

# PRELIMINARY OBSERVATIONS OF THE STATUS OF SHALLOW WATER REEFS AT SANDY ISLAND, CARRIACOU, GRENADA

A Report to the Grenada Board of Tourism & the Kido Project Environmental Station

Carriacou

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## SUMMARY

Sandy Island is an uninhabited cay lying off the west coast of Carriacou. Surrounded by clear waters and coral reefs, with an extensive white sand beach and quiet water on its south side and a palm canopy on the island, it has long been a treasured spot for Carriacouans. More recently, it has become a favored site for yachters, shore parties from cruise boats and SCUBA divers. Photos of the island are often used as centerpieces of advertisements for the region. Carriacouans have expressed concern about increasingly large losses of the island to erosion during severe storms, and about degradation of the island and the surrounding reefs believed to be associated with the intensified tourist traffic. Proposals have been made to implement a number of conservation measures. A preliminary survey of the nature and health of the shallow water (0-4 m) coral communities, which are the most important in relation to erosion of the island, was conducted on June 20, 1996 .

Coral communities in water deeper than 3-4 m on the east and northeast flanks of the island appeared to be in generally good condition, except that there has been some anchor damage of beds of finger coral.

The sea bottom on the south protected side of the island where yachts anchor is sand and rock with some beds of finger coral. These beds have been completely destroyed by anchors. Heavy growth of algae in the area is suggestive of nutrient and organic pollution.

The east, north and west flanks of the island have been built up by growth of the elkhorn coral, *Acropora palmata* , in the reef crest zone (0.5-3.5 m). Covered by living thickets of this species when Prof. Patriquin visited the site in 1969, today this zone consists of a now dead, algal covered "elkhorn coral framework".

The highly degraded condition of the elkhorn coral is attributable primarily to two diseases which were not of local origin, however, local factors (overfishing and nutrient pollution) may have exacerbated the problem.

The elkhorn coral suffered near 100% mortality at many locales in the Caribbean (including Sandy Island) due to an outbreak of "White Band Disease" in the late 70's/early 80's; it has not since recovered, nor have other species filled its niche.

The high algal cover is attributable to a second disease epidemic which caused mass mortalities of the long spined black sea urchin (*Diadema antillarum*) throughout the Caribbean in 1983/84. It has only recently begun to be seen in significant numbers again, and only at some locales. Corals are slow growing species which are readily overgrown by faster growing algae when the algae are not regularly grazed by herbivores or when excessive nutrient input stimulates very rapid algal growth. As well as encroaching on corals, the heavy algal growth suppresses settlement of coral larvae on old coral, which helps to perpetuate an algal dominated state. Surgeonfish, parrotfish, and black sea urchins are the most important herbivores in the Caribbean. Intensive fishing reduces the populations of herbivorous fish, leaving the black sea urchin as the principal herbivore. Hence, when the sea urchins died off, algal growth on shallow reefs increased sharply, except where there were still large fish populations. Today at Sandy Island, fish stocks appear to be low and the black sea urchin is just beginning to reestablish.

Most of the massive structures formed by elkhorn coral remain at Sandy Island, some still in the original growth position and some broken down, and still provide protection to the island. Over the east and northeast flanks of the island, this old framework is now firmly bound together by encrusting coralline algae and other binding organisms, and is probably quite resistant to further disruption. However, on the northwest and west flanks, exceptionally heavy growth of mat-forming and bushy algae - possibly stimulated by nutrient pollution from yachts - has prevented growth of encrusting organisms, and the framework can be pulled apart by hand. Residents report that recent erosion of the island has been most severe on the northwest sector of the island and occurred when storm waves approached from the northwest; this can be attributed to puncturing of the fragile elkhorn coral framework in that area.

In the absence of regeneration of elkhorn coral, it appears likely that Sandy Island would eventually be lost entirely, that this loss would occur mostly through catastrophic events, rather than gradually, and that the catastrophic losses will become increasingly large relative to what's left with each event. In this context, Sandy Island is in a very precarious condition.

Unexpectedly, the survey revealed a new population of healthy, living elkhorn coral, probably not more than a few years old, on the east flank of the island. Colonies up to 75 cm maximum linear dimension were observed, in densities of 1-6 colonies per 4 sq meter area. Also in that region, long spined, black sea urchins are abundant, and there is low algal cover of dead coral. Density of living elkhorn coral and of sea urchins in the reef crest zone decline in a gradient from east to west on the north side of the island; correspondingly, algal cover increases, forming thick mats over the old elkhorn coral, towards the west of the island. No living elkhorn coral was observed on the northwest and west flanks. Black sea urchins were observed in only one patch on the west flank; they were maintaining the patch largely free of algae, in marked contrast to the adjacent areas which bore thick algal mats and had no sea urchins.

These patterns suggest that re-establishment of elkhorn coral on the east flank was dependent on prior re-establishment of black sea urchins and their grazing down of algae on the old coral. This situation is of considerable interest scientifically, and is especially encouraging in regard to Sandy Island, because it offers the possibility that elkhorn coral is "on its way back". We suggest that the recovery process could be accelerated by establishing "recovery centres" in areas now covered by thick algal mats. This would involve scraping to remove the algal mat, introducing sea urchins to maintain a low cover, and once the urchins have stabilized and algal cover remains low, transplanting elkhorn coral into the sites. Once established, it would be critical that the potential for physical damage to the new colonies by swimmers and boats is reduced to an absolute minimum. Reducing nutrient and organic pollution from yachts and shore parties, and allowing larger standing stocks of herbivorous fishes to develop would further increase the chances of success.

Other measures proposed by Carriacouans to protect the integrity of the existing coral populations, such as establishing permanent moorings for boats, limiting numbers of visitors at one time, removing garbage, reducing wave force by sinking a wreck to create an artificial reef off of the northwest flank and increasing the erosion resistance of the island by planting more vegetation, are sensible, and can help the shallow water communities to return to a more healthy and attractive state.

The proposed development of the site with an educational focus is a very appropriate initiative. The Sandy Island system, while limited in extent, illustrates most of the major features of healthy Caribbean reefs, and spatially and historically, the major features of reef decline, both natural, and anthropogenic, and of local and non-local origin. It is an excellent "lab" in which to test and develop some new coral reef management techniques which could help to ensure and accelerate the return of elkhorn coral, and probably other species.

