

STATUS OF WESTERN ATLANTIC CORAL REEFS IN THE LESSER ANTILLES

A.F. Smith, C.S. Rogers- and C. Bouchon'

Caribbean Natural Resources Institute, Clarke St., Vieux Fort, St. Lucia
 - Virgin Islands National Park, P.O. Box 710, St. John, USVI 00831
 Université Antilles-Guyane, B.P.592, 97159 Pointe-A-Pitre, Guadeloupe, FWI

ABSTRACT

The Lesser Antilles include high volcanic islands with a limited marine shelf, and low coralline islands with a more extensive shelf. Within the group, reefs are affected to a greater or lesser degree by widely differing conditions of rainfall and runoff, hurricane damage, recreational use and fishing pressure. While degradation is reported in many areas, there are few long-term studies that quantify trends in reef status. In recent years there has been an increase in the number of management initiatives, and in the number of reef areas under active and effective management.

INTRODUCTION

Over the past 10 - 20 years, progressive degradation of the reefs in the Lesser Antilles (Fig. 1) has been accompanied by growing recognition of their economic and ecological importance, and increasing interest in coral reef monitoring and management. Many of the reefs have less live coral, fewer and smaller fish, and more algae than before as a result of a combination of human and natural factors. In the Lesser Antilles, hurricanes and coral diseases have had especially severe consequences. Recent devastating hurricanes include Gilbert (in 1988), Hugo (in 1989), Luis and Marilyn (in 1995).

In many locations, the primary reef-building coral in shallow water, *Acropora palmata*, has been severely affected by white band disease, and little recovery has been observed. At some sites, new colonies of the species have been destroyed by major storms. The other dominant reef-building species, *Montastrea annularis*, has suffered severe losses from physical damage by hurricanes. The series of bleaching episodes, probably associated with above normal water temperatures, have caused partial mortality of many species. The massive die-off of the long-spined sea-urchin, *Diadema antillarum* in 1983-1984, combined with overfishing, has led to dramatic increases in the abundance of macroalgae which injure coral colonies through shading and abrasion, and which hinder coral recruitment and survival. On islands with steep topography and high population densities, sedimentation from clearing steep hillsides and input of nutrients from land based sources are particularly damaging.

Marine-based tourism has expanded rapidly in the region. More cruise ships visit the islands, and new docks, marinas and hotels have been built, often after dredging and filling of coastal areas. Diving tourism is also developing rapidly in many islands. In some of the islands with narrow fringing reefs, there is concern that the concentration of recreational diving at popular sites will contribute to their physical degradation.

STATUS OF REEFS AND THEIR MANAGEMENT**US Virgin Islands**

Most of the coral reefs around St. Thomas, St. John, and St. Croix are shallow fringing reefs which parallel the islands' coastlines. Many of them are true coral reefs established on a framework of coral skeletons deposited over thousands of years. Elsewhere, coral reef organisms grow on submerged boulders and rock ridges near shore. Over 40 species of scleractinian corals have been found on USVI reefs (Beets and Lewand 1986, personal observations).

Coral reefs in the USVI are facing the same pressures as reefs elsewhere in the Caribbean (Rogers 1985; Beets et al. 1986). Hurricanes and other major storms, higher than normal water temperatures, and coral diseases have combined with destruction from boat anchors and boat groundings, careless land use,

dredging, pollution, and overfishing to cause reef deterioration. Within the last 15-20 years, the amount of live coral has declined while the abundance of algae has increased. The increase in algae probably reflects both the increase in substrate from the death of the coral and the inability of the herbivorous fish and sea urchins to keep the algal growth in check.

Long-term monitoring of permanent transects on reefs around St. John began in 1989 in Lameshur Bay and Buck Island, and in 1991 in Newfound and Francis Bays. These sites have provided detailed information on the effects of storms and on recovery of reefs from storms and anchor damage (Rogers et al. 1991; Rogers 1992). Perhaps the most conspicuous change on USVI coral reefs over the last few decades is the decline in elkhorn coral (*Acropora palmata*), the primary reef-building coral in the Caribbean, apparently due to white band disease. (Robinson 1973; Gladfelter 1982).

At Buck Island, white band disease and physical destruction from Hurricanes David and Tropical Storm Frederic (1979) reduced the live cover of elkhorn from 85% to 5% (Rogers et al. 1982, Gladfelter 1991) and Hurricane Hugo in 1989 led to further declines (Gladfelter 1991).

In 1987, a study of 50 *A. palmata* colonies in Hawksnest Bay off the north shore of St. John indicated that only 10 remained undamaged seven months after initial observation (Rogers et al. 1988). Heavy ground seas and damage from snorkelers and boats were responsible for the decline.



Fig. 1 : The Lesser Antilles.

