1998

Status of Coral Reefs in the Northern Areas of the Wider Caribbean

Judy Lang
University of Texas at Austin

Pedro Alcolado
Instituto de Oceanología, Habana, Cuba

Juan Pablo Carricart-Ganivet
Depatmento de Ecología Acática, Chetumal, México

Mark Chiappone
The Nature Conservancy

H. Allen Curran
Smith College, acurran@smith.edu

See next page for additional authors

Authors

Judy Lang, Pedro Alcolado, Juan Pablo Carricart-Ganivet, Mark Chiappone, H. Allen Curran, Phil Dustan, Gudrun Gaudian, Francisco Geraldes, Steve Gittings, Robbie Smith, Wes Tunnell, and Jean Wiener

GCRMN

GLOBAL CORAL REEF MONITORING NETWORK

Status of Coral Reefs of the World: 1998

Edited by Clive Wilkinson

AUSTRALIAN INSTITUTE OF MARINE SCIENCE

Published on behalf of the Global Coral Reef Monitoring Network by the Australian Institute of Marine Science

Dedication

This book is dedicated to the President, Vice-President, the Government and People of the United States of America for their concern for the coral reefs of the world and for their foresight in establishing the International Coral Reef Initiative and supporting the Global Coral Reef Monitoring Network.

Postal addresses:

PMB No 3
Townsville MC QLD 4810
Australia

PO Box 264
Dampier WA 6713
Australia

Telephone: (07) 4753 4444 (08) 9183 1122
Facsimile: (07) 4772 5852 (08) 9183 1085
World Wide Web: http://www.aims.gov.au

National Library of Australia Cataloguing-in-Publication data:

Status of coral reefs of the world : 1998

ISBN 0 642 32218 X

1. Coral reefs and islands. I. Wilkinson, Clive R.
II. Australian Institute of Marine Science.

578.7789

FOREWORD

Coral reefs are particularly important to millions of people around the world as sources of high quality protein, medicinal, and cultural products. They also provide raw materials for dwellings along the coast, and protect fragile shorelines from storm damage and erosion. Many economies are also dependent on reefs and their products. The coral reefs, and the white sand beaches they produce, are worth hundreds of million of dollars in tourism to some tropical countries, and are the mainstay of many small island developing states. Lobster, conch, snapper, and grouper are increasingly in demand by thriving tourist industries as well as the international seafood market.

Coral reefs are also of great value to the world at large as they are the hotspots of marine biodiversity. For example, a small coral reef in Indonesia may support over 300 species of corals, 700 species of fish, and many thousands of other animals and plants.

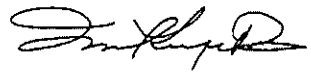
But in the early 1990s, alarm calls were sounded from all quarters — the reefs of the world were in serious trouble, with large-scale degradation occurring in East Africa, South and Southeast Asia, parts of the Pacific, and across the Caribbean. These calls were made up of a series of individual reports of reefs being damaged by human activities, or often by a combination of human and natural stress, but there were no clear assessments documenting the status of reefs around the world. Thus came a response by governments, donor agencies, and the scientific community to set up global monitoring programs that could help decision makers and the public evaluate the health of the world's reefs.

In 1994, the government of the USA stimulated the formation of the International Coral Reef Initiative (ICRI), and a subsequent Framework for Action, which included the establishment of a Global Coral Reef Monitoring Network (GCRMN), which has produced this book. About this time, the International Center for Living Aquatic Resources Management in Manila (ICLARM), a member of the Consultative Group for International Agricultural Research, set up a global database — ReefBase. Subsequent monitoring efforts include Reef Check, a rapid assessment technique which developed out of Hong Kong, and AGRA, a regional initiative for the Gulf of Mexico and the Caribbean. It is very pleasing to note that these programs are

not simply research oriented, but are designed to provide resource managers with the type of information they need to make wise decisions for reef conservation.

The World Bank also recognised the importance of coral reefs to its clients, as a global public good under increasing threat from unsustainable development. The Bank, in partnership with the Global Environment Facility and others, is currently supporting the preparation and implementation of a growing portfolio of coral reef conservation and management projects around the world. These include national projects in Indonesia, Madagascar, Mauritius, the Seychelles, Egypt, India, and Mozambique, and regional initiatives in Mesoamerica and the Red Sea. The World Bank has also been a strong supporter of the International Coral Reef Initiative since its inception, and is now pleased to be a co-sponsor of the GCRMN.

