Chapter 4. STATUS OF CARIBBEAN CORAL REEFS

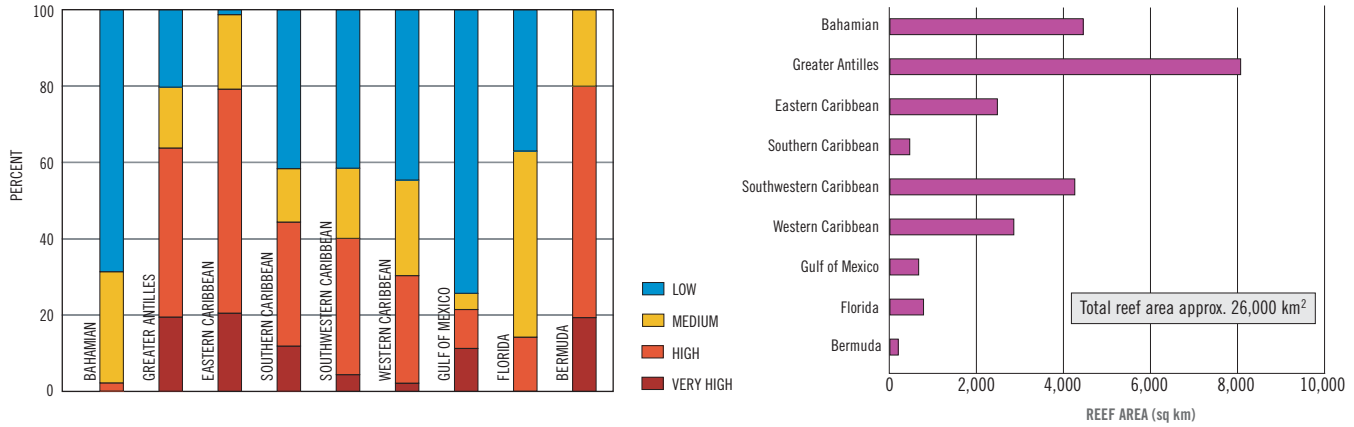
PHOTO: KRISHNA DESAI

Coral reefs in the Caribbean have undergone massive changes over the past several decades[87] as they evolved from a coral-dominated to an algal-dominated state.[88] Evidence of decline is widespread. Surveys conducted between 1998 and 2000 under the Atlantic and Gulf Rapid Reef Assessment (AGRRA - *see Appendix C*) found coral diseases throughout most of the Wider Caribbean, with very few areas exhibiting no occurrences.[89] AGRRA surveys reported few sightings of large-bodied snappers and groupers, and Reef Check surveys recorded an absence of Nassau Groupers in over 80 percent of the sites surveyed across the region.[90] They were once among the commonest fishes of the Caribbean. This strongly suggests the entire region is overfished for many heavily targeted species.[91] Reef Check surveys have also identified sewage pollution as a problem in nearly one-quarter of sites surveyed since 1998.[92] Monitoring of live coral cover by the Caribbean Coastal Marine Productivity Program (CARICOMP – *see Appendix C*) between 1993 and 2001 found declines in live coral on nearly two-thirds of sites for which time series data were available.[93] However, the AGRRA program found a mean live coral cover of 26 percent on sites around 10 m depth, suggesting that despite significant loss from many large-scale disturbances, considerable coral remains.[94]

Chapter 3 examined threats to Caribbean coral reefs, on a region-wide, threat-by-threat basis. This chapter examines these threats, along with available information on condition and protection of reefs, in greater geographic detail for nine Caribbean sub-regions. *(See Map 10.)* Figure 3 provides a summary by sub-region of reef area and the Reefs at Risk Threat Index. More detailed country profiles—including information on status of, threats to, and protection of coral reefs for 35 Caribbean countries and territories—are available online at http://reefsatrisk.wri.org.

MAP 10. CARIBBEAN SUB-REGIONS

FIGURE 3. SUB-REGIONS BY REEFS AT RISK THREAT INDEX AND REEF AREA



BAHAMIAN

The Bahamian Banks form an extensive archipelago of islands, cays, and sandbanks separated by deep ocean channels, extending more than 800 km from Southern Florida to Hispaniola. The northern and central islands rest on two large bank systems—the Little Bahama Bank and the Great Bahama Bank—with water depths of less than 10 m.[95] Further south and east are a number of smaller banks and isolated islands, with the politically separate Turks and Caicos Islands (TCI), consisting of the Caicos Bank and Turks Bank, at the southeastern end.[96]

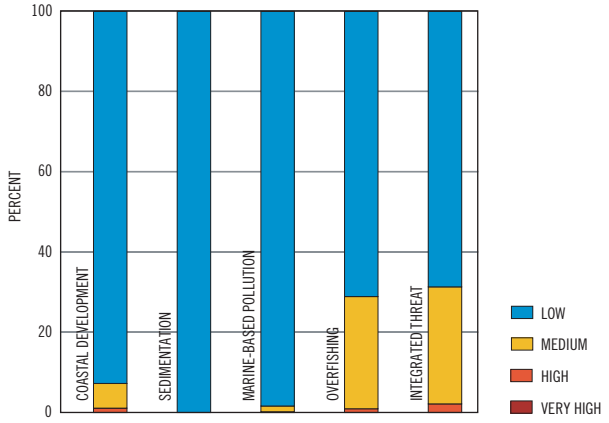
The reefs there are extensive. There are thousands of small patch reefs, dozens of narrow fringing reefs, and some bank barrier reefs, such as the Andros Barrier Reef. The reefs are most prominent on the windward north and eastern sides of the islands and cays.[97]