The USVI have been hit by four hurricanes and numerous tropical storms in the last 15 years. Some of the most severe damage was associated with Hurricane Hugo in 1989 (Edmunds 1991a; Hubbard et al. 1991; Rogers et al. 1991; Bythell et al. 1992).

At long-term monitoring sites around St. John and Buck Island, coral cover, initially less than 30%, dropped by 40 to 73% following Hugo (Edmunds 1991a; Rogers et al. 1991; Rogers 1992; Bythell and Bythell 1992). The dominant coral species, *Montastrea annularis*, declined about 35% in Lameshur Bay. Studies have shown that no substantial recovery in total coral cover has occurred, although coral recruitment is occurring. Decreases in the amount of living *M. annularis* are of particular concern because this is now the major reefbuilding species in the Caribbean.

In 1995, Hurricanes Luis and Marilyn caused severe damage to reefs off the north side of Buck Island and the south side of St. John. In some north shore bays on St. John, more physical destruction was associated with boars, which broke loose and dragged across coral colonies, than from the storm itself.

Although the physical destruction from hurricanes and white band disease has produced the most drastic changes in USVI reefs, other stresses are also taking their toll. Probably the greatest potential threat to the reefs around the USVI is sedimentation associated with runoff from coastal development sites. A theoretical study of sediment runoff indicated that reef distribution around St. John is a function of watershed size, bay exposure and bathymetry, distance from sources of land-derived sediments, and storms (Hubbard 1987). Current development of private land inside and adjacent to park boundaries and construction of new roads has increased the flow of sediment into nearshore waters (Anderson 1994).

Black band disease has been reported for several species of hard corals, including *Montastrea annularis* and *Diploria strigosa*, around St. John (Edmunds 1991b) and at Buck Island Reef National Monument (Bythell et al. 1992). While the effects of black band disease are small compared with other stresses, it should not be ignored because it infects primary reef building species. Like coral bleaching which was observed in the USVI in 1987 and 1990, this disease appears to be correlated with higher sea water temperatures.

Increasing pressure from trap fishing has resulted in a decline in reef fish populations and a change in relative abundance of fish species on St. John reefs. In the 1960s, groupers and snappers made up 33% of the catch (Dammann 1969). By the 1980s parrotfishes were the principal catch (deGraf and Moore 1987), and a subsequent decline in average size of trapped parrotfishes indicates that these are now being overfished (Appeldoorn et al. 1992).

With respect to natural resource protection, national parks are a mixed blessing. Virgin Islands National Park attracts close to 1 million visitors a year, most of them arriving on cruise ships or smaller boats. A single anchor drop from a cruise ship in 1988 led to the destruction of almost 300 square meters of reef. Monitoring at this site reveals no significant recovery of hard coral 8 years later (Rogers, unpublished data). A survey of 186 boats in 1987 revealed that 32% were anchored in seagrasses and 14% in coral communities. About 40% of anchors in coral and 58% in seagrass beds were causing damage (Rogers et al. 1988). The installation of mooring buoys and limits on the size of vessels allowed in park waters have resulted in less pressure on these reefs, but in some areas there is little coral left to protect.

British Virgin Islands

The British Virgin Islands include Tortola, Virgin Gorda, Anegada, Jost van Dyke and approximately 40 smaller islands and cays. Tourism has expanded considerably in the BVI in recent years, primarily based on marine attractions. Yacht charter and recreational boating services, cruise ships and diving tourism are particularly important to the BVI economy. The development of the necessary infrastructure has resulted in coastal degradation, through increased siltation from

land reclamation, dredging and construction, and pollution from sewage outfalls. Anchor damage has been implicated in reef degradation, and the large numbers of novice divers are believed to be responsible for damage to corals at dive sites.

many reefs were badly damaged by Hurricane Hugo in 1989, particularly *Acropora palmata* zones in shallow water. In 1995, Hurricanes Luis and Marilyn were also destructive, but there are no data on the level of impact.

Three marine protected areas have been legislated to date. The Baths National Park and the Wreck of the Rhone Marine Park both include some coral reef areas, and are managed by the National Parks Trust. To reduce the impact of boat anchors the National Parks Trust and the Dive Operators Association collaborated in establishing permanent moorings at heavily used sites, starting in the Wreck of the Rhone Marine Park. The BVI mooring system has become a highly successful means of generating revenue for management (Geoghegan 1994). Horseshoe Reef protected area near Anegada is managed by the Government's Conservation and Fisheries Department, which attempts to limit diving and fishing.

Anguilla

Five marine parks were established in 1993, four of which are designed to protect reef areas. These four are Sandy Island, Prickly Pear, including the Seal Island reef system, Island Harbour and Dog Island Marine Parks, which are under the management of the Department of Fisheries. The first three islands have been developed for tourism, but infrastructure development itself has had little impact due to the low level of run-off and the distance of most reefs from shore. However, impacts from the large number of visitors include anchor damage and breakage of shallow corals by snorkelers. The reefs at Dog Island are reported to be pristine, and visiting is discouraged by the Department of Fisheries to maintain the system intact for comparative purposes, although a monitoring programme has not yet been started.