I welcome this summary report on the status of the world's reefs, and urge you to join in supporting efforts such as these to understand not only the physical dimensions of coral reef integrity and health, but the social and economic aspects of how we affect and are affected by the health of these vital marine ecosystems. As we know, the threats to coral reefs from all quarters are increasing. The following report summarizes the unprecedented massive coral bleaching event that occurred during the El Niño-La Niña ocean current oscillations of 1997–1998. From the information provided by this and other monitoring efforts, we can begin to develop a critical baseline against which to monitor trends and evaluate our attempts to introduce better management of reef resources. Only in this way can we hope to reverse the degradation that threatens the very existence of coral reefs and preserve for future generations the contemplation of these natural wonder.



Ismail Serageldin 19 October, 1998
Vice-President, Special Programs
The World Bank

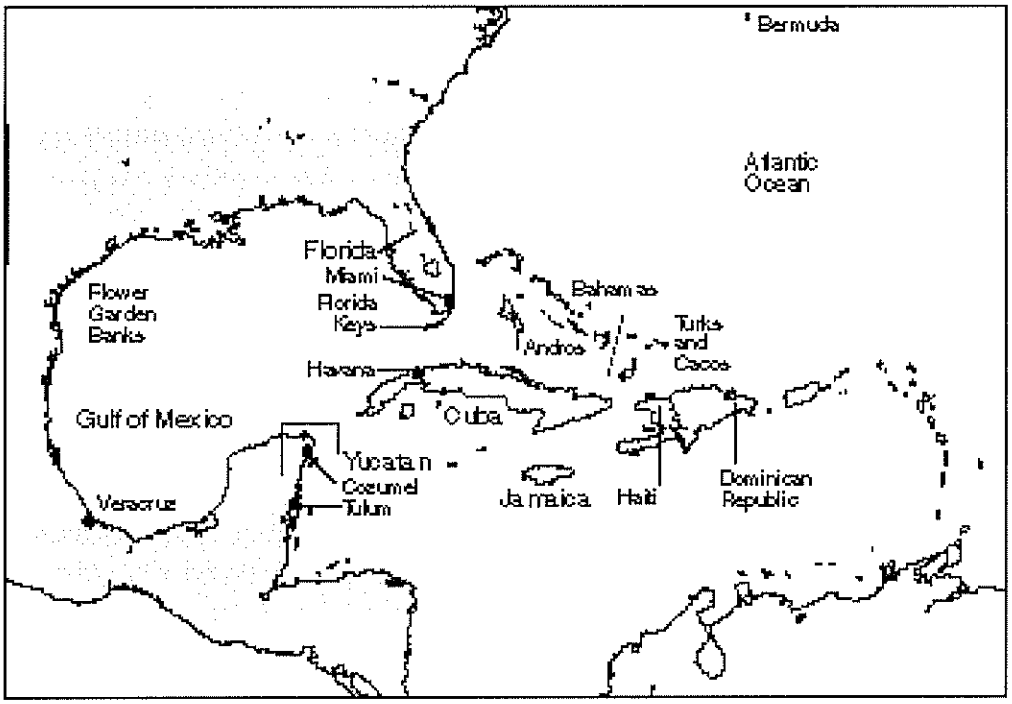
CONTENTS

8. Status of coral reefs in the northern areas of the wider Caribbean

Judy Lang, Pedro Alcolado, Juan Pablo Carricart-Ganivet, Mark Chiappone, Al Curran, Phil Dustan, Gudrun Gaudian, Francisco Geraldes, Steve Gittings, Robbie Smith, Wes Tunnell and Jean Wiener

Abstract

Most of the reefs in the northern area of the wider Caribbean (NAWC) are in fair to relatively good condition, with few examples of marked reef degradation. Reef growth in some areas is naturally limited by temperature extremes (especially cold snaps), the influence of the North American continent, and/or upwelling. Hurricanes often have a major impact on exposed reefs. White-band disease (affecting Acropora spp.) has reduced live coral cover on many reefs during the last several decades. Stony corals have been degraded or lost on a few reefs near large cities in Cuba and Hispaniola, near Veracruz (Mexico) and in the



