aggregations;
- The Fisheries (Antifouling Paints Prohibition) Amendment Regulations (2005) which bans the importation of antifouling paints containing organotins, or herbicides such as diuron or irgarol;
- A Total Economic Valuation model of Bermuda's coral reefs which is being developed to assist in integrating policy and decision-making for marine developments. The model can be used to establish damage compensation fees following ship groundings, and assessing costs and benefits involved in dredging shipping channels.

A Bermuda Government White Paper on The Marine Environment and the Fishing Industry in Bermuda in 2005 contains a commitment to enact conservation measures, which focus on education and public awareness, scientific research, recovery plans for species and habitats, addition of more marine parks and better information management. The White Paper explicitly outlines the position on MPAs, bio-prospecting, scientific research, shipping, impacts of recreational boating, dredging, marinas, moorings, mariculture, aquarium collecting of ornamentals, mining of the seabed, solid waste disposal, sewage, oil/gas spills, land-based sources of pollutions, anti-fouling paints and marine debris/dumping. Bermuda would benefit from additional legislation to protect the marine environment. For example, there are no specific laws regarding ship damage to habitats; and the Bermuda Planning Act does not extend into the marine environment.

The following recommendations focus on coral reef monitoring, conservation management, capacity building, education and outreach activities:

- Increase government funding for long-term research and monitoring;
- Continue implementation of the Protected Species Act and associated recovery plans;
- Formalize the use of Environmental Impact Assessments for major marine developments;
- Incorporate Total Economic Value models into legislation regarding mitigation, remediation, and restitution following environmental impacts;
- Adopt existing, and develop more, habitat specific conservation and management plans;
- Increase funding and staffing for all environmental programs and initiatives;
- Continue to improve existing educational programs; and
- Educate the judiciary and legislators about the importance of the marine environment.

Cayman Islands

Marine protection laws have been revised to reduce the catch of lobster and conch during the open season. Laws to close spawning aggregations have been established and enforced. Permanent moorings numbers have been reduced to lower diver impacts in Bloody Bay. Monitoring is a standard component of the management in the Cayman Islands and coastal environmental management and coastal planning departments are faced with the challenge of an increased demand for coastal development since 2005. This development may create a risk for much of the productive mangrove habitats.

Cuba

The loss of live coral in southern Cuba was mainly due to unusually frequent and intense hurricanes from 2001 to 2006 and to increases in diseases. In north–central Cuba the main causes seemed to be macro-algal proliferation due to very low abundance of herbivores (parrotfishes and *Diadema*), and to the gradual impact of microbial diseases. Considerable effort is given to coral reef, seagrass and mangrove forest protection despite major economic constraints. Efforts include intensive pollution control strategies, such as obligatory tertiary wastewater treatment in tourist developments, the gradual eradication of unsustainable and harmful fishing practices (set nets and bottom trawling) since 2004, the implementation of new MPAs, and a sustained environmental education campaign. These actions are included within the new third phase of the UNDP/GEF Sabana-Camagüey Project, as well as national and local initiatives. Future challenges include:

- Full implementation of the official ban (MIP-CITMA Joint Resolution No. 1/97) on coral collection;
- Additional improvement of fishery regulations, with full protection of parrotfish;
- Provision of alternative livelihood generators through increasing ecotourism, promoting and implementing sustainable economic practices in tourism, fishery, agriculture/cattle raising sectors; and
- Additional improvements to laws and regulation enforcement.

Haiti

There are no MPAs and, even if they were introduced, it is unlikely that current levels of human damage could be much reduced. The following actions are recommended:

- Establish at least one MPA;
- Establish permanent monitoring sites to collect baseline data;
- Implement marine pollution mitigation measures;
- Promote reforestation and the use of alternative fuel sources;
- Expand public educational activities; and
- Increase public sector responsibility and accountability in resources management.

Jamaica

It is important to implement sustainable monitoring programs which inform on the status of the reefs and act as effective warning systems when reefs are threatened. While the outlook is still bleak for the fishing industry due to the significant reduction in the near-shore fishery, public education campaigns, coupled with continued monitoring and effective management, may yet reverse existing trends and lead to the recovery of the Jamaican reefs.

Climate change damage to coral reefs in Jamaica will ripple throughout the socioeconomy of Jamaica especially through continued decline of fish catches. Recent management responses have included:

- Implementing a stringent permit and licensing system for activities which damage coral reefs;
- Increasing the number of sites being monitored, as well as the frequency of visits;
- Implementing public education campaigns on the importance of coastal ecosystems with special emphasis on the direct correlation between the loss of habitat and general economic losses of the country.

The quandary facing managers remains balancing conservation and economic growth. There is a chronic shortage of human and financial resources to implement effective monitoring and conservation programs. This is hindered by inadequate enforcement, outdated legislation and fines that are ineffective in halting the continued degradation of the island's natural resources

Turks and Caicos Islands

There are distinct gradients in human pressures with some islands being more developed than others, with a construction boom on some with associated stresses. The Department of Environment and Coastal Resources continues to improve capacity to monitor and track these changes and they have increased the level of public information. Coral reef conservation has focused on removing corals threatened during construction and attempting reef restoration with small scale engineering processes. Efforts have also been made to strengthen the legislation with newly drafted laws.

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