Anguilla has not been directly hit by a hurricane since 1960, but very high waves generated by Hurricane Luis in 1994 caused extensive damage to reefs, particularly to *Acropora palmata* stands in shallow water.

The Netherlands Antilles

The windward group of the Netherlands Antilles consists of the islands of St. Eustatius, Saba and St. Maarten. St. Eustatius is surrounded by a flat sandy plateau, and has the least coral development of the three. The coast consists mainly of steep cliffs and there is little shoreline development, apart from an oil trans-shipment facility. Hurricanes Luis and Marilyn in 1995 caused severe damage to soft corals and sponges, but local divers reported that recovery was rapid and that the rough seas removed large amounts of sediment that had accumulated from the eroding cliffs. Reefs along two sections of the coast are now protected within the St. Eustatius Marine Park, established by the Island Legislation in 1996, and managed by the St. Eustatius National Parks Foundation.

Saba has a steep topography which limits coastal development, and adverse human impacts are apparently minimal. The island is becoming increasingly popular as a diving destination. NO adverse effects from have yet been documented, but it is recognized that there is potential for degradation from increased visitation. The impact of Hurricanes Luis and Marilyn in 1995 were not assessed quantitatively, but there was apparently little damage to the island's marine environment. All reefs around the island, to a depth of 60m, are protected within the Saba marine Park, which was legally established in 1987 and is run by an NGO, the Saba Conservation Foundation. The park is actively managed by a permanent staff and has been completely self-financed since 1993. Trends in biomass of coral reef fish species have been monitored since 1991. At that time, four years after the establishment of the park, biomass of commercially important species was two times greater in the no fishing zone than in the fished area (Polunin and Roberts 1993). Biomass increased in both areas by a further 60% between 1991 and 1993 (Roberts and Hawkins 1995).

St. Maarten is the Dutch southern portion of an island shared with St. Martin, one of the French Antilles. Rapid population growth and a dramatic expansion of tourism have resulted in major infrastructure development, without any physical planning strategy. A recent study indicated that marine habitats including reefs on the west and south coasts are seriously threatened by pollution, devegetation, siltation and eutrophication from sewage input and the very high level of recreational boating (Nijkamp et al. 1995). South coast reefs also suffer from anchor damage.

The **heavy seas generated by Hurricane Luis** damaged reefs, seagrass beds and beaches. Reefs suffered from smothering by resuspended sand and *Acropora palmata* stands in shallow water were damaged, but the effects have not been reported in detail. Local divers report that conditions at their dive sites have largely recovered.

No protected areas have yet been legislated in St. Maarten, but the Island Government is in the process of determining conservation priorities and will soon develop an action plan for establishment of a marine park.

The French West Indies

The French West Indies comprise the islands of Martinique, the Guadeloupe Archipelago, St. Barthélemy and the French part of St. Martin.

On the leeward side of Martinique, reef formations are absent from the north-west and west coast, due to the narrow insular shelf and sedimentation from the erosion of Montagne Pelée, but there are flourishing veneers. The northern part of Atlantic coast is largely devoid of coral reefs due to the steepness of the bottom and sedimentation. Further south, fringing reefs have developed along the coast protected by a barrier reef.

Guadeloupe is composed of two islands, Basse-Terre which is high and volcanic and Grande-Terre which is flat and calcareous. Other islands in the archipelago include La Désirade, Marie-Galante and Les Saintes Archipelago plus some small islets. The Caribbean coast of Guadeloupe is devoid of coral reefs due to the narrowness of the insular shelf and to sedimentation, but the most diversified coral communities of Guadeloupe are found on the hard substrata of this coast. On the Atlantic coast of the island there is a system of fringing reefs. The surrounding islands are devoid of coral reefs (Les Saintes) or possess narrow fringing reefs (Marie-Galante, La Désirade).

A shallow insular shelf that supports the islands of St. Barthélemy and St. Martin is mainly covered with sediments which are periodically resuspended by hurricanes, which has probably limited the development of coral reefs around these islands.

The coral reefs of Martinique were affected by swells from Hurricanes David (in 1979) and Allen (in 1980). Surge action severely damaged *Acropora palmata* and *A. cervicornis* communities on shallow outer reef slopes (Bouchon and Laborel 1986). Guadeloupe Island suffered from Hurricane Hugo in 1989 and Hurricanes Luis and Marilyn in 1995. Hurricane Hugo mainly affected the branching coral species of the shallow fore reef zone. A delayed mortality affecting colonies of all species was also observed in the following month (Bouchon et al. 1991) and populations of *A. palmata* and *A. cervicornis* did not recover. Hurricanes Luis and Marilyn affected the coral reefs of Guadeloupe more severely than Hugo, destroying corals, sponges and gorgonians to 25 m depth on the outer reef slopes and causing heavy siltation on the reefs.