The Bahamas and TCIs possess some of the least threatened coral reefs in the Caribbean region. Only about 30 percent of the sub-region's coral reefs were identified as threatened by overfishing, and this is the only threat identified in most areas. Coastal development and pollution from marine-based sources threaten few coral reefs in the area, and watershed-based threats rated low, owing to the narrow, flat topography of most of the islands. This is reflected in observations of reef condition, which has declined in waters off the more developed and populated islands, but is generally good in isolated offshore banks.[98]

In the Bahamas, the commercial and export fishery is well-developed. In addition, a recreational and local consumption fishery[99] targets the commercially valuable lobster, conch, grouper, snapper, and jacks.[100] The populations of grouper and conch both show evidence of overfishing.[101] Reef fishes are little exploited in the TCIs, and fishing pressure on herbivores is almost nonexistent. There are concerns about poaching by foreign fishers, mostly from Haiti and the Dominican Republic, using illegal methods. Declines in lobster and conch populations are causing some fishers to turn to reef fish as an alternative resource, which may change the fishery situation.[102]

Growing tourism has led to localized problems—such as waste management,[103] destruction of coastal habitats for hotel and marina development, and diver damage to

REEFS AT RISK IN THE BAHAMIAN BANKS



corals[104]—on some of the islands. Several large developments and the likely introduction of cruise ships to the TCIs threaten the viability of the national parks, nature reserves, and sanctuaries adjacent to these areas.

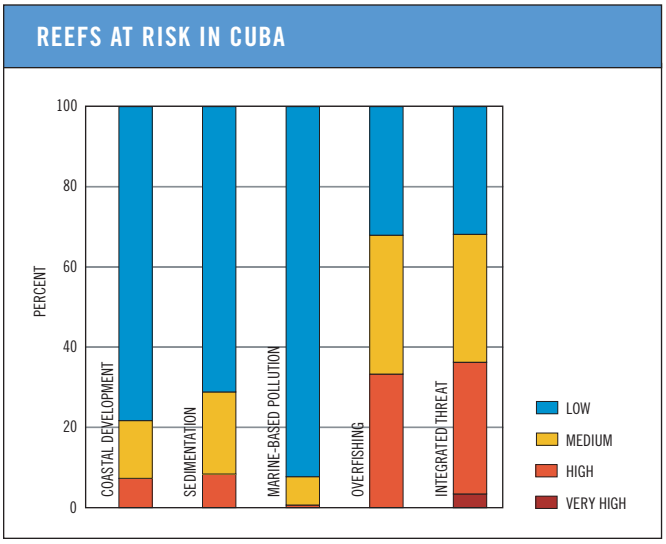
Concerned about the continued degradation of its marine resources, the government of the Bahamas was a pioneer in reef protection, establishing its first Land and Sea National Park in 1958 in Exuma Cays. The park became a no-take fisheries replenishment area in 1986, the first of its kind in the Caribbean. The reserve supports a concentration of conch 31 times greater than outside the park.[105] This success contributed to the government's announcement of a policy decision in 2000 to protect 20 percent of the Bahamian marine ecosystem and 10 new national parks were established in 2002. In the TCIs, a Conservation Fund was recently established to provide monetary support for management, financed by a 1 percent share of all tourist and accommodations taxes.

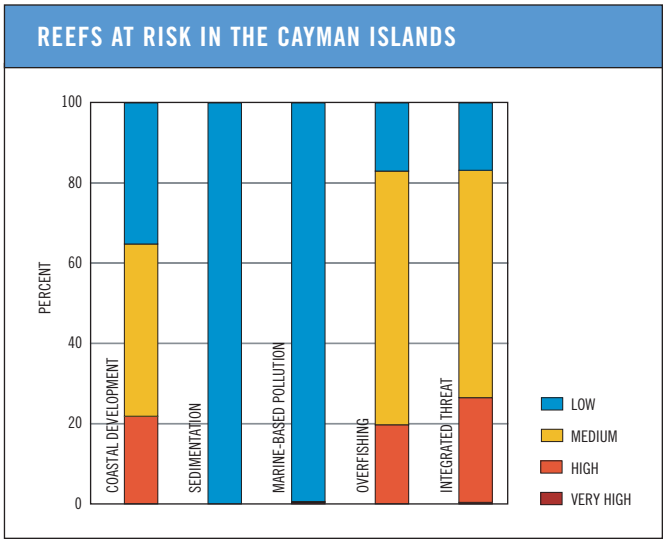
GREATER ANTILLES

Located in the center of the Caribbean Sea are the islands of the Greater Antilles: Cuba, the Cayman Islands, Jamaica, Hispaniola (made up of Haiti and the Dominican Republic), and Puerto Rico. This study estimates that coral reefs cover over 8,600 sq km within the Greater Antilles. More than one-third of them are located within the territorial waters of Cuba, which has a broad shelf area and chains of offshore islands and coral cays. The narrower shelves of the other islands support mainly fringing and small barrier reefs. Jamaica and the Dominican Republic also have important offshore bank reefs.

Overall, we rate more than two-thirds of Cuba's reefs as threatened, with over 35 percent at high threat. Overfishing is the main threat to Cuba's reefs, with over 65 percent of the reefs threatened. Landing statistics for the commercially important snapper and grouper indicate decreasing annual catches and decreasing maximum size over the last 20 years due to unsustainable fishing practices.[106] However, Cuba's coral reef fishery is probably in better condition than those of other Caribbean countries.[107] About one-quarter of reefs were rated as threatened by sedimentation and pollution from inland sources, around one-fifth by coastal development, and fewer than 10 percent by marine-based sources. The low sedimentation and coastal development threats are mainly due to the offshore location of many reefs, outside the influence of land-based sources of pollution,[108] and to Cuba's relatively undeveloped tourist industry. Remote reefs (e.g., around the southern archipelagos) are in very good condition but, near large population centers such as Havana, signs of decline are evident, with low coral cover, overgrowth by algae, and disease outbreaks.[109]