Florida Keys. Many reefs in less densely populated areas are relatively undisturbed by human activities, apart from fishing, and would be vulnerable to increased tourism and any regional or global climate changes. Stocks of reef fish are stable or increasing in a few areas where fishing effort has declined (Bermuda, parts of the USA). Elsewhere, depletion of reef fish stocks range from relatively small (parts of the Bahamas, Turks and Caicos Islands), to severe (Haiti, Veracruz). Populations of the important, algal-grazing urchin, Diadema antillarum, remain small throughout the NAWC, and where there is severe nutrient pollution and/or intensive fishing, fleshy algae are abundant. Citizens in all NAWC nations are becoming aware of the ecological value and socioeconomic benefits of intact coastal ecosystems. Efforts to conserve and sustainably manage coral reefs are on the increase throughout the NAWC.

INTRODUCTION

The northern area of the wider Caribbean (NAWC) extends from the Dominican Republic and Bermuda on the east, to the Yucatan Peninsula and Veracruz coast of Mexico in the west. It includes three archipelagos with six nations (Bermuda; the Bahamas, and the Turks and Caicos Islands in the Bahamian Archipelago; and on the large islands, Cuba, and Dominican Republic and Haiti on Hispaniola), and two continental mainland countries (Mexico; United States of America). Reef types commonly include nearshore fringing reefs, shallow patch reefs, bank reefs or bank-barrier reefs along island or continental shelf margins, plus a few atoll-like structures. The cover of live reef corals is usually less than 40% of the bottom.

The NAWC is partially subtropical, and much of this area is also under the influence of the massive North American continent, therefore it spans a moderate range of environmental conditions. There are fewer coral species on the northern reefs, but some of the largest head corals (especially Montastraea spp.), and highest coral cover, are found at 15–20 m on the deep crests of the low diversity Flower Garden Banks in the northwestern Gulf of Mexico. There are only three species of Acropora in the wider Caribbean (compared with many species in the Indo-Pacific), but none of these are found in the more northerly areas (Bermuda; northern Gulf of Mexico; eastern USA north of Boca Raton, Florida). In other areas of the NAWC that are protected from high waves, the elkhorn coral Acropora palmata can dominate shallow reef zones, while the staghorn, A. cervicornis, may be prominent between 10–20 m. The fused staghorn (Acropora prolifera) is rare. However, an unfortunate development has occurred during the last 20 years, as numerous Acropora stands have lost much of their cover because of exposure to temperature extremes, white-band disease, and the direct or indirect effects of pollution. Dead colonies have been found in the 'relatively pristine' central-eastern Bahamas, Turks and Caicos Islands, and Cuba, on 'clearly perturbed' reefs of the Dominican Republic and Florida Keys, and on the 'highly impacted' reefs of southern Veracruz. Modest recolonization is occurring on many of these reefs.

The prevailing northeast trade winds do not routinely generate waves as large as those in the eastern Caribbean, but hurricanes are common throughout the NAWC, as are winter storms when large, polar fronts come down through North America. Average seasonal variations of surface seawater temperature range from about 4°C in the Dominican Republic and the Mexican Caribbean, to about 13.5°C (~15–28.5°C) in Bermuda. Unusually low temperatures have caused mortality of common corals (Acropora, Agaricia, Montastraea, Porites) on reefs in the northern Bahamas, northern Veracruz and southern Florida during severe winters (e.g. in 1970, 1977, 1981). Upwelling of cold, nutrient-rich waters may restrict offshore reef development along the northeastern Yucatan shelf, and may also affect coral reefs in the Bahamas, Cuba, Dominican Republic and USA.

Bleaching events are more likely to occur when sea-surface temperatures increase by as little as about 1°C above the long-term average for about a week in summer. As many as eight mass bleachings have occurred on some NAWC reefs since 1983; 1998 has been a major year for coral bleaching, at least in the Bahamas, Bermuda, Haiti, the Mexican Caribbean and Florida. Coral diseases are also more common during the warm summer months.

Populations of the long-spined urchin, (Diadema antillarum) died out suddenly throughout its entire range in the wider Caribbean during 1983–1984. Fleshy algae capable of smothering corals have subsequently proliferated in some areas of the NAWC, particularly where over-fishing has removed large-sized herbivorous fishes.