Hurricane Luis also struck St. Martin and St. Barthélemy. It caused some damage to coral reef communities but more importantly generated a large amount of suspended sediment. On the shallow insular shelf, calcareous sand was ground into fine, nearly colloidal mud, which remained in suspension for months, killing many benthic organisms which had survived to the immediate impact of the hurricane.

Massive bleaching of coral communities has never been observed in the French West Indies, but has been a chronic

phenomenon affecting some coral colonies every year, in September, when the water temperature reaches 29°C.

In 1984 the reef communities of the Caribbean coast of Martinique were invaded by the brown algae *Sargassum* spp. (Bouchon et al. 1992) which is still present in 1996 (Littler et al. 1992; pers. obs.). The most probable cause is eutrophication originating from the city of Fort-de-France (Bouchon et al. 1987; Littler et al. 1992). Today, the coral reefs of both Martinique and Guadeloupe suffer from proliferation of brown algae belonging to the genera *Sargassum*, *Turbinaria* and *Dictyota*. The reefs of St. Martin and St. Barthélemy have been colonised by *Dictyota*.

The Pigeon Islets on the leeward side of Guadeloupe, constitute one of the most famous SCUBA diving spots of the French West Indies, with consequent physical damage from up to 80,000 divers per year. They are partly protected by a ban on **most fishing activities and the installation of permanent moorings**.

In Martinique, an ongoing project to establish a marine reserve in the Baie-du-Trésor has not yet been completed. In Guadeloupe, the marine reserve of the Grand Cul-de-sac Marin was created in 1987 and is managed by the Parc National de la Guadeloupe. It constitutes also a MAB's Biosphere Reserve, including coral reefs, seagrass beds and mangroves. There are also two projects of marine reserves concerning the islets of Pigeon and those of Petite Terre on the Atlantic coast of the Guadeloupe.

In St. Barthélemy, a marine reserve will be created at the end of the year 1996. For St. Martin, there is an ongoing project.

St. Kitts and Nevis

Since the review by Wells (1988) there have been no recent studies of the reefs of St. Kitts and Nevis. There is no documentation of trends in the condition of reefs, although it has been suggested that many of the reefs show lower species diversity than similar habitats in the region, and that they have been adversely affected by sedimentation (URF/CCA 1991a).

Marine conservation efforts in St. Kitts have focussed on the low and dry South East Peninsula, and more recently on a number of deeper reefs off the west coast which are believed to have a higher diversity and coral cover than other reefs around the island. Both of these areas are becoming increasingly important for recreational diving. Although the Southeast Peninsula marine and Recreation Park has been proposed, it has not yet been legislated, and there is concern that clearing of land may result in an increase in sedimentation on adjacent reefs.

Montserrat

There is little published information on the reefs of Montserrat, but the following details were available from a recent assessment (D. Brosnan pers. com). Corals are found primarily as a series of scattered patch reefs ranging in depth from 2m to 40m. Reefs are most abundant off the west and north coasts, with additional reefs on the northeast and southeast. Runoff and steep topography probably limit the distribution of reefs around the island, particularly near ravine outflows that carry sediments.

Impacts from human activities, including pollution and diving tourism are low, and reefs are relatively pristine, with high diversity. However pot fishing and the newly introduced practice of spearfishing are potentially destructive, given the limited extent of reefs. No marine protected areas have been designated to date.

Hurricane Hugo in 1989 caused extensive damage, particularly to larger branching corals (IRF 1993), but there was no documentation of the impacts. Hurricane Luis in 1995 was also destructive. As a result of ongoing volcanic activity, ash and runoff of volcanic sediment, together with sediment resulting from the last hurricane, are currently impacting patch reefs on the south and southwest coasts.

Antigua and Barbuda

Antigua and Barbuda are coral limestone islands. Antigua has a deeply indented coastline surrounded by reefs except on parts of the west and south coasts. On Barbuda, reefs are found along most of the coast, and an extensive algal ridge runs along the east coast. A number of surveys have been conducted (IRF/CCA 1991b) indicating that reefs are under stress from sedimentation, presumably as a result of the relatively high level of shoreline development and destruction of wetlands that has accompanied the growth of tourism.

Hurricane Hugo in 1989 caused extensive damage to reefs on the south and southeast coasts of Antigua (IRF/CCA 1991b). In 1995 Hurricanes Luis and Marilyn caused considerable damage particularly to branching corals on shallow reefs, but no quantitative data are available yet.