The reefs in the Cayman Islands are managed under strict marine conservation laws establishing a zoned system of MPAs. However, this has not prevented overfishing of conch and lobster, and increased human usage is a major concern.[110] The analysis found an estimated 80 percent of the reefs are threatened, predominantly from overfishing as well as coastal development (resulting from population



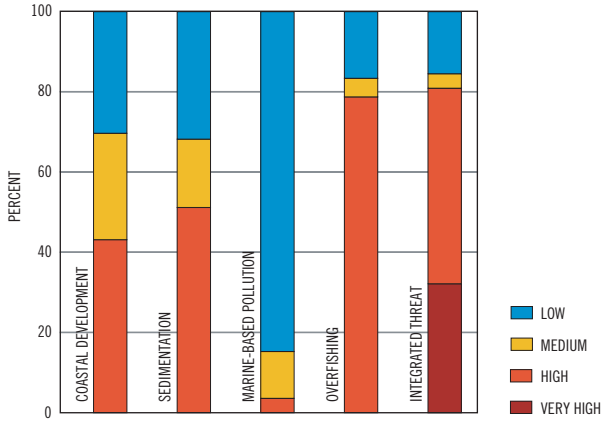


growth and intensive tourism, including impacts from cruise ships).[111] AGRRA surveys in 1999 and 2000 found the reefs to be in generally good condition, though with some obvious signs of impact, particularly on the more developed island, and focus of the dive industry, Grand Cayman.[112]

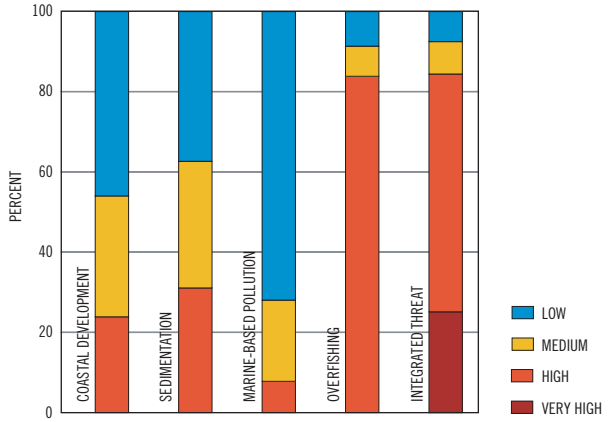
Over 80 percent of the reefs in Jamaica, Haiti, and the Dominican Republic are identified as threatened by human activities, with one-third under very high threat. The majority of reefs are threatened from multiple sources. Widespread unemployment, densely populated coastal zones, easy access to the reefs, and narrow shelf areas mean the reef resources have been heavily used to provide livelihoods and sustenance. Unfortunately, this open and unregulated access has reduced the overall productivity of the reefs for all. Illegal fishing activities are common, and capacity for enforcement of regulations is limited.[113] However, Jamaica is developing new regulations for reef fisheries and existing regulations for the Pedro Bank conch export fishery allow it to remain open under the Convention of International Trade in Endangered Species (CITES). In contrast, the international trade in conch from Haiti and the Dominican Republic is banned under CITES.

In Jamaica and the Dominican Republic, huge growth in the tourism industry has generated some alternative employment opportunities, but not enough to reduce fishing pressure. Also, mass tourism brings its own suite of problems, with swelling coastal populations and unmanaged coastal development threatening an estimated 70 percent of reefs.

REEFS AT RISK IN JAMAICA AND HISPANIOLA



REEFS AT RISK IN PUERTO RICO



Similar tourism-related pressures, compounded by rapid urban and industrial development over the past 40 years, threaten more than half of Puerto Rican coral reefs.[114] Both the permanent population and tourist traffic have grown rapidly,[115] and nearly 60 percent of the people live within 10 km of the coast. (*See Appendix A, Table A3.*)

Overfishing threatens over 90 percent of Puerto Rico's coral reefs. Puerto Rican reef fisheries have plummeted during the last two decades and show the classic signs of overfishing.[116] Reported fish landings fell 69 percent between 1979 and 1990.[117] This analysis identified sedimentation and pollution from inland sources as threatening over 60 percent of the commonwealth's reefs; coastal development as threatening over one-half, with marine-based threats jeopardizing about one-quarter. Overall, over 90 percent of Puerto Rico's reefs were rated as threatened, with over 80 percent at high risk and therefore among the most threatened in the Caribbean. Most common diseases have been observed on the degraded reefs surrounding the main island and have caused considerable damage to depths of 30 m.[118]

Except for the Caymans, all the island nations rely heavily on agriculture for livelihoods and export earnings from sugar, coffee, bananas, or tobacco. Land clearing and poor agricultural practices have led to increased erosion. Near the mouths of rivers, sedimentation from soil erosion threatens many reefs. Puerto Rico, with its more diversified economy, is less reliant on agriculture.

Lacking political and financial support, protection of the reef resource is limited in Cuba, Jamaica, and the Dominican Republic, and nonexistent in Haiti. Puerto Rico has put natural reserves under government jurisdiction, but these reserves afford coral reefs only slight protection, and effective management is limited by lack of laws regulating fishing activities and recreation.[119]

EASTERN CARIBBEAN

Extending from the U.S. Virgin Islands south to Grenada, the Eastern Caribbean sub-region encompasses one of the world's most compact aggregations of nations and autonomous territories.[120] The island chain consists mostly of mountainous and forested volcanic islands (from Saba 700 km south to Grenada), typically with small marine shelves, as well as a number of flatter coralline islands, with wider shelf areas (U.S. Virgin Islands, British Virgin Islands, Anguilla, St. Maarten/St. Martin, Antigua and Barbuda, and Barbados). Reef development has been most extensive along the sheltered western shorelines of the drier limestone islands. This study estimates a coral reef area of about 2,600 sq km in the Eastern Caribbean sub-region.