These features, together with the convenience of access to the site, its symbolic significance as an idyllic tropical isle, and the obvious sentiment of Carriacouans towards Sandy Island make it, potentially, a valuable research and

educational site. Developed in this context, restoration of the Sandy island reefs could stimulate more broadly based community based restoration and conservation of coral reefs, and provide new economic opportunities.

## INTRODUCTION

Sandy Island is an uninhabited cay lying approximately 800 m from shore on the west coast of Carriacou. Surrounded by clear waters and coral reefs, with an extensive white sand beach and quiet water on its south side and a palm canopy on the island, it has long been a treasured spot for Carriacouans. More recently, it has been regularly visited by yachters who anchor in the lee of the island, and by shore parties from large cruise boats. Photos of Sandy Island are frequently centerpieces in advertising literature for Grenada and its Grenadine islands, conveying the classical image of an idyllic tropical isle.

Carriacouans have been especially concerned by recent erosion of the island during storms, degradation of adjacent reefs, garbage accumulation, and the increasing intensity of use by cruise boat operations which may land as many as 250 persons at one time. A recent article by Mrs. Ester Fleary outlined these concerns. Carriacouan Mr. Cuthbert Snagg recently received an MBE award (Member of the British Empire) for environmental work, particularly in relation to Sandy Island where he initiated clean-up operations (1) A Save Sandy Island project was established in late 1995, promoted by an active sale of t-shirts, community meetings, and media involvement. The Kido Project Environmental Station, at Sanctuary, Carriacou, produced a formal "Save Sandy Island" plan in response to a request from Mrs. Ester Fleary, Director at the Grenada Board of Tourism for Carriacou. The plan proposes that Sandy Island become part of the National Marine Parks system, and requests assistance for twelve specific management initiatives including:

1. Scientific study
2. Appointment of a Park Manager
3. Assistance of a Peace Corps volunteer for 2 years
4. Establishment of a user fee system
5. Installation of 7 fixed moorings for yachts
6. Installation of 5 fixed moorings for dinghy/small boat use
7. Installation of garbage collection sites
8. Implementation of a revegetation program
9. Reconstruction of the western reef using sunken wrecks
10. Distribution of information on the project
11. Networking in the Caribbean in support of the project
12. Establishing a Save Sandy Island Day to popularize the project, fundraise etc.

With appropriate management of the site, they suggest that it could generate a sustained income of \$95,500 per annum.

The Carriacou Environmental Committee sought some independent assessment

by regional scientists of the condition of the reefs. A visit to Carriacou by Professor Patriquin provided an opportunity for an examination of the site and preparation of this report in consultation with Dr. Wayne Hunte (2) This preliminary study focused on the shallow water reefs (0-4m) as these are the most important in relation to erosion of the island. This document reports the results of this study, puts the observations in the context of coral reef degradation globally and in the Caribbean, and offers some recommendations for managing Sandy Island's coral reefs.

### Background: degradation of coral reefs globally and in the Caribbean(3).

Coral reefs are dynamic structures, continually being added to by growth of corals and other skeletal and binding organisms, and continually being detracted from by erosional processes of both a biological and a physical nature. Large losses in structure and cover by living coral tend to occur over short intervals during exceptional storm events, while net growth of reefs occurs over longer intervals between these events, thus significant change can take place through natural processes within an individual's lifetime. Certain periods in geological history have been exceptionally favorable for growth of coral reefs, other have not. Over periods of hundreds of millions of

years, there have been recurrent massive extinctions of whole reef systems and species, followed after millions of years, by evolution of

new reef forming species and new reefs. Geological studies indicate that the last 6000+ years has been a generally favorable period for coral reefs all over the world, and scientific studies and various informal documents suggest that reefs globally were in generally good health and flourishing for at least the first 50 years of this century.

Since the early 1970's, there have increasing numbers of reports of serious reef decline - especially of the shallower reefs - leading even to predictions that we are witnessing a mass extinction of reefs and reef species(4). Whether that is the case is still, in scientific terms, far from clear, however, there is scientific consensus that there has been serious net degradation of reefs globally, associated with population growth, industrialization and tourism. The Caribbean reefs appear to have suffered more overall and to be more sensitive than those of the Indo-Pacific, possibly because of the more limited species diversity (5). Because of the exceptional importance of coral reefs to fisheries and physical integrity of land in many tropical countries, and more recently, to tourism, the issue of coral reef health is of considerable socioeconomic significance.

In the Caribbean, generalized degradation of reefs since the early 1970's has been associated with the following factors; they affected even remote reefs and reefs in parks

1. Exceptional storm events, such as Hurricane Allen's massive impact on Jamaican and Barbados reefs in 1980 (6). These are natural events, which reefs are generally able to recover from over periods of years to decades.

2. "Bleaching" of corals associated with high surface water temperatures. High temperatures can cause corals to expel the symbiotic algae they contain in their tissues, with resultant "bleaching" and death of the affected polyps. Bleaching events have been recorded since the last century, but appear to have increased in frequency since the early 1980's, possibly as a result of Global Warming. 1982/3, 1987 and 1990 were years of widespread reports of bleaching (7).

3. White Band Disease. This disease, whose exact pathology is not certain, caused almost complete loss of one of the most important shallow water reef building corals in the Caribbean, the elkhorn coral (*Acropora palmata*); the same or a related disease attacked a related deeper water species, the staghorn coral (*A. cervicornis*). It appears as a white band at the base of a colony or branch and moves progressively over the entire colony, killing it. The disease was first noted in the 1976, and by the mid 1980s had spread throughout the Caribbean. Elkhorn coral forms massive branching structures of up to 3 m in height. Collectively they form an interlaced network which grows into breaking waves of the reef crest zone, where it is commonly the only significant species. Significant recovery has not been reported (8). It is not known whether this sort of die-off is a "natural" event that occurs recurrently at very long intervals, or whether this was a first time event. However, one study of the geological record below a living reef suggests the latter (9). The full implications of the die off are not yet clear, but it has been predicted that in the absence of recovery, significant changes including increased erosion will occur, and coral reef biologists have expressed pessimism about the prospects for recovery (10).