Human coastal population density varies from fairly low (2 to 63 per km^2 in Yucatan, Mexico; 20 to 30 per km^2 in the Bahamas, Turks and Caicos Islands) or moderate (250 per km^2 in the Florida Keys), to fairly high (up to 2200 per km^2) near major cities like Havana (Cuba), Santo Domingo (Dominican Republic) and Veracruz (Mexico). Tourists often outnumber local populations at popular coastal resorts: 7 to 1 in Puerto Plata (Dominican Republic), 8 to 1 in Cozumel (Mexico), 10 to 1 in Bermuda, 12 to 1 in the Bahamas, 38 to 1 in the Florida Keys, and 75 to 1 in Tulum (Mexico).

Watersheds in many of the continental and large insular parts of the NAWC were deforested so many decades ago that it is not now possible to estimate how freshwater and terrestrial soils naturally impacted coastal reefs. Nowadays, reefs located near some permanent settlements, tourist resorts, marinas, agricultural fields, and river mouths are suffering from the effects of excessive sediments, nutrients and, in several nations, pesticide pollutants. Chemical pollution (e.g. hydrocarbons, heavy metals), and/or physical damage from boat groundings, are characteristic impacts near large ports and cities.

Manatee (Trichechus manatus) and jewfish (Epinephelus itajara) are commercially extinct throughout the NAWC. Populations of queen conch (Strombus gigas) and/or spiny lobster (Panulirus argus) are greatly reduced in some areas. Fishing pressures have been so intense in Haiti and Veracruz that many of the edible fish and invertebrates caught by artisanal fishers are below sexual maturity.

STATUS OF CORAL REEFS

The Bahamas

The Bahamas cover a large area (260,000 km^2), with thousands of small patch reefs, dozens of narrow fringing reefs, and a few atoll-like and bank-barrier reefs. Reef development in much of the Bahamas is naturally limited by exposure to hurricanes (windward sites), by unusually cold winters (northern Bahamas) and by turbid, high salinity waters (leeward bank margins). Many Bahamian reefs are in fairly good condition, although white-band and other diseases have affected corals from San Salvador in the east to Andros in the west.

Edible reef animals are still common on many Bahamian reefs, but there is some local over-exploitation of whelk (Cittarum pica), queen conch, spiny lobster, and several species of grouper. Limited illicit fishing activities include use of toxic chemicals, harvesting of hawksbill turtles (Eretmochelys imbricata), undersized queen conch, and spiny lobster; in some areas spiny lobster are fished out of season or with prohibited diving gear. Artificial shelters are often positioned close to reefs where it is feared they may aggregate existing spiny lobsters, rather than enhance natural stocks. There is a legal harvest of adult green turtles (Chelonia mydas) during an open season (April–July). Sand is still being mined from a few reef sites on a fairly small scale.

There are four parks or reserves with coral reefs in the Bahamas, and eight other reef sites are informally protected (one of which is likely to be given formal protection under a new Fisheries Act which should be in force by the end of 1998.) Over half of the commercial dive sites have mooring buoys.

Bermuda

Fringing, bank-barrier and lagoonal patch reefs are found on the Bermuda Platform which, together with the nearby Challenger and Argus Banks, occupy a total area of about 900 km^2 in the Sargasso Sea. The warm waters of the Gulf Stream allow Bermuda to be the most northerly (32°20'N) coral reef in the Atlantic Ocean. The number of reef coral species is less than half of that in Florida (20 vs 48), yet the health of these small reefs is good overall. Grazing by parrotfishes (scarids) and surgeonfishes (acanthurids) was sufficient to prevent

even a temporary increase in the cover of fleshy algae after most of the Diadema died in 1983. However, the occasional grounding of large vessels and subsequent salvage operations have collectively destroyed about 1% of Bermuda's outer reefs since 1940. Queen conch are also commercially extinct.

Bermuda is remarkable for its high priority on conservation, despite supporting one of the largest human population densities on earth (over 1000 per km^2). A high level of protection for about a quarter of the Bermudian coral reefs is provided in two coral reef preserves, three seasonally protected no-take fishing areas and nine very large protected dive sites. Recreational fishers have bag limits, and commercial trap fishing for finfish was totally banned in 1990. Recently the number of convictions for use of illegal fish traps has increased in Bermuda.