The analysis identified overfishing as the most pervasive threat to reefs within the Eastern Caribbean, affecting almost all reefs as evidenced by the absence of larger fish in the catch and scarcity of some of the larger species.[121] Though largely artisanal or small-scale commercial, fishing is an important activity on most of these islands.[122] Easy access to the reef resources, high population densities on many islands, and scarcity of other employment opportunities contribute significantly to the threat from overfishing.

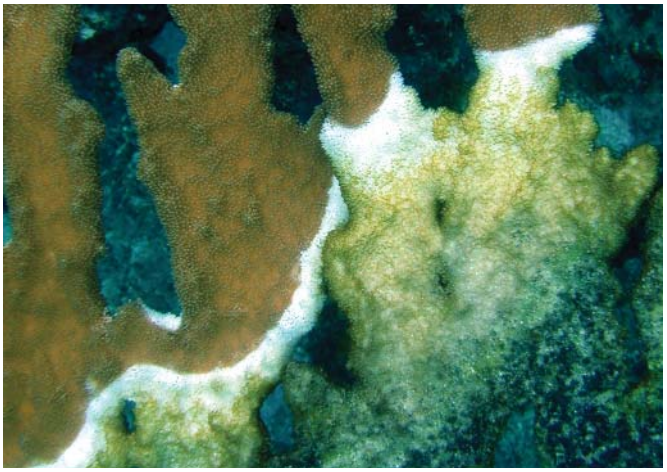


PHOTO: ANDY BRUCKNER

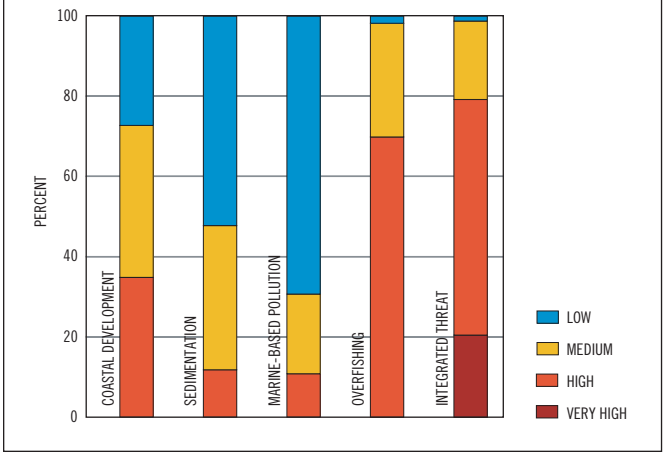
Coral diseases, such as white band, have affected reefs throughout the Caribbean.

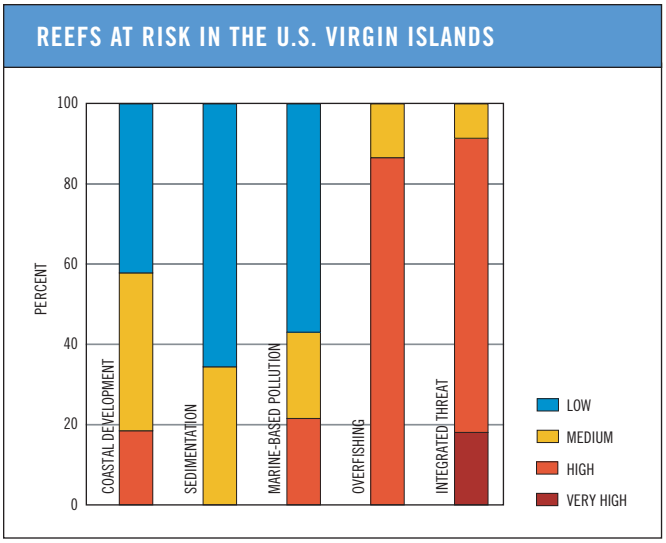
Second in importance is coastal development, identified as threatening more than 70 percent of the sub-region's reefs. The development of the necessary infrastructure to support high population densities and tourism growth has resulted in coastal degradation through increased siltation from land reclamation, dredging and construction, and pollution from sewage outfalls. Also, tourist activities such as yachting have been cited as contributing to the degradation of reefs through anchor damage and local pollution.

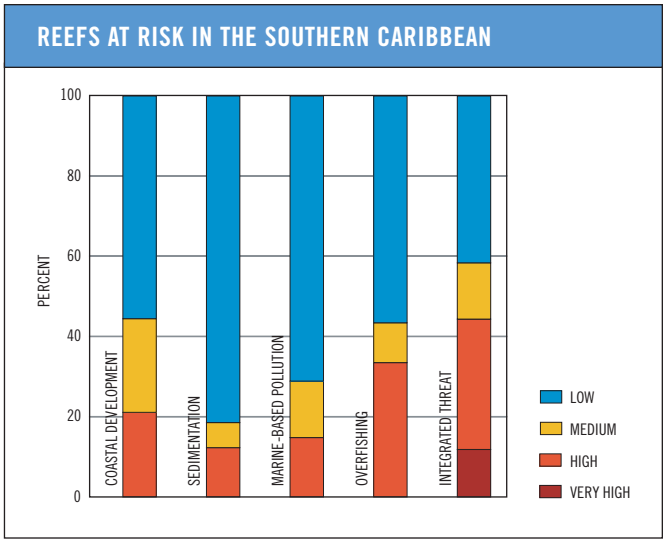
Historically, many of the islands depended on agriculture for export earnings, mainly from sugarcane and bananas. Although agriculture has been surpassed by tourism in terms of earnings,[123] it is still important, and poor land-use practices and excessive deforestation have led to increased sedimentation and pollution in the coastal zone. Sedimentation and pollution from inland sources were identified as threatening nearly one-half of the reefs in the Eastern Caribbean sub-region.