4. Black Band disease This disease is caused by a blue green alga which attacks head corals (brain corals, boulder coral, starlet coral). The alga forms a band that moves progressively over the colony leaving dead polyps behind it. It may destroy the entire colony or only a patch. The disease was first noted in 1973 and in the '80s and '90s has been reported throughout the Caribbean. *Montastrea annularis* and *Diploria strigosa*. are most susceptible. As in the case of the White Band Disease, it is not understood with certainty whether it is purely a recent phenomenon (11).

5. Mass mortality of the black sea urchin.

There is general consensus that the epidemic loss of the long spined, black sea urchin, *Diadema antillarum* is responsible for much of the decline in coral cover in shallow water communities observed in the Caribbean since 1983.

Early experiments showed that removal of this sea urchin from areas with low herbivorous fish populations leads to greatly increased abundance of filamentous and fleshy algae and reduced cover by encrusting coralline algae and corals. Reduced coral abundance is due to heavy growth of algae preventing new colonization of old surfaces by coral larvae, shading of coral, and to progressive deterioration of coral colonies at their margins. Between January 1983 and February, 1984, currents spread a pathogenic agent from Panama throughout the Caribbean causing greater than 93% mortality of black sea urchin at all sites. Predictably, there were immediate effects on algal cover, and subsequently on coral cover. Recovery has been reported from only a few locales (13). On Jamaican reefs, algal cover increased from <5% before the mass mortality to >90% currently, while coral cover decreased from 27-77% to less than 5% at most locales (14).

Prevention of settlement and/or increased mortality of settled larvae is an especially drastic effect of heavy algal cover, as it greatly reduces the ability of the reef system to recover from losses due to hurricane events or disease.



It is surprising that removal of a single species can have such a dramatic effect on the coral reef system; in part that may be because over fishing had greatly reduced the abundance of herbivorous fishes, particularly parrotfish and surgeonfish, which also graze on these algae.

In addition to these generalized factors, locally one or more of the following factors have contributed serious coral reef decline, or are restricting the ability of the local reefs to recover from declines associated with factors described above

6. Overfishing of herbivorous fishes; as described above, this helps to tip the coral/algae balance in favor of algae. There is some evidence that the mass mortality of black sea urchins in 1983/4 had lower impact on reefs where there had moderate to low fishing than on heavily fished reefs (15).

7. Excess nutrients, and/or organic loading, associated with agricultural runoff or sewage, or boats and ships; the excess nutrients stimulate growth of algae which as described above compete with coral; at very high levels, nutrient may even have direct negative impacts of corals.

8. Sedimentation associated with deforestation, dredging, mining, agriculture, building developments; some coral species, e.g. starlet coral, are quite tolerant of sedimentation although they usually exhibit reduced growth; while others, e.g. elkhorn coral, are intolerant of sediments

9. Direct physical destruction due to construction activities, anchor damage, boat groundings; snorkellers and divers placing hands, flippers on corals can also cause death of underlying tissue in certain species. Dynamiting to stun fish, although illegal, has been a problem in certain areas in the W Indies.

10. Pollution by toxic chemicals, e.g. herbicides, oil, toxic chemical wastes

All of these factors have affected shallow reefs in the eastern Caribbean (16) and it was expected that one or more of them would be a factor at Sandy Island.

## METHODOLOGY

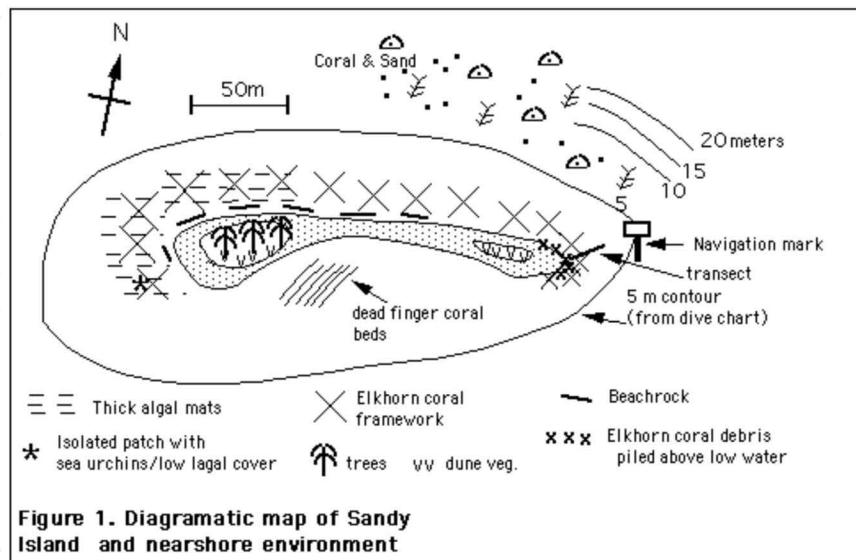
Prof. Patriquin examined the Sandy Island site on June 20, 1996. A bottom profile to 46 m from shore was made at the eastern tip of the island using a graduated 2 m pole to measure distances. Then the bottom on the north side to a distance of approx. 50 m from shore was examined by snorkeling, moving in a zig zag pattern with the current towards the west end of the island, and again beginning on the south side of the island and moving west (see Fig. 1).

Counts of elkhorn coral colonies and sea urchins were made within 2 x 2 m areas. Features specifically examined were coral species, percent coral cover (visually estimated), presence of sea urchins (*Diadema antillarum*), surgeonfish and parrotfish, the extent and type of cover by algae (mat/bushy/encrusting corallines) and the size and constituent nature of sand.