Cuba

Numerous fringing and bank-barrier reefs border much of Cuba's 3200 km-long shelf margin, although over 50% are separated from the mainland by cays or by broad, shallow lagoons that contain many patch reefs. Most of the Cuban reefs are in relatively good condition, excepting those near large population and industrial centres (along less than 3% of the shoreline), where the seawater is conspicuously polluted. There has been some localized death of Acropora from white-band disease. Sediment in runoff may affect some nearshore reefs along 30% of the mainland coast. Increases in large, fleshy algae on some offshore reefs since the die-off of Diadema antillarum are probably related to high concentrations of phosphate in effluents from the sugar industry and other wastewaters.

Stocks of most reef fishes in Cuba are in comparatively good condition (larger fish sizes, high biomass), and artificial shelters for spiny lobsters have been used sustainably for several decades. However, Nassau grouper (Epinephalus striatus) and sharks are overfished. There is limited, illegal harvesting of several species of gorgonians, black coral, spiny lobster, and turtles.

There are no marine protected areas in Cuba, but tourist operators are informally protecting the reefs near some resorts. Only a few commercial dive sites have mooring buoys. In 1997, anchoring, erecting structures, dredging, dumping sediments and solid wastes, using explosives, and unauthorized collection of all corals, were prohibited by a joint resolution of the Ministries of Fisheries Industry and of Science, Technology and Environment.

Dominican Republic

Fringing reefs, and small barrier reefs are scattered along less than 170 km of the coastline of the Dominican Republic, with some offshore bank reefs. Many coastal reefs are in fairly poor condition, and may have been damaged by anthropogenic increases in sediments (due to upland deforestation, wetland removal, soil erosion, and coastal construction), nutrients (from fertilizers as well as domestic wastewaters) and pesticides (in agricultural runoff). Large, fleshy algae have proliferated at the expense of reef corals at many localities, including an underwater park (La Caleta). Coral reefs have clearly declined near polluted coastal cities (Santo Domingo; Haina). Small-scale breakage of corals by snorkellers and SCUBA divers is conspicuous at numerous dive sites, particularly near the most popular tourist centres on the north and east coasts.

Artisanal fishing has been reduced within the last decade, and reef fish populations are increasing. Nevertheless, queen conch, spiny lobster, groupers, snappers, grunts, aquarium reef fish, black corals, hermit crabs, and 'live rock' are still intensively harvested (both in and out of legal seasons) in some parts of the Dominican Republic. Illegal collection of loggerhead, hawksbill, and green sea turtles is on the decline.

Approximately 20% of the coral reefs in the Dominican Republic occur within marine parks and sanctuaries. Efforts to both monitor and manage these protected areas have been initiated. About a quarter of the commercial dive sites have mooring buoys.

Haiti

Little is known about the barrier, fringing, and patch reefs that skirt the coastline of Haiti and its offshore islands. Soil erosion and wetland removal are particularly severe (perhaps less than 1% of the native vegetation remains intact). There are no sewage treatment plants, nor sanitary landfills in this nation of 8 million people. Nutrient pollution has contributed to the growth of fleshy algae that are smothering corals on reefs near Port-au-Prince and Cap Haitian. Port-au-Prince is also severely polluted with oil, industrial chemicals, and trash. Although fishing permits are required by law, the number of active fishing boats greatly exceeds the number with permits, and fishing is so intense that few fish reach reproductive size. There are no marine protected areas in Haiti, although one is planned, and none of the commercial diving sites have mooring buoys (although these are being planned).

Mexico (Veracruz)

The 29 small, platform-type reefs in the southwestern Gulf of Mexico are among the most stressed by both nature and humans in the entire Caribbean. Corals on reefs near the coast are sometimes killed by low winter temperatures or by runoff during the rainy season. Cold-

induced mass bleaching of head corals (Colpophyllia, Diploria, Montastraea) has occurred as recently as December, 1994. Anthropogenic increases in sediments and nutrients, plus agricultural and industrial chemical pollution, have probably contributed to the disappearance of many corals within the last 20–30 years, and to their replacement by fleshy algae, particularly in the shallow (3–5 m) zones of the nearshore, southern Veracruz reefs. Coral skeletons contain relatively high concentrations of heavy metals, particularly on reefs near the port of Veracruz.