A number of MPAs have been established in the Eastern Caribbean, and many proposed, but inadequate funding, poor enforcement, and lack of local involvement in the management process have limited the effectiveness of resource protection, particularly against overexploitation. However, a few MPAs are outstanding for their effective planning and management of the reef resource, including Saba Marine Park and St. Eustatius Marine Park in the

REEFS AT RISK IN THE EASTERN CARIBBEAN







Netherlands Antilles, and the Soufrière Marine Management Area, St. Lucia. *(See Box 3.)*

Almost 600 sq km of coral reefs are found around the U.S. Virgin Islands (USVI). Overfishing is the main threat to reefs, with over 85 percent under high threat. Effects of intensive fishing are evident and fisheries are close to collapse—even those inside MPAs are deteriorating.[124] Marine-based pollution is also a significant threat, due to the many millions of visitors to the parks who arrive each year on cruise ships or smaller boats.[125] Growing tourism contributes to coastal development, and wastewater disposal poses a particular problem. Intense visitation of some reefs has also caused damage.

Frequent natural disturbances take their toll on reefs as well. Eight hurricanes have swept across the USVIs since 1979. Diseases have ravaged the corals over the last three decades,[126] and periodic bleaching episodes, particularly in 1998, all contribute to the overall stress and degradation of reefs here. The hard coral cover is declining. At the Buck Island National Monument, for example, the cover dropped from 85 percent in 1976 to 5 percent in 1988 because of hurricanes and disease.[127]

SOUTHERN CARIBBEAN

On the continental shelf of the Southern Caribbean, reef development is severely inhibited by upwelling and by freshwater and sediment runoff.[128] The best developed and more diverse coral reefs are found around the chain of islands and archipelagos running parallel to the continental coast: Curaçao and Bonaire (under the jurisdiction of the Netherlands) and the Venezuelan island systems of Islas las Aves, Islas los Roques, La Orchilla, and La Blanquilla. Reef development around Trinidad is slight, largely due to the influence of the Orinoco River, which delivers huge volumes of sediment-laden fresh water.[129]

This analysis did not identify any reefs around the offshore Venezuelan islands as threatened, due to low population pressure and little development. However, fishing and a growing tourism industry represent potential threats.[130] In contrast, human activities, particularly artisanal fishing, are estimated to threaten all the reefs around the offshore islands of Aruba and Tobago. Marine-based pollution is also a threat on Curaçao and Aruba, where large oil refineries have been operating since the early 1920s. The threat from coastal development on Bonaire comes mainly from the direct and indirect impacts of increasing dive tourism.[131]

The Bonaire Marine Park is a model for reef protection. Established in 1979 and declared a national park in 1999, it is protected under island legislation and has been under continuously active management since 1991. *(See Box 3.)*

Reefs along the continental Venezuelan coast are subject to pressure from overfishing, coastal development, and some port facilities. Deforestation has increased sediment loads to coastal waters,[132] and all reefs along the continental coast were identified as under high threat from land-based sources. Although most Venezuelan coastal coral reefs are located within national parks with protective regulations, inadequate staffing and logistical and financial capacity prevent full enforcement.[133]

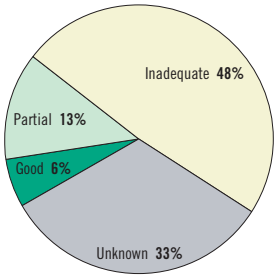
BOX 3. MARINE PROTECTED AREAS

To gain a better understanding of the actual protection afforded reefs in the region, the Reefs at Risk in the Caribbean Project asked experts to evaluate the effectiveness of Marine Protected Areas (MPAs). Particularly with the growth of tourism and fisheries in coral reef areas, MPAs are an important management tool for conserving coral reefs. Many Caribbean nations have established parks or protected areas to safeguard marine biodiversity while helping to maintain economically important marine resources.[a] The Reefs at Risk in the Caribbean Project identified 285 designated MPAs across the 35 states and territories of the Caribbean region *(see Appendix A, Table A5)*.

Because compiling detailed information on a region-wide basis is very difficult, the MPAs were assessed on only four broad criteria: existence of management activity, existence of a management plan, availability of resources, and extent of enforcement. Combined, these criteria were used to generate a simple measure of management effectiveness. Of the 285 parks, only 6 percent were rated as effectively managed and an additional 13 percent were judged to have partially effective management. Nearly half were rated as having an inadequate level of management and, therefore, offered little protection to the resources they were designed to protect. The level of management was unknown for about one-third. This lack of information most likely reflects a deficiency in human and financial resources. Thus, although about 20 percent of the region's coral reefs are contained within MPAs,[b] only about 5 percent of the region's reefs are within MPAs with effective or partially effective management.

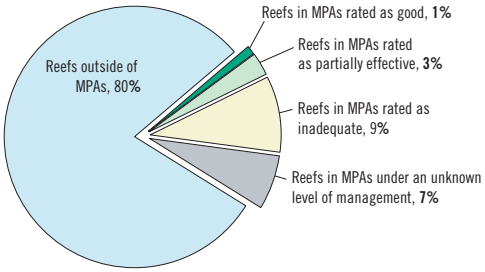
Common reasons for MPA failure are lack of long-term financial support and a lack of support from the local community, which can usually be traced to a lack of local involvement in planning and a failure to share financial or other benefits from protection. Sustainable financing for MPAs must be developed if they are to function well in the long term.[c] Only a handful of parks in the Caribbean directly generate income. For example, Bonaire Marine Park introduced an annual diver admission fee of US$10 in 1992, which currently raises 60 percent of the park's budget, and Saba Marine Park raises 70 percent of its income through diver fees. Revenues from a yacht-mooring system in the British Virgin Islands (BVI) exceeded US$200,000 in 2002, which allows the BVI Marine Conservation Program to be completely self-sustaining.[d]

Management Effectiveness of Caribbean MPAs



Number of MPAs in the region is approximately 285.