The Palasrer Reef marine Park on Barbuda, and the Diamond Reef marine Park on Antigua were legally established in 1973, but management has not yet been implemented. Great Bird Island is to be legally designated as a protected area, with the intention of following a participatory planning and implementation process.

Dominica

Dominica has a very narrow coastal shelf, and reef development is limited. At a few locations on the south, west and northwest coasts coral veneers on rock are well developed, often on steep slopes and walls, and are highly regarded as spectacular dive sites. The low population level and lack of extensive coastal development has meant that reef communities have not been severely impacted by human activities (IRF/CCA 1991c), but diving tourism is reported to be increasing rapidly.

NO hurricanes have struck the island since Hurricane David in 1979, however, storm surge and rain resulting from Hurricane Luis in 1995 resulted in heavy sedimentation and destruction of *Porites* sp. stands on reefs along the southwest coast.

The Soufriere SCott'S Head Marine Reserve on the south west coast is about to be legally established and management activities have begun with the installation of permanent moorings through a collaborative effort by Government and the diving community.

St. Lucia

Fringing reefs and coral veneers are found along all of St. Lucia's coasts. Some small patch reefs are found on the south east coast, but the majority are narrow fringing reefs lying close to shore. NO further detailed studies on their structure and distribution have been made since those reviewed by wells (1988). The spectacular reef communities along parts of the west coast are of great importance to fisheries and the area is becoming increasingly popular as a diving destination. The most significant natural disturbances in recent years have been caused by a number of storms and hurricanes in 1994 and 1995. Tropical Storm Debbie in 1994 was one of the wettest to hit St. Lucia this century and caused landslides and erosion that resulted in heavy siltation from runoff. A study of three reefs on the southwest coast shortly after the storm revealed considerable damage, with coral mortality as high as 50% at the most heavily impacted site. Sediment depth and the proportion of bleached corals were highest at sites near river mouths (Nowlis et al. in press). In 1995, the heavy seas that accompanied Hurricanes Luis and Marilyn caused severe damage to reefs on the west coast, particularly to shallow stands of *Porites porites* but there are no quantitative data available on destruction or recovery.

AS with most of the Lesser Antilles of volcanic origin, the limited extent of the reefs and the concentration of population in the coastal zone have meant that inshore resources are subjected to intense uses and impacts. On the west coast, particularly in the vicinity of Soufriere, the growth of tourism and the impacts from urban development resulted in conflicts between user groups, for example between fishermen and divers over reef areas, and between fishermen and yachts anchoring in fishing zones (Renard and

Koester 1995). marine reserve areas and fishing priority areas were legally established in 1986 and a management plan was proposed (OAS 1989), but they lacked any input from the user communities and were at least partly responsible for an escalation in conflicts. In response to the worsening situation, a process of conflict resolution and participatory planning was started in 1992, under the auspices of a local non-governmental organization, the Soufriere Regional Development Foundation. The negotiation process lasted 18 months and involved all institutions and user groups concerned with the reefs and other coastal resources of the Soufriere area. This resulted in agreement, endorsed by Government, on the establishment of the Soufriere marine Management Area (Soufriere Regional Development Foundation 1994) which was officially launched in July 1995. Management of the area is under the supervision of a Technical Advisory Committee which includes representation from the fishermen, hoteliers, dive operators, community institutions and all of the relevant government agencies.

Barbados

Barbados is densely populated and has experienced rapid increase in coastal development and tourism, with a consequent degradation of the marine environment. On the west coast of the island, eutrophication has resulted in an increase in algal abundance, reduced coral recruitment and survival of juveniles, and increased turbidity and sedimentation rates (Tomascik and Sander 1985, 1987a,b; wittenberg and Hunte 1992). A long-term study of coral cover on a west coast reef indicated an increase in dead coral surfaces from 22% to 43% over a 20-year period up to 1992, due to eutrophication effects listed above and the effects of Hurricane Allen in 1980 (Scoffin, 1994). In a study of trends in West coast reefs from 1982 to 1992, the mean percent loss of species on the study reefs was 24%, and mean decline in abundance was 34% (Bellairs Research Institute 1989, 1994). The Government's Coastal Zone Management Unit established a monitoring programme for west and south coast reefs in 1987, to be repeated at five year intervals, to ensure an adequate information base for planning mitigation measures.

At present, the Barbados marine Reserve, on the west coast at Folkstone, is the only legislated marine protected area on the island. A marine park is being planned for Carlisle Bay, with the possibility of it's being managed by the Professional Association of Dive Operators, in collaboration with the government.

St. Vincent and the Grenadines

There has been little documentation of the reefs of St. Vincent since the review by Wells (1988). The shelf around St. Vincent is **narrow, with little reef development** on the north and east coasts. **On the west coast coral veneers are well developed on rocky substrates around headlands. Some** fringing reefs exist on **the south and south east coasts. Reef** development is much greater on the shelves surrounding the Grenadine Islands to the south, and are important for both fishing and tourism. of particular importance in this regard is the small group of Grenadine islands that make up the Tobago Cays.