Queen conch are commercially extinct, and reef corals, black corals, seashells and other curios, spiny lobsters, sea-urchins, along with many edible and non-edible fish and sea turtles are over-harvested (often illegally) on the Veracruz reefs. Reef coral skeletons were extensively used in the construction of public buildings and a fort during the 17th and 18th centuries. Large-scale physical damage includes boat groundings, military manoeuvres, and the construction of the Veracruz harbour; at a much smaller scale, corals are smashed by recreational snorkellers and SCUBA divers. Over 70% of the Veracruz reefs are contained within a marine park, although levels of management and enforcement are minimal.

Mexico (Yucatan)

The Yucatan Penninsula contains narrow barrier and fringing reefs on the eastern (Caribbean) coast, and fringing reefs around offshore islands in the southeastern Gulf of Mexico (its western flank). There are also several atoll-like structures on offshore banks (Alacran on Campeche Bank, Chinchorro). Limited upwelling of cold, nutrient-rich water may naturally restrict reef development on the northeastern margin of Campeche Bank.

Coastal development is expanding so rapidly along much of Mexico's Caribbean coastline, and with such little consideration of existing regulations that, with the possible exception of the Sian Ka'an Biosphere Reserve, the continued integrity of these coastal resources is seriously threatened. Nearshore water quality is particularly poor near some major tourist resorts. Reefs near the petroleum industry's platforms in the southeastern Gulf of Mexico are routinely exposed to small hydrocarbon spills. Black coral, queen conch, other invertebrates, fish, and sea turtles are collected illegally in the Yucatan. Large-sized algal grazing fishes have been over-harvested on some reefs, and fleshy algae capable of overgrowing reef corals may be increasing in cover.

About a third of the Yucatan's coral reefs are located within seven marine parks, reserves, and protection zones, but there is little effective management. Local residents are providing informal protection at several dive sites. Artificial shelters for spiny lobsters have been deployed sustainably in a large bay for several decades.

Turks and Caicos Islands

At the southeastern extension of the Bahamian archipelago, the windward fringing reefs of the Turks and Caicos Islands are exposed directly to the open waves of the Atlantic Ocean. Water quality is generally very good, as there is no major agriculture apart from small market gardens, and no major industry other than a small brewery, and a factory to make drinking water. The ten large hotels are all based on one island, and most have their own desalination and sewage treatment facilities.

Queen conch and spiny lobster are fully exploited, mostly for export, and some of the latter are caught illegally with bleach. Most reef fish are harvested sustainably. Three snorkel trails were established in 1997 to reduce diver damage to popular patch reefs, and for public outreach education. Dive operators also brief tourists in correct 'reef etiquette'. The three marine national parks have well-maintained mooring buoys for dive boats, however, management strategies are still being determined. Dropping anchor within the marine parks is a punishable offence and there have been some successful prosecutions.

Florida Reef Tract (USA)

There are a few dozen bank-barrier reefs, and thousands of lagoonal patch reefs, off the southeastern coast of Florida and the islands of the Florida Keys; further southwest is the atoll-like Dry Tortugas reef. This 320 km-long reef tract is influenced by the clear Florida Current (Gulf Stream) and by the turbid waters of Florida Bay, which can be either warm and of high salinity or cold and, sometimes, of low salinity. Few reefs have developed opposite the wide tidal passes located in the middle region of the Keys, and some reef corals die during severe winters (most recently in 1981).

Water quality has markedly deteriorated in the Keys over the last 30 years. Changes of water flow patterns in Florida Bay (due to the causeways connecting the islands to the mainland), increases in sedimentation (from recreational boat traffic, dredging, historical infilling, and wetland removal), and of nearshore nutrient concentrations (from local wastewaters, and fertilizers from the agricultural fields of southern Florida), plus industrial pollutants from Miami, have probably all contributed to this decline. Live coral cover has significantly decreased on some bank-barrier reefs. White-band and other coral diseases have been obvious for over 20 years, as have mats of sediment-trapping turf algae that gradually encroach over reef corals and restrict the settlement of new recruits. The large amount of boat traffic results in major damage to shallow reefs and seagrass beds from propellor scrapes (especially of recreational boats) and groundings (commercial vessels in particular). Queen conch and Nassau groupers are commercially extinct, spiny lobsters are fully exploited, and many species of groupers and snappers are also over-collected.