Protection of the Caribbean's Coral Reefs



Area of reefs in the region is approximately 26,000 sq km.

Notes:

a. J.A. Dixon, L. Fallon Scura, and T. van't Hof. 1993. "Meeting Ecological and Economic Goals: Marine Parks in the Caribbean." *Ambio* 22 (2-3): 117-125.

b. The scale of the data and the degree of completeness of the MPA data set limit the analysis. Many MPAs are represented only by points, not their actual spatial boundaries, so their extent had to be approximated. Thus, this analysis provides only a rough estimate based upon the best available data.

c. B. Kelleher, C. Bleakley, and W. Wells, *A Global Representative System of Marine Protected Areas. Volume II: Wider Caribbean, West Africa and South Atlantic* (Washington DC: The Great Barrier Reef Marine Park Authority, The World Bank and the World Conservation Union (IUCN), 1995).

d. J.C. Smith Abbott (Director, BVI National Parks Trust), personal communication, 12 January 2004.

SOUTHWESTERN CARIBBEAN

Large volumes of fresh water from extensive mainland water systems flow into the coastal waters of the Southwestern Caribbean, and therefore reef development close to shore is generally poor. Localized areas of significant reef development are found in the central Nicaraguan shelf (Miskito Cays and the Corn Islands),[134] off the Panamanian coast (the Bocas del Toro and San Blas archipelagos),[135] and in the Colombian oceanic archipelago of San Andrés and Providencia,[136] located more than 700 km from the Colombian continental coast.

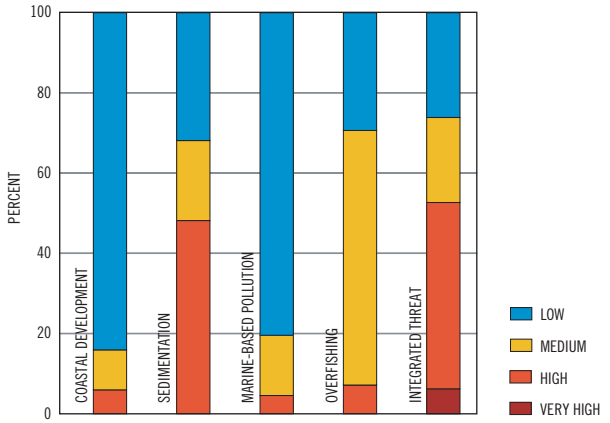
The Nicaraguan shelf is the broadest in the Caribbean, and most reefs around offshore cays and islands escape direct continental influences. Overfishing is the predominant threat to Nicaragua's reefs, with about 15 percent identified as threatened. Threats to reefs from land-based sources and marine-based sources are low. The only inhabited islands are the Corn Islands toward the south, where high population density, coastal development, and overfishing are affecting the reefs. The islands contribute significantly to the Nicaraguan lobster and scalefish export fishery.[137]

Farther south along the continental coast toward Costa Rica, Panama, and Colombia, sedimentation is the prevalent stressor, threatening all but a few reefs around some small Colombian coastal islands. Extensive and indiscriminate deforestation and poor agricultural practices in inland watersheds have increased runoff and erosion. Uncontrolled tourist activity is a large and growing problem for many continental areas. Marine-based pollution is harming Panamanian reefs in the west around the Bocas del Toro archipelago; however, these reefs still hold some of the most extensive stands of elkhorn coral remaining in the Caribbean.[138]

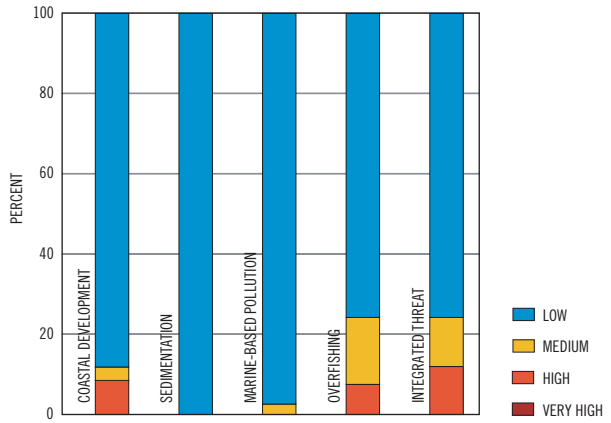
Some of the best reefs in Panama are found in the Kuna-Yala (San Blas) Reserve, managed independently of the government by the indigenous Kuna since 1938.[139] A unique threat not captured in the Reefs at Risk analysis, however, is the traditional Kuna practice of coral mining and landfilling, which significantly modified some reefs in the area over decades.[140] Growing tourism has further encouraged the Kuna to extract corals to sell as souvenirs.[141]

About two-thirds of Colombia's coral reefs in the Caribbean are found within a series of oceanic islands (San Andrés, Providencia, Santa Catalina), atolls, and banks that make up the San Andrés and Providencia archipelago. Only the three major islands are permanently inhabited; tourists and fishers visit the cays, atolls, and banks occasionally. Overfishing and coastal development are the main threats to reefs around the populated islands. Human pressure is a particular problem on San Andrés, where a resident population of more than 60,000 and a booming tourist industry inhabit a surface area of only 25 sq km, making this the most densely populated island in the Caribbean.[142] Reefs close to high-density coastal populations are also threatened by discharges of untreated sewage into coastal waters.