Over the past 15 years a number of reports have indicated the condition of the reefs in Tobago Cays has deteriorated due to a variety of factors that **include storm damage, white** band and other diseases, physical damage from fishing gear and boat anchors, and localized pollution from visiting yachts (Heyman et al. 1988; IRF/CCA 1991d). There have been no detailed studies of the relative importance of the various impacts. An action plan for the establishment of the Tobago Cays Marine Park was recently approved by Government. Although a management system is not yet in place, a process of consultation with resource users has begun and permanent moorings have been installed to reduce anchor damage by the increasing number of visiting yachts.

Grenada

There have been few studies of Grenada's reefs since those reviewed by Wells (1988), and no long-term quantitative data are available (IRF/CCA 1991e). Attention has focussed on inshore habitats on the south east coast, particularly

Grande Anse Bay, where coastal development, primarily for tourism, is most intense. Following reports that nearshore reefs showed reduced diversity of coral species and an abundance of benthic algae characteristic of elevated nutrient levels, a sewerage system was installed for the area, but there are no recent data on trends in the condition of the adjacent reefs.

A number of reefs on the west coast of Grenada, and in the Grenada Grenadines, are becoming increasingly important for recreational diving. A system of marine parks has been proposed, to be implemented by the Fisheries Department of the Government of Grenada, but no areas have yet been legislated. There have been no documented effects of natural events, such as hurricanes.

CONCLUSION

It appears that the trend of reef degradation that was described by Rogers (1985) has continued in the Lesser Antilles during the past decade. Human causes include the many impacts that result from coastal development, such as increased siltation, nutrient enrichment, dredging and construction, and clearing of vegetation. The impacts of storms and hurricanes have been severe and frequent in recent years and various diseases have affected corals on many islands.

It is also apparent that countries in the region differ greatly in the resources required for establishing management structures, and for carrying out studies of the trends in the condition of their reefs that are needed for management decisions.

certainly the challenges are formidable but there have been some encouraging advances in reef protection and management. Overall, one of the most positive signs is the increasing awareness of the ecological and economic value of coral reefs. Several new parks or management areas have been established and are providing valuable lessons for the region. In Saba and the BVI, revenue generation from user fees is a significant step towards ensuring continuity in management, and avoiding the inconsistencies in funding that have hindered progress elsewhere. A lack of public support for management initiatives has been a significant drawback in the past, and the recent trend towards participatory planning, conflict resolution and collaborative management is significant. In St. Lucia, the collaboration of government, NGOs and community groups has resulted in a constructive and dynamic management arrangement in an area previously plagued with conflicts and inadequate management. An inability to enforce protective legislation has been identified as a major hindrance to management, and improved public participation and support are seen as an effective means of reducing the need for enforcement, especially where human and financial resources are limited. The collaboration of user groups is also a means of reducing the cost and improving the efficiency of management, as demonstrated by the involvement of the diving community in the establishment of mooring systems in many islands, including Barbados and Dominica, is a good example.

Despite the diversity of conditions in the region, there is much to be learned from those islands that have developed effective coastal zone management programmes, marine management areas and marine parks, and where research and monitoring are providing data on the effects of stresses on reef communities, to help the region address the many common problems in maintaining its reef resources.

ACKNOWLEDGEMENTS

CANARI gratefully acknowledges the support of the French mission for Cooperation and Cultural Affairs in the Lesser Antilles for preparation of this paper. Thanks are also expressed to the Parc National de la Guadeloupe for its support. Sincere thanks are extended to the many colleagues in the region who provided information. This is CANARI Contribution No. 235.