The entire Florida reef tract is under some form of state or federal management. Mangroves are expanding on artificial islands (dredge spoils). Shipping lanes are better defined, and the heavy fines imposed after major groundings are being used to salvage corals, repair reef foundations, and for follow-up research and monitoring. There are mooring buoys at all commercial diving sites. Pump-out facilities are being installed at public marinas and docks. To date, fishing is restricted in only 0.5% of the Florida Keys National Marine, however, planning is under way to declare larger areas of the Dry Tortugas as a fishing reserve. Queen conch populations are being re-stocked with captive-bred juveniles.

Flower Garden Banks (USA)

The East and West Flower Garden Bank reefs, which cover less than 90 km^2, are located 200 km south of the Texas/Louisiana border. Naturally protected by their remoteness from the mainland and by their depth; even hurricanes inflict relatively little damage to the head corals that predominate on the 15–20 m deep bank crests. Water temperatures are neither as warm nor as cold as sometimes happens at comparable latitudes in Florida and the Bahamas.

Live coral cover has been relatively high (about 45% on the bank crests) since monitoring first began in 1972, and coral diseases are rare. There was a rapid expansion of fleshy algae in 1984 after the sea urchin, Diadema antillarum, died off, but this was reversed within a year, apparently after the populations of large, herbivorous parrotfishes (stoplight, Sparisoma viride and Queen, Scarus vetula) increased.

Strong regulations have meant that there has been remarkably little impact from the petroleum industry, although there are about 4000 hydrocarbon production facilities and over 35,000 km of pipelines in the northwestern Gulf of Mexico. Harvesting of reef organisms was restricted to hook-and-line fishing, anchoring by commercial vessels was prohibited, and mooring buoys for dive boats were installed, when the Flower Garden Banks became a National Marine Sanctuary in 1992.

MANAGEMENT OF CORAL REEFS

Tourism has brought considerable economic benefits to many nations in the NAWC, but the coastal reefs that attract many of these visitors are often stressed by sediment and nutrient pollution, and by over-harvesting of reef resources. There is increasing awareness of the perils of unrestrained population and economic growth on societies and the environment. Many individuals, NGOs, foundations, industries, financial, and academic institutions, and even governments, are collaborating to conserve or restore coastal habitats, in part because they recognise the major benefits that derive from reef-based tourism. Most NAWC nations have some

form of environmental legislation, but enforcement is particularly poor in Haiti and Mexico. Government commitment to international treaties like MARPOL, CITES, and the Convention of Biological Diversity has enhanced compliance with local environmental, fishery and development regulations in the Turks and Caicos Islands, Cuba, and the Dominican Republic.

Concepts of integrated coastal (or catchment) management are just beginning to be applied in this area. The Global Environmental Fund (GEF) of the World Bank is funding a Cuban project to protect biodiversity and establish responsible coastal tourism development in the Sabana-Camaguey ecosystem. Mexico has joined with three nearby Central American countries in the Meso-American Caribbean Coral Reef System Initiative, which is a regional approach to reef conservation and sustainable management supported by the World Bank. After extensive input from a citizens Sanctuary Advisory Council, the multiple-use, integrated coastal management plan for the Florida Keys National Marine Sanctuary was adopted in 1997.

Shoreline development is closely controlled in Bermuda; comparable projects in the Turks and Caicos and in Cuba are restricted to the landward side of beach dunes. Turbidity barriers, or some other method of sediment control, are required at coastal construction sites in Florida, and are sometimes used in the Mexican Caribbean.

Artificial wetlands and composting toilets are helping to remove nutrients from wastewater in several coastal villages along the Mexican Caribbean. Methods of removing nutrients from wastewater are presently being tested in the Florida Keys, and the Key West ocean outfall is being discontinued as part of legislation banning the discharge of raw sewage into US navigable waters. Live-aboard boats must also comply, and pump-out facilities are being installed along the coastlines of Florida and Texas.