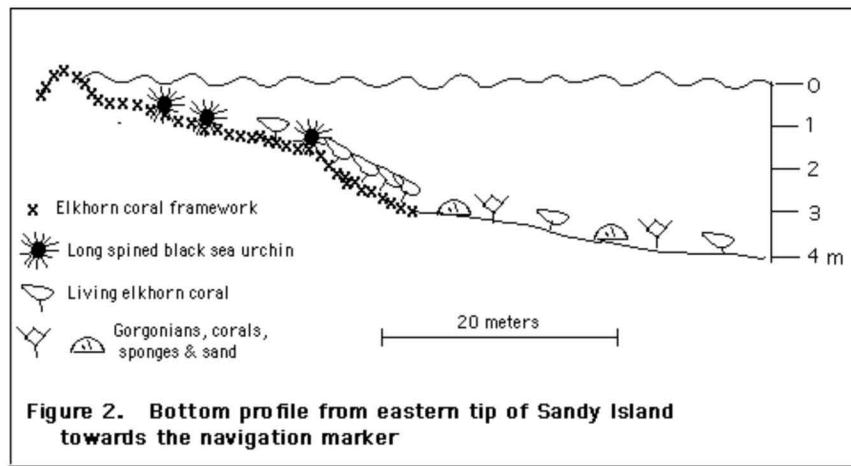
### MAJOR FEATURES

#### The elkhorn coral framework

The most prominent feature of the shallow waters (0-4m) surrounding the island, is the occurrence of an "elkhorn coral framework" in a distinct band or zone on the east, north and west flanks of the island (Fig. 1, 2). This framework consists of completely dead, structural remains of elkhorn coral, *Acropora palmata* (photo plate II). The zone extends normal to shore over a distance of approximately 20-



50 m, at depths of approximately 0.5 to 3.5 m (depth to the top of the framework). The elkhorn coral framework is separated from the beach by a shallow, sandy or sand/loose rubble bottom of a few to approximately 10m width except around the eastern end of the island; there, consolidated (bound) elkhorn coral rubble has accumulated above the low water line forming an emergent, rampart-like structure.



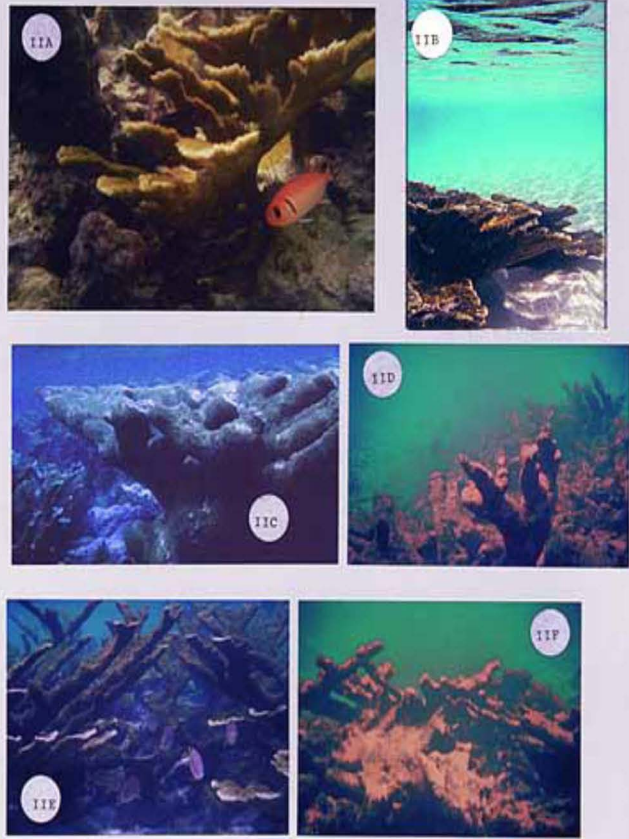
This distribution corresponds approximately to the reef crest zone of healthy reefs. Elkhorn coral was commonly the only significant species in the reef crest zone through the Caribbean prior to the Caribbean wide die-off of elkhorn coral in the late 70's/early 80's associated with an epidemic of "White Band Disease" (see Background, above). In 1969 living elkhorn coral formed characteristic dense, thickets of interlaced branches in the most exposed areas at Sandy Island (photos II C, E); in 1996, such thickets were still largely intact in some areas (photo IIF) , while in others, they had been largely disrupted (photo IID).

Except on the east/northeast flank of the island (described below), there are no living elkhorn corals in the elkhorn coral framework, and few other living or dead corals, except for some fire coral (*Millepora* spp.) In the northwest flank, there are some large, healthy colonies of lobed boulder coral, *Montastrea annualaris* (Plate III H) bordering seaward oriented channels which form breaks in the continuity of the elkhorn coral framework. These channels are regions of strong seaward return flow of water during storms.

## PLATES

	<p><b>PLATE I</b> <b>The Island proper</b></p> <p><b>IA</b> Sandy Island, viewed from the SW, June 25, 1996. There are 7 yachts anchored in its lee. Anchors have destroyed beds of finger coral in this area, and wastes appear to have stimulated heavy growth of algae. <b>IB</b> "No Dumping" sign and absence of garbage is due to volunteer activities of Carriacouans. <b>IC</b> Low dunes stabilized by saltbush <b>ID</b> View from the west end; there is a beach rock formation near shore. <b>IE</b> Nearby Jack Adam Island: leachates from discarded conch shells have polluted the immediately adjacent waters, causing excessive growth of seaweeds and killing corals.</p>
	<p><b>PLATE II</b></p>