REEFS AT RISK IN THE CONTINENTAL SOUTHWESTERN CARIBBEAN



REEFS AT RISK IN THE SAN ANDRES AND PROVIDENCIA ARCHIPELAGO



Protection along the continental coast is minimal. Parks have been established in each country, but national legislation and institutional frameworks are weak, and funding for monitoring and enforcement is limited. The archipelago of San Andrés and Providencia was declared the Seaflower Biosphere Reserve in 2000 by UNESCO's Man and Biosphere (MAB) Program[143] Although extractive or disturbing activities are now regulated, infrastructure and resources are still scarce for effective control.

WESTERN CARIBBEAN

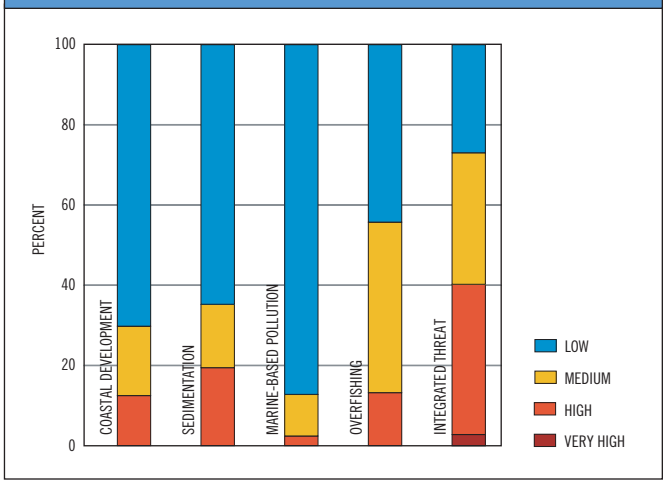
The Western Caribbean subregion includes one of the longest reef systems in the region. The Mesoamerican Reef stretches from the Mexican Caribbean coast of the Yucatan Peninsula to the Bay Islands off the coast of Honduras. This reef system includes a near continuous barrier reef, which runs for 220 km off the coast of Belize.

Overfishing is the most pervasive threat to reefs in the Mesoamerican reef. Off Mexico's Yucatan Peninsula, the Caribbean reefs have been subject to intense artisanal fishing since the 1960s,[144] when this formerly underdeveloped and isolated coast was opened to the pressures of modern development.[145] In Belize, there is evidence of overfishing by small-scale local fishers and industrial fishing fleets.[146] Intensive fishing in Honduras has affected the reef populations around the Bay Islands, and fishers also travel to remote offshore banks instead of fishing the heavily exploited fringing reefs.[147]

Coastal development is rapid, with tourism burgeoning in many coastal areas. The Mexican state of Quintana Roo has become a very successful resort area and is now the main tourist destination within the country. Coastal development is spreading quickly southward along the coast, and the government plans to build a huge, high-density tourist resort complex extending down to the Belizean border.[148] In Belize, larger cays and tourist centers, like Amergis Caye and San Pedro Town, are growing rapidly as a result of tourist-based economic activity.[149]

Sedimentation is a problem for reefs near the coasts, particularly off southern Belize and continental Honduras, where the intensification of agriculture and logging over the last few decades has resulted in increased erosion. Nutrient

REEFS AT RISK IN THE MESOAMERICAN REEF



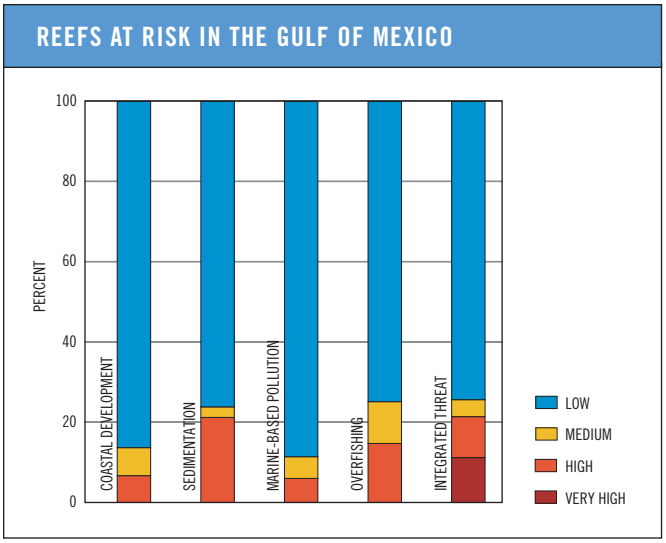
pollution is also a problem due to runoff of fertilizer from banana and citrus plantations, from southern Belize down through Guatemala and Honduras. However, standards for minimizing the environmental impact of banana cultivation are being encouraged through initiatives such as the Better Banana Project.[150]

Reefs in the Mesoamerican reef, particularly near Belize, were severely damaged by two large-scale, natural disturbances in 1998. A bleaching event, coinciding with high sea-surface temperatures,[151] was followed by Hurricane Mitch, a Category 5 storm. Bleaching caused catastrophic coral loss in the lagoonal reefs of Belize,[152] while the hurricane caused widespread coral destruction in fore reefs and outer atoll reefs.[153] The full consequences of these events will take years to emerge.