Mooring buoys have been installed at nearly all commercial dive sites in the Turks and Caicos Islands and in the USA, and are being placed elsewhere in the NAWC. Anchoring by commercial vessels has been banned on the Flower Garden Banks, and boat groundings on the Florida Keys have been greatly reduced, since both were designated as National Marine Sanctuaries.

There are laws against collecting hard corals in most NAWC countries, and there are no recent reports of fishing with explosives. The use of poisons to capture aquarium or edible fishes has greatly declined. Reef fish populations are increasing in some areas where market pressures have reduced the numbers of active fishers (Dominican Republic), or where fishing regulations are enforced (Bermuda, Cuba, some reefs in the USA). Queen conch and spiny lobster fisheries are locally sustainable in some NAWC nations. Alternatives to fishing on coral reefs include artificial reefs in Cuba, Mexico, and the USA, and fish aggregating

devices in the Dominican Republic and Mexico. Queen conch populations are being stocked with captive-bred juveniles in Florida.

Although steady progress is being made by NGOs and government agencies at funding and training personnel (especially in Bermuda and the USA), at this time only a few of the NAWC's marine protected areas are adequately monitored or effectively managed. Nonetheless, the GEF is supporting the development of coral reef monitoring protocols in the Bahamas (some of which will be conducted in protected areas), as well as ecological assays and biodiversity inventories at four marine parks in the Dominican Republic. Mexico has formed a multi-disciplinary and broadly representative scientific and technical advisory committee (Comite Cunsultor Cientifico y Tecnico de los Arrecifes Coralinos — COCCYTAC) to advise government on improved monitoring and management of Mexican MPAs as part of their commitment to the International Coral Reef Initiative and the Global Coral Reef Monitoring Network. Some of the supposedly protected areas in the Bahamas, Turks and Caicos Islands, Dominican Republic, parts of southern Yucatan, as well as many unprotected areas in Cuba, are sufficiently remote from large human populations as to be relatively unaffected by direct human activities, excepting periodic over-fishing. Ever larger numbers of divers are helping to protect reef resources from illegal fishing, clean up trash, conduct reef monitoring surveys, and educate others about the value of intact reef ecosystems.

Conclusions

Research is needed to determine the long-term consequences of coral diseases and mass bleaching (since 1987) on some NAWC reefs, and whether these phenomena are linked to local or regional anthropogenic stresses. Populations of Diadema antillarum have not recovered since the 1983–1984 mortality event, and fleshy algae are overgrowing reef corals in some areas of the NAWC, particularly where intensive fishing has removed algal-grazing fish. Within the last 20 to 30 years, reef corals have clearly declined near major sources of pollution (Havana, Santo Domingo, Veracruz) and in the Florida Keys.

Stewardship of coral reefs within the NAWC's marine protected areas varies from essentially nil (Mexico) to good (Bermuda, Flower Garden Banks). Apart from over-harvesting, direct human impacts on the remote reefs of the Bahamas, Turks and Caicos Islands, Cuba, and the Flower Garden Banks are comparatively low. With the possible exception of the Sian Ka'an Biosphere Reserve, most of the Caribbean reefs of Mexico are threatened by an explosive growth in tourism; elsewhere pressures from fishing or recreational diving range locally from modest to excessive.

The authors come from institutions throughout the western Atlantic: Judy Lang, University of Texas at Austin, USA; Pedro Alcolado, Instituto de Oceanología, Habana, Cuba; Juan Pablo Carricart-Ganivet, Departamento de Ecología Acuática, Chetumal, México; Mark Chiappone, The Nature Conservancy, Miami, USA; Al Curran, Smith College, Northampton, Massachusetts, USA; Phil Dustan, University of Charleston, USA; Gudrun Gaudian, Department of Environment and Coastal Resources, Grand Turk, Turk and Caicos Islands; Francisco Geraldes, Universidad Autónoma de Santo Domingo, Republica Dominicana; Steve Gittings, National Oceanic and Atmospheric Administration, Rockville, Maryland, USA; Robbie Smith, Bermuda Biological Station for Research; Wes Tunnell, Texas A&M University-Corpus Christi, USA; Jean Wiener, Fondation pour la Protection de la Biodiversité Marine, Port-au-Prince, Haiti.