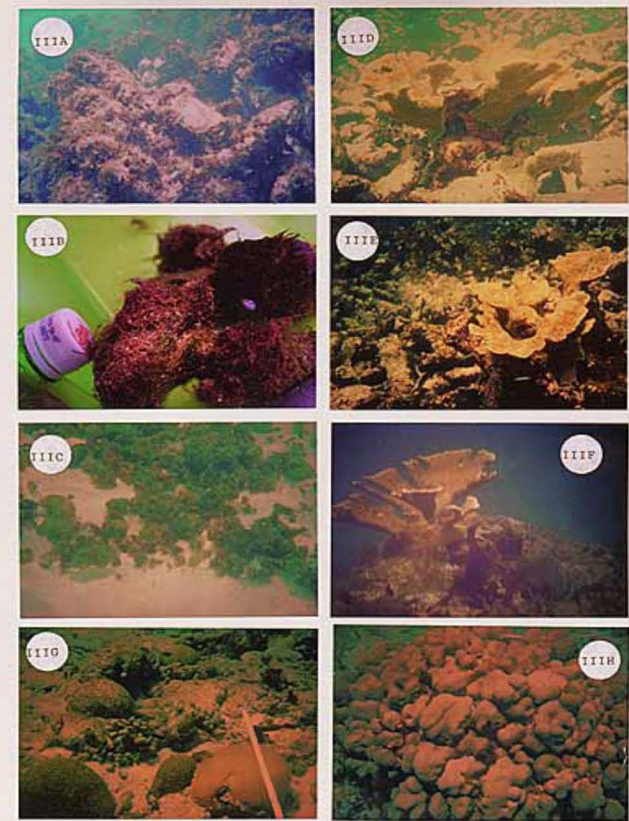




### Elkhorn coral 1969 and 1996

**IIA** 1969: note presence of black sea urchins, which graze algae on old coral surfaces preventing excessive growth. **IIB** 1969: Elkhorn coral in quiet water has characteristic platy branches. **IIC**: 1969: Elkhorn coral in high wave energy area has predicted hydrodynamic features for this environment\*: thickened branches, branches held at low inclinations, and branches facing into the waves and into the backwash. **IID**: 1996: Remnants of colonies such as those in photo IIC, no longer in growth position. **IIE**: 1969 Elkhorn coral in intermediate wave action area has flattened branches at higher angle of inclination than in IIC. **IIF**: 1996. Remnants of colonies such as those in photo IIE, still largely in original growth position

\*Graus, R.R., Chamberlain, Jr., J.A. & Boker, A.M. 1977. Structural modification of corals in relation to waves and currents. In: Reefs and Related Carbonates - Ecology and Sedimentology (edited by S.H. Frost, M.P. Weiss & J.B. Saunders). Studies in Geology No. 4 of The American Society of Petroleum Geologists, Tulsa, Oklahoma, pp 135-153.



### PLATE III ALGAE, NEW ELKHORN CORAL, CORAL-SAND BOTTOM and BOULDER CORAL

**IIIA** Dense algal growth on old elkhorn coral on the west flank of Sandy Island. **IIIB** Algal mat removed from old elkhorn coral on west flank. **IIIC** Loose algal mat on the sandy bottom inshore on west flank. **IIID,E,F** Living elkhorn coral on east flank of Sandy Island (photos D,E) and near Pelican Rocks at Anse la Roche on Carriacou proper (photo E). Note sparsity of algae on old coral. **IIIG** Coral-sand bottom at approximately 4 meters depth on east flank of Sandy Island. **IIIF** Lobed boulder coral, northwestern flank of Sandy Island appears completely healthy; nearby is elkhorn coral debris covered with algae.

#### New elkhorn coral and associated biotic gradients in the elkhorn framework zone.

Over most of the elkhorn framework zone in 1996, there are no signs of living elkhorn coral. However, living colonies were found on the eastern flank of the island (Fig. 2; photos III D, E). The largest individual colonies are 75 cm in maximum surface dimension and there is a full range of smaller colonies. (This compares to maximum surface dimensions up to several meters in 1969). These colonies appeared completely healthy, and as yet, do not

exhibit, old, encrusted growth, thus they appear to be of recent origin. Actively growing elkhorn coral occurs in greatest abundance and most regularly on the slope going from 1.5 to 3 m (Fig. 2). Occasional individual colonies or localized aggregations of living colonies occurred on the old elkhorn coral framework shoreward of the slope, where few other corals except for fire coral are found, and they also found mixed with other coral species on the coral-sand bottom seaward of the slope (Figure 2). In the areas of greatest density, intermingling of branches from different colonies forms an almost complete canopy. Numbers of elkhorn corals in five successive 2 x 2 m quadrats placed along the contours of the slope were 6,1,1,3,4,4.

Living elkhorn corals up to 1 meter maximum linear dimensions were also observed adjacent to Carriacou island proper at Anse La Roche (photo II F), which is described in a separate report (17). Other locations were not examined.

In the same area that the living elkhorn coral was observed on the southern flank of Sandy Island, long spined black sea urchins (*Diadema antillarum*) are also abundant, and algal growth, which is dense elsewhere, is sparse. The black sea urchin is an important grazer of the algae that grow on old, dead portions of coral; it was killed off by a Caribbean wide epidemic in 1983/4, and has only recently begun to return in high numbers and in only some areas (see Background, above). Numbers of sea urchins observed in six 2 x 2 m quadrats were 10, 6, 2, 5, 3, 7, 8. (These numbers refer to sea urchins readily observed; they are low estimates of total numbers as more urchins were readily found on more careful examination of the cavitous framework).

The density of the living elkhorn coral decreases with increasing distance west along the north side of the Sandy Island, reaching near zero at about one-third of the distance towards the west end of the island. Frequency of patches of black sea urchin also decrease in frequency in the same direction. Algal cover, in contrast, increases, from very little on the dead elkhorn coral on the east flank (photo III D, E) to a uniform "fuzz" at one third of the distance towards the western extremity of the island, and to heavy overgrowth at the western extremity of the elkhorn coral framework (photos III A, B).

In the area of heaviest overgrowth of the old elkhorn coral by algae (Fig. 1), algal cover is 100% and the algae form a dense turf up to several centimeters thick (photo IIIB) which in some areas is topped by bushy growth usually characteristic of high nutrient systems. There are 5+ species common in this assemblage including *Digenia simplex*, *Ulva* (close to shore), an unidentified filamentous alga, *Laurencia obtusata*, and delicately branched *Amphiroa* sp. and *Centroceros* sp. (Please note that this description is based on field examination of only a few samples).

There is a notable absence of the sand-forming *Halimeda* species through the entire area. Correspondingly, *Halimeda* platelets are not a common constituent of the sand on the island.

Over most the elkhorn coral framework at Sandy Island, the old, dead elkhorn coral fragments making up the framework, while mostly no longer in growth position, are firmly bound together by encrusting coralline algae. Where this is the case, further disruption of the existing framework will probably be slow. However, in the northwestern and western flanks, the existing framework - some if it consisting of dead colonies that are still in growth position and some of redistributed material - could be pulled apart by hand.

Thus there appears to be an overall positive correlation between occurrence of living elkhorn coral, sea urchins, binding by coralline algae, and paucity of mat and fleshy algae.