REFERENCES

- Anderson DM (1994) Analysis and modelling of erosion hazards and sediment delivery on St. John, US Virgin Islands. Colorado State University, Master's Thesis, 153 pp
- Appeldoorn R, Beets J, Bohnsack J, Bolden S, Matos D, Meyers S, Rosario A, Sadovy Y, Tobias W (1992) Shallow water reef fish stock assessment for the U.S. Caribbean. NOAA Technical Memorandum NMFS-SEFSC-304, 70 pp
- Beets J, Friedlander A (1990) Long-term monitoring of fisheries in the Virgin Islands National Park: impact of Hurricane Hugo. Annual Report to the National Park Service, *h pp*
- Beets J, Lewand L (1986) Collection of common organisms within the Virgin Islands national Park/Biosphere Reserve., Virgin Islands National Park/Biosphere Reserve. Virgin Islands Resource management Cooperative. Biosphere reserve research report no.3, 45 pp
- Beets J, Lewand, L, Zullo E (1986) Marine community descriptions and maps of bays within the Virgin Islands National Park/Biosphere Reserve. Virgin Islands Resource Management Cooperative. Biosphere reserve research report no.2, 117 pp
- Bellairs Research Institute (1989) Community descriptors (1987) for nearshore and offshore reefs on the south and west coast of Barbados. Report to Coastal conservation Project, Barbados, pp 99
- Bellairs Research Institute (1994) Temporal changes in coral reef communities on the west and south coasts of Barbados. 1982-1992. Report to Coastal Conservation Project, Barbados, pp 62
- Bouchon C, Laborel J (1986) Les peuplements coralliens des côtes de la Martinique. *Ann Inst Oc6anogr Paris* 62 (1):199-237
- Bouchon C, Bouchon-Navaro Y, Imbert D, Louis M (1991) Effets de l'ouragan Hugo sur les communautés coralliennes de Guadeloupe (Antilles françaises). *Ann inst Oc6anogr Paris* 67 W:5-33
- Bouchon C, Bouchon-Navaro Y, Laborel J, Louis M (1987) Influence of the degradation of the coral assemblages on the fish communities of Martinique. *Proc 38th Gulf and Caribbean Fisheries Institute, Martinique, November 1985:452-468*
- Bouchon C, Bouchon-Navaro Y, Louis M (1992) A first record of a Sargassum (Phaeophyta, algae) outbreak in a Caribbean coral reef ecosystem. *Proc 41st Gulf and Caribbean Fisheries Institute, St. Thomas, USVI:171-188*
- Bythell, JC, Bythell M (1992) Benthic reef community dynamics at selected sites at Buck Island Reef National monument, 1988-1991: Monitoring fixed linear transects using the chain transect technique. In: Bythell JC, Gladfelter EH, Bythell M (eds) Ecological studies of Buck Island Reef National Monument, St. Croix, US Virgin Islands: a quantitative assessment of selected components of the coral reef ecosystems and establishment of long-term monitoring sites. Part 11. NPS Coral Reef Assessment Program, pp 1-13
- Bythell JC, Gladfelter EH, Bythell M (1992) Chronic and catastrophic natural impacts on three common Caribbean reef corals: causes and scale of partial and whole colony mortality. In: Bythell JC, Gladfelter EH, Bythell M (eds) Ecological studies of Buck Island Reef National Monument, St. Croix, US Virgin Islands: a quantitative assessment of selected components of the coral reef ecosystems and establishment of long-term monitoring sites. Part II. NPS Coral Reef Assessment Program pp 40-52
- Dammann AE (1969) Special Report. Study of the fisheries