The Belize Coastal Zone Management Authority and Institute is a model of integrated coastal management for the region. The country's system of 13 MPAs is well-established, with most under active co-management with local NGOs.[154] Monitoring across the whole sub-region will increase under the World Bank/GEF Mesoamerican Barrier Reef System project, which has developed a standardized monitoring protocol for the region.[155]

GULF OF MEXICO

Reef development in the Gulf of Mexico is extremely limited due to the large inputs of sediment-laden freshwater from the North American continent. In U.S. waters, there



are scattered coral and reef developments; the best documented is the Flower Garden Banks, located 190 km southeast of Galveston, Texas. In Mexican waters, isolated groups of small formations along the southwestern Gulf, and numerous slightly larger reefs are found along the outer Yucatan shelf, including the very large atoll-like reef at Alacranes in the northern Campeche Bank.[156]

The Flower Garden Banks National Marine Sanctuary is managed and protected by the National Marine Sanctuary Program run by the National Oceanic and Atmospheric Administration (NOAA). Illegal fishing by both commercial longliners and recreational spearfishers has been reported in the area.[157] Other threats are low, and the coral is in excellent condition.[158] The live coral cover has changed little since 1972, averaging 47 percent in 1995 and 52 percent in 1997.[159]

Pressures are high on nearshore Mexican reefs, such as those near the large port of Veracruz, due to urban, agricultural, and industrial wastes carried in the outflow of major river systems.[160] In the 1970s, disease caused massive mortality of *Acropora* coral in the southwestern Gulf and around Alcarnes.[161] In addition, Mexican reefs close to the shore and to urban areas have been exploited by fishers for hundreds of years and more recently by recreational users. Though not captured in this analysis, even the reefs farther offshore on the Campeche Bank are under pressure from fishers who navigate up to 300 km of open ocean to fish in outboard motor boats 24 feet long and equipped with just a small ice chest.[162] Also not captured in the analysis is the threat to offshore reefs from activities associated with the Gulf's many oil fields. The threat comes from oil and gas exploration, the associated vessel traffic, and risk of spills.

FLORIDA

Florida's coral reefs are extensive. The Florida Keys are a chain of 822 low-lying islands. The reef tract arches 356 km along the shallow offshore waters of the Keys, from the 683-sq km Biscayne National Park south of Miami to the Dry Tortugas. The tract is almost continuous, and most of it lies within the boundaries of the 9,800-sq km Florida Keys National Marine Sanctuary (FKNMS).[163]

Our analysis probably understates the threat to coral reefs in Florida. Most of these reefs are more than 4 km offshore and thus do not register as threatened by development on the Keys. Also, because south Florida is very flat, the area does not score high for watershed-based threat. The analysis identified over 60 percent of Florida's reefs as threatened.

The decline in reef health in southeastern Florida and the Keys is well documented. For example, live coral cover in the FKNMS decreased by 38 percent from 1996 to 1999, and observations of coral disease increased.[164] Over the past 20 years, coral bleaching has become more frequent, lasted longer,[165] and been responsible for some of the dramatic declines in coral cover in the sanctuary since 1997.[166]

The predominant threat comes from overfishing, with almost 60 percent of reefs threatened. Serial overfishing throughout the Keys has dramatically altered reef fish popu-

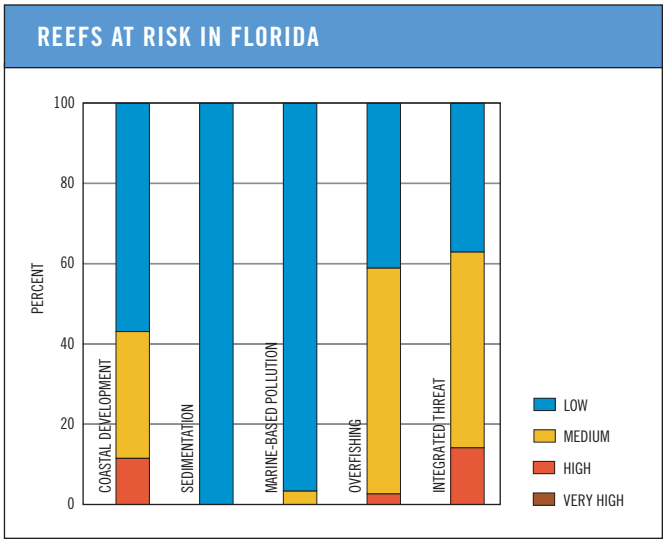


PHOTO: WOLCOTT HENRY©

Reef decline in the Florida Keys is well documented through extensive monitoring.

lations. Targeted reef fish are highly exploited. In the Florida Keys, 23 out of 35 market fish species are overfished,[167] and 26 of 34 fish species are considered overfished in Biscayne Bay.[168] Pressure comes not only from commercial fishing but also from recreational fishing in South Florida, which has grown exponentially since 1964, with no set limits on the number of boats allowed to fish.[169] Several, mostly very small, no-take zones have been declared in the FKNMS to conserve dwindling fish stocks, and early results show improvements.[170]

However, the greatest pressures, direct and indirect, on the reefs of the Keys come from the millions of seasonal and temporary visitors that swell local populations. Direct damage has been documented from boat groundings and anchors as well as divers and snorkellers who touch, kick, or stand on corals. Indirect impacts come from sewage pollution to nearshore waters because of increasing development and the use of septic tanks as the sole method of wastewater treatment.

The reefs are also subject to indirect impacts from altered freshwater flow into coastal waters. Water management systems for flood control, agriculture, and urban water supplies have dramatically altered freshwater flow through the Everglades and into the ocean. Florida Bay and nearshore waters provide critical nursery and juvenile habitat for a variety of reef species, and declines seen in these areas indirectly affect the overall health and structure of offshore reefs.[171] This freshwater also carries excess nutrients, and eutrophication of nearshore water has been documented.[172]

BERMUDA

Bermuda is a crescent-shaped chain of about 150 islands. Around them grow the most northerly coral reefs in the world, surviving because of warm water eddies from the Gulf Stream. The most pervasive threat identified in this analysis is from overfishing, affecting all reefs (although this is probably overestimated since no account is taken of the ban in the use of fish traps on Bermuda's reefs). Other threats to reefs come from marine-based sources since Bermuda is a popular cruise destination (over 60 percent of the reefs are rated as threatened), and coastal development (about half are rated as threatened). Sedimentation was not rated as an important threat, owing to the relatively small islands and gentle topography. The observed condition of the reefs is fairly healthy, with few declines in live coral cover since the early 1990s, and corals are relatively free from disease and bleaching.[173]