Close to southwest extremity of the elkhorn coral framework, where algal cover is very heavy, a single patch about 5 m diameter was found that was largely clear of algae. Black sea urchins were observed in the patch, but not outside of it, thus, the sparsity of algae in the patch is attributed to grazing activity of the black sea urchins. The coral debris within this patch was not in growth position, and appeared to have been physically disturbed (possibly thrown around by wave action or disturbed by traps which are set in this area) at some time.

Surgeonfish and parrotfish are important herbivorous fish species in the Caribbean (18). While at the site, several large schools of surgeon fish were observed on the eastern flank. Small to medium sized parrotfish were common towards the southern border of the old elkhorn coral framework on the west flank of the island, and both surgeon fish and parrot fish were observed in lower numbers elsewhere.

#### Communities beyond the elkhorn coral framework

Beyond the elkhorn coral framework, in depths greater than 3-4 m, a coral-sand bottom slopes gently to deeper water; it includes many gorgonians (sea whips, sea fans), brain corals, starlet coral (*Porites asteroides*), occasional elkhorn coral, boulder coral (*Montastrea annularis*) and the finger coral (*Porites porites*), giving 5-30% coral cover (photo III G). There are also interspersed beds of finger coral which give 50-60% cover in some regions. Overall, these coral-sand communities looked healthy, and were without notable diseases on living corals, or significant overgrowth by algae. Occasional, completely dead but intact brain corals were observed; these may have been killed by black band disease.

#### The anchorage in the lee of the island



The sea bottom on the south, protected side of the cay where yachts anchor is sand and rock, with some completely dead beds of finger corals. There is a heavy cover of algae over most of the bottom. These include a bushy alga (*Acanthophora spicifera*.) and soft filamentous algae; towards the west this cover blends into the algal cover on the elkhorn coral framework. Overall, this bottom is unattractive. The heavy algal growth is suggestive of localized nutrient and organic pollution.

### Currents

While at the site, there was a strong current flowing from east to west beginning at about 10 m from shore to the north and south of the island, and impacting on shore on the eastern flank. The current was strongest in the area of the highest density of living elkhorn coral and high sea urchin density, on the east flank. The west flank was mostly in the lee of the island in regard to current; there was little water motion in that area and water was noticeably warmer than elsewhere.

According to Carriacou dive operator, Tankred Mueller, the current at Sandy island normally flows NE to SE, and rarely flows in the reverse direction, perhaps for only 5 days a year. Swells normally approach from the north or northeast. He comments that when swells come from the north or northwest, or worse, from the west, there is direct damage. Reportedly in October 1992, the northwest swells from a storm hit Sandy for some days, eroding drastically the base and bringing down the remaining 8 grown palm trees on the "eastern cay", and removing a considerable chunk of beach off the northwest side of the "western cay". The sand was slowly brought back by wave action. He comments reports that at depths 7-8 meters on the northwest of Sandy there was up to 40 cm less sand (he measured it because he has a permanent dive mooring buoy and inspected its foundations). Tankred reports that NW ground seas can be felt at depths of 20 m.

### CONCLUSIONS

Below, the observations above are interpreted with reference to the scientific literature to arrive at five main conclusions (highlighted).

**(i) The die-off of elkhorn coral, and the absence to date of substantial renewal or replacement of this species are attributable to factors beyond local control (mass mortalities of elkhorn coral, and subsequently of black sea urchins, in the late 70's/early 80's); however, local factors (nutrient/organic pollution from yachts and overfishing) may have exacerbated the problem.**

The complete degradation of the elkhorn coral zone that was flourishing and healthy in 1969 (photo plate II) is attributable to two major events that were not of local origin. First, there was the mass mortality of elkhorn coral associated with White Band Disease which ravaged elkhorn coral throughout the Caribbean over a roughly 8 year period the late 70s/early 80's (19). The scale of the die-off at many locales (>99%) eliminated the usual source of "seed" for new colonies when exceptional storm events cause great damage viz., broken fragments of elkhorn coral. Regeneration of the community was then dependent on larval settlement and subsequent growth which is much slower than regeneration from fragments.

Second, following closely on the heels of the first event, there was mass mortality of black sea urchins, associated with a disease which swept the Caribbean over an even shorter interval (roughly one year) and caused greater than 93% mortality throughout the Caribbean (20). Research conducted prior to this event had suggested that the black sea urchin plays a keystone role in coral reef communities in the Caribbean through its continual grazing down of algae growing on old coral. Coral and algae compete for space, nutrients and light; the algae are fast growing and capable of quickly outgrowing corals, however in coral-dominated communities, such growth is restricted by low nutrient supply (corals are better able to grow under low nutrient conditions) and by grazing of herbivorous invertebrates and fish.

When sea urchins were removed experimentally from areas where herbivorous fish stocks were low due to overfishing, algal growth increased many fold, encroaching on coral colonies and reducing settlement of coral larvae. Predictably, mass mortalities of sea urchins in 1983/4 was followed by sharp increase in algal cover, except in locales where there were still large populations of herbivorous fishes to compensate for loss of urchins (15).

It appears that once established, an algal dominated system may be quite stable, as a dense cover of algae reduces settlement of coral larvae, and even settlement of sea urchin larvae (21) ; further there may be selection of species or forms of algae that are structurally or chemically resistant to grazing by the fishes (which otherwise would not be limited by settlement and slow movement as are sea urchins) (22). The result is that the change in state initially brought about by catastrophic disturbances of short duration, can persist well beyond the causative disturbance(s) (23), creating "an alternative stable state"(24).

While the major factors leading to deterioration of the elkhorn coral at Sandy Island were not of local origin, overfishing and nutrient pollution which are under local control, may have exacerbated the problem. Stocks of parrot fish and surgeonfish at Sandy Island appear to be well below those that would occur on an unfished or

moderately fished reef, presumably due to intensive fishing, but selection of resistant forms of algae may also be involved.

Algal growth of the intensity that occurs on the elkhorn coral in the west flank is usually associated with nutrient enrichment whether natural or artificial (25). These nutrients could emanate directly from yachts, or from polluted sediment in the region where yachts anchor; the heavy algal growth in that area is suggestive of nutrient pollution. Nutrients may be moved into the western flank area by eddies breaking off from the westward moving currents; released into the quiet waters, they would reside there long enough to be taken up by algae, stimulating growth. A very graphic example of nutrient stimulated algal growth and associated coral death can be observed at nearby Jack Adam Island; there, conch shells have been discarded in recent years forming large mounds from which there is seepage of putrid material (photo IE) into the adjacent submarine where rocks are covered by heavy growth of algae and corals have died.