- potential of the Virgin Islands. Virgin Islands Ecological Research Station, Contribution 1, 197 pp
- deGraf J, Moore D (1987) Proceedings of the Conference on Fisheries in crisis. NOAA/Caribbean Fisheries Management Council/Government of the U.S. Virgin Islands, 147 pp
- Edmunds PJ (1991a) Effect of Hurricane Hugo on the primary framework of a reef along the south shore of St. John, US Virgin Islands. *Mar Ecol Prog Ser* 78:201-204
- Edmunds PJ (1991b) Extent and effect of black band disease on a Caribbean reef. *Coral Reefs* 10:161-165
- Geoghegan T (1994) Financing strategies for protected areas in the insular Caribbean. *Parks* 4(2):28-38
- Gladfelter WB (1982) white-band disease in *Acropora palmata*: implications for the structure and growth of shallow water reefs. *Bull Mar Sci* 32:639-643
- Gladfelter WB (1991) Population structure of *Acropora palmata* on the windward forereef, Buck Island Reef National Monument: seasonal and catastrophic changes 1988~1989. In: Bythell JC, Gladfelter EH, Bythell M (eds) Ecological studies of Buck Island Reef National Monument, St. Croix, US Virgin Islands: a quantitative assessment of selected components of the coral reef ecosystem and establishment of long term monitoring sites. Part 1. NPS Coral Reef Assessment Program, pp 53-61
- Heyman AM, Riegert TJ, Smith A, Shallow T, Clark JR (1988) Development of the Tobago Cays National Park: project proposal. Government of St. Vincent and the Grenadines/ Organization of American States, Kingstown, St. Vincent. pp 62
- Hubbard DR (1987) A general review of sedimentation as it relates to environmental stress in the Virgin Islands Biosphere Reserve and the eastern Caribbean in general. Virgin Islands Resource Management Cooperative. Biosphere reserve research report no.20. NPS. pp 42
- Hubbard DK, Parsons KM, Bythell JC, Walker ND (1991) The effects of Hurricane Hugo on the reefs and associated environments of St. Croix, US Virgin Islands-a preliminary assessment. *Journal of Coastal Research Special Issue* No.8.33-48
- IRF (1993) Montserrat environmental profile. Island Resources Foundation, St. Thomas, USVI, pp 124
- IRF/CCA (1991a) St. Kitts and Nevis country environmental profile. Island Resources Foundation, St. Thomas, USVI and Caribbean Conservation Association, Barbados, pp 277
- IRP/CCA (1991b) Antigua country environmental profile. Island Resources Foundation, St. Thomas, USVI and Caribbean Conservation Association, Barbados, pp 212
- IRF/CCA (1991c) Dominica country environmental profile. Island Resources Foundation, St. Thomas, USVI and Caribbean Conservation Association, Barbados. pp 239
- IRF/CCA (1991d) St. Vincent country environmental profile. Island Resources Foundation, St. Thomas, USVI and Caribbean Conservation Association, Barbados, pp 222
- IRF/CCA (1991e) Grenada country environmental profile. Island Resources Foundation, St. Thomas, USVI and Caribbean Conservation Association, Barbados, pp 276
- Littler MM, Littler SD, Lapointe BE (1992) Modification of tropical reef community structure due to cultural eutrophication: the southwest coast of Martinique. *Proc 7th Int Coral Reef Symp, Guam*, 1:335-343
- Nowlis JS, Roberts CM, Smith AH, Siirila E. Human-enhanced impacts of a tropical storm on nearshore coral reefs. *Ambio* (in press)
- OAS (1989) Proposal for the development of the Pitons National Park. Department of Regional Development, Organization of American States, Washington, DC, USA.
- Polunin NVC, CM Roberts (1993) Greater biomass and value of target coral-reef fishes in two small -Caribbean marine reserves. *Mar Ecol Prog Ser* 100:167-176.
- Renard Y, Koester SK (1995) Resolving conflict for integrated coastal management: the case of Soufriere, St. Lucia. *Caribbean park and protected area bulletin* 5(2):5~7
- Roberts CM and JP Hawkins (1995) Marine fisheries reserves for the Caribbean. *Caribbean park and protected area bulletin* 5(2):8
- Robinson AH (1973) Natural vs. visitor-related damage to shallow water corals; recommendation for visitor management and the design of underwater nature trails in the virgin Islands. NPS Report. pp 23
- Rogers CS (1985) Degradation of Caribbean and western Atlantic coral reefs and decline of associated fisheries. *Proc 5th Int Coral Reef Symp* 6:491-496
- Rogers CS (1992) A matter of scale: damage from Hurricane Hugo (1989) to US Virgin Islands reefs at the colony, community, and whole reef level. *Proc 7th Int Coral Reef Symp* 1:127-133
- Rogers CS, McLain L, Tobias C (1991) Effects of Hurricane Hugo (1989) on a coral reef in St. John. *Mar Ecol Prog Ser* 78:189-199
- Rogers CS, McLain L, Zullo E (1988) Damage to coral reefs in Virgin Islands National Park and Biosphere Reserve from recreational activities. *Proc 6th Int Coral Reef Symp* 2:405-410
- Rogers CS, Suchanek TH, Pecora FA (1982) Effects of hurricanes David and Frederic (1979) on shallow *Acropora palmata* reef communities. *Bull Mar Sci* 32:532-548
- Scoffin TP (1994) History of a fringing reef on the west coast of Barbados 1974 - 1992. In: R.N. Ginsburg RN (comp) Proceedings of the Colloquium, on Global Aspects of Coral Reefs: Health, Hazards and History, 1993. Rosenstiel School of Marine and Atmospheric Science, University of Miami, pp 273-278
- Soufriere Regional Development Foundation (1994) Soufriere Marine Management Area, agreement on the use and management of marine and coastal resources in the Soufriere region, St. Lucia. Soufriere Regional Development Foundation, Soufriere, St. Lucia, pp 25
- Tomascik T, Sander F (1985) Effects of eutrophication on and reef-building corals. I Growth rate of the reef-building coral *Montastrea annularis*. *Mar Biol* 87:143-155
- Tomascik T, Sander F (1987a) Effects of eutrophication on reef building corals. II Structure of scleractinian coral communities on fringing reefs, Barbados, West Indies. *Mar Biol* 94:53-75
- Tomascik T, Sander F (1987b) Effects of eutrophication on reef-building corals. III Reproduction of the reef building coral *Porites porites*. *Mar Biol* 94:77-94
- Wells SE (ed) (1988) Coral reefs of the world, 1. Atlantic and Eastern Pacific. IUCN and UNEP, pp 371
- Wittenberg M, Hunte W (1992) Effects of eutrophication and

Nijkamp H, Djohani R, Meesters E (1995) The marine environment of St. Maarten. Report by AID ENVIRONMENT to Dienst VROM, St. Maarten. 24pp

sedimentation on juvenile corals. I. Abundance, mortality and community structure. Mar Biol 112:131-138