**(ii) Increased erosion of the island in recent years is attributable to the degradation of elkhorn coral beginning sometime in the late 70's/early 80's; in the absence of regeneration of elkhorn coral, most of what remains of Sandy Island will probably be lost**

Living elkhorn coral thickets such as those shown in Photos II C & E greatly reduce wave energy in the lee of the thickets. Normally these thickets are dynamic structures, continually being added to by new growth, and detracted from through continuous activity of boring organisms and physical fragmentation. Exceptional storm events can cause extremely large losses of living elkhorn coral (26) however, in many or most situations they have reestablished in the longer term, as evidenced by the occurrence of elkhorn coral as a major constituent in limestones (27). Indeed, Sandy Island likely owes its existence to the persistence of elkhorn coral for many hundreds or thousands of years.

In a healthy reef, establishment of new colonies of elkhorn coral, for example after extensive storm damage, occurs mainly by growth of fragments broken off from preexisting colonies (28). The White Band Disease effected complete or very nearly complete mortality of elkhorn coral, eliminating this source of new coral. Regeneration from larval settlement has been very limited so far and other species have not moved in to fill the niche once occupied by elkhorn coral. Thus for 12+ years, there has been virtually no additions to balance losses.

Growth of encrusting coralline algae appears to have stabilized the old framework on the east flank and over much of the north flank of the island. Thus the island area to the lee of the east and northeast flanks, may at this point be relatively stable. However towards the west flank, and on the west flank, the heavy growth of mat-forming and bushy algae has precluded growth of encrusting corallines, and the framework there is not firmly bound together. Hence it could be expected that the framework in that area - which still retains a lot of the original structure - will be progressively punctured and that the adjacent land mass will still be subject to heavy erosion when strong wave approach from the west or northwest. Residents report that recent losses have been most severe on the northwest part of the island, which is consistent with this concept.

In the absence of regeneration of elkhorn coral, it seems a pretty safe prediction that most of what remains of Sandy Island will be lost, that this loss will occur mostly over short intervals during exceptional storms, rather than gradually, and that the losses will become increasingly large relative to what's left with each event. In this context, Sandy Island is in a very precarious condition.

**(iii) There are encouraging signs of recovery of elkhorn coral at Sandy Island; this recovery is linked to recolonization and maintenance of low algal cover by black sea urchins**

The size distribution and morphology of the living elkhorn corals on the eastern flank are similar to those described by Jordan-Dahlgren on the Veracruz reef complex in a 1993 paper on "Recolonization patterns of *Acropora palmata* in a marginal environment"(29). He suggested that the largest colonies at that site, which were about 1 m in maximum linear dimension, could date back to a mortality event 20 years previous, assuming a growth rates of 8-9 cm per year, and thus could be survivors of the old colonies, or have arisen from larval settlement. The more numerous, smaller colonies, he suggests, were only a few years old, and must have arisen from larval settlement. The maximum colony dimension at Sandy Island was about 75 cm, but the maximum linear growth dimension was less than that, probably about 40 cm. Thus these colonies are possibly a maximum of only 5 years old, and are mostly less than 5 years. This population has likely developed relatively recently through settlement of larvae carried to the island by currents.

Larval settlement in *Acropora* species is strongly suppressed by algae (30) . The consistent co-occurrence of black sea urchins in areas where living elkhorn corals were observed, and of sea urchins in all areas where algal cover is low (with or without elkhorn coral) suggest that recolonization of old coral by sea urchins is a prerequisite for larval settlement and subsequent growth of elkhorn coral. Photographs taken in 1969 also illustrate the occurrence of black sea urchins in elkhorn coral stands, and little algal growth on old coral (Photo IIA).

There appears to be some relationship of re-establishment of sea urchins to currents; the area of elkhorn coral and high sea urchin density occurs on the upstream, eastern flank of the island where there is a consistent current onto the slope. The one patch of sea urchins found on the west flank, lay on the edge of the westward moving current south of the island. It can be hypothesized that areas impacted directly by currents have greater influx of larvae. On the east/northeast flank, where algal cover is low over a broad area, it is possible also (or as an alternative hypothesis) that nutrient pollution was minimal in this upstream area compared to other areas around the island, even before sea urchins began to return, resulting in greater survival of settled larvae than in areas with heavier algal cover. The fact that encrusting coralline algae are common through the east/northeast flank may indicate that this area has always had less algal cover than on the northwest/western flank.

**(iv) There has been extensive anchor damage of coral communities at Sandy Island**

Whole beds of finger coral on the leeward side of the island where yachts anchor were observed to have been completely disrupted by anchors. Partial damage of finger coral beds was noted in other areas which is probably due to anchors from smaller boats. Anchor damage and boat groundings associated with tourist traffic are cited as a major cause of reef decline in the Caribbean (31); Sandy Island is no exception.

**(v) The coral communities beyond the elkhorn coral framework to the east and north of the island, at depths of 3-4 m and greater, appeared to be in generally good condition, however, more critical examination is needed to properly assess their health.**

In general, there appears to have been less degradation of deeper water reefs than of shallower reefs in the Caribbean (32).

#### ACCELERATING THE RECOLONIZATION BY ELKHORN CORAL

As discussed above, the algal-dominated state, once established, tends to resist reversion to the original state because the heavy algal growth prevents settlement of invertebrate larvae, including those of sea urchins; further and there may be selection for forms and species of algae that not edible by the more mobile fish grazers. Coral debris in the one patch of sea urchins/low alga cover observed on the west flank appeared to have been physically disturbed at some time; this could have exposed fresh surface not covered by algae, which would favor settlement and survival of sea urchin larvae. The patch had sharp boundaries with uniformly high algal cover outside of it, and low algal cover within it; this suggests that once established within a high algal region, sea urchins are capable of maintaining low algal cover within the patch and presumably, of expanding the patch at its edges as the population grows.

We propose that the recovery of elkhorn coral at Sandy Island could be accelerated by establishing a number of such "recovery patches" in the areas presently lacking black sea urchins and living elkhorn coral. In each patch, algae would be scraped off of the old coral debris, and black sea urchins introduced simultaneously to the patch; when the black sea urchins have proven to be established and to limit algal regrowth, pieces of living elkhorn coral would be transplanted into the site and stabilized in their new positions by use of cement or epoxy.

Efforts to reestablish coral communities by transplanting have been successful in some areas or with some species, but not in others (33). Two factors are in favor of it being successful with elkhorn coral at Sandy Island:

(i). Elkhorn coral normally exhibits vigorous asexual regeneration (regeneration by regrowth of fragments broken off from existing colonies) (34), and, the species has been found to very amenable to transplanting (Dr. D. Hubbard, USVI, personal communication).

(ii). When numbers of any species get very low, there is a high probability of going extinct (or locally extinct) because catastrophic events can completely wipe out the few individuals remaining. New recruitment of elkhorn coral has been observed at other sites in the Caribbean, but they have been repeatedly set back by hurricane damage (Dr. W. B. Gladfelter, USVI, personal communication). The Grenadines lie outside of the main hurricane belt, which greatly increases the odds of an experiment of this sort being successful.

There are some uncertainties about whether newly established elkhorn coral populations, whether established by natural or artificial means, will be sustained. The new colonies at Sandy Island were likely established by settlement of larvae produced elsewhere. We do not know that source. Studies have indicated that sexual reproduction by elkhorn coral is seasonal (35). Regardless, new colonies of the coral are now present, and can be replicated by asexual reproduction, i.e. taking fragments and transplanting them. New colonies were observed also at Anse La Roche in Carriacou, suggesting that for the moment there is a significant influx of larvae of this species coming into the nearshore waters of Carriacou.

Another uncertainty concerns the possibility that new populations will again be wiped out by White Band Disease. The disease has been seen to reoccur since the epidemic die-off (36) but it is possible that some or all of the new recruits would be resistant to it, and/or that conditions that were conducive to its epidemic development in the 1970's and 80's will not reoccur. For the moment, the answer to the questions of whether white band could again

strike and wipe out the population is simply unknown. Similarly the disease that caused the epidemic die-off of the black sea urchin could reoccur.

Regardless Dr. W. B. Gladfelter commented that it would be worthwhile to attempt to assist recovery, as we propose, especially given the more favorable odds with respect to hurricanes in comparison to other areas.

### Increasing the odds

It is reasonable to expect the elkhorn coral to continue to recover and reestablish its canopy structure, however, given the still very low level of the population, the return could be seriously set back by chance events such as exceptional storms, or by human activity. Elkhorn coral is an environmentally sensitive species, requiring clean, clear water, and not very tolerant of low salinity or suspended sediment. The species has been lost in regions affected by human habitation, well before the modern decline (37); increased sediment load is often the major factor as this species lacks effective sediment removing mechanisms. Establishing accelerated recovery centres is one way of significantly increasing the odds in favor of regeneration of the elkhorn community at Sandy Island; another, is to minimize existing or potential negative human impacts on the system, including

(i) physical damage due to anchors and boat groundings;

(ii) physical damage due to snorkellers and divers: if the recovery of elkhorn coral at sandy Island becomes a matter of public interest, it will be important to encourage people not to approach the living colonies which are readily broken by stepping on them;

(iii) nutrient/organic pollution from yachts and shore parties;

(iv) severely reduced stocks of herbivorous fishes due to overfishing;

(v) sedimentation: any activities in the vicinity of Sandy Island that could increase the sediment load (or load of nutrient or toxic materials) in water flowing onto elkhorn coral should be avoided.

It seems worthwhile to attempt to reestablish the elkhorn coral at Sandy island because it may be the only chance to do that. If successful, this could lead to the techniques being used elsewhere in the Grenadines, essentially reversing what otherwise would be a long term loss with very considerable ecological, geological and probably economic impact.

Accelerating the process of return of sea urchins and control of algae, even without return of elkhorn coral, could be of benefit by allowing more growth of encrusting coralline algae. That would strengthen the old framework, and may provide a base for growth of other coral species as appears to have occurred on the west coast of Barbados following decline of elkhorn coral associated with human settlement (38).

Regardless of the outcome, this exercise provides a focus for people to learn about and become sensitive to the ecology of the coral reefs and to learn techniques that might be used in conservation and restorative work with other species and at other locations.

## RECOMMENDATIONS

**1. Steps should be taken to reduce as much as possible, existing or potential negative impacts of high tourist traffic on the reefs at Sandy Island. These include primarily damage from boat anchors, boat groundings, foot damage from snorkellers and divers, and nutrient/organic pollution.**

Installation of moorings as recommended by the Save Sandy Island Plan addresses the issue of anchor and boat grounding. Physical damage from deliberate or inadvertent handling of corals by snorkellers and divers is especially of concern in relation to the new elkhorn coral growth. Other of the Save Sandy Island Plan's recommendations provide some structure for dealing with this issue, viz. their proposed management initiatives 2,8,10. The issue of nutrient./organic pollution from yachts needs also to be specifically addressed. A combination of public education and regulation may be required to deal effectively with this issue.

**2. Some regulation of fishing in order to increase stocks of herbivorous fishes should be considered.**

There are a number of options that could be considered, e.g. a complete fishing ban, rotational harvests (fishing allowed in only certain sectors at any one time), fishing zones, regulation of mesh size, species restrictions. As current stocks are probably below "maximum sustainable yield", some regulation could actually increase the stocks and the sustainable harvest at the same time (39). Increased stocks would also increase the ecotourism value of the island. The fragility of the reef and the need to site traps and secure them properly to minimize physical damage to the reef is also a factor to be considered.



**3. Care should be taken to avoid operations in adjacent waters that might pollute the water flowing onto the Sandy Island reefs with nutrients, toxic chemicals or increase its sediment load.**

Elkhorn coral is particularly sensitive to water quality problems of this nature.

**4. Formal scientific documentation of the Sandy Island site and trials of the proposed "accelerated reef recovery technique" would be valuable scientifically; by combining a scientific study with training of local personnel in coral reef ecology, and using the information and skills to make Sandy Island a recognized site for ecotourists, the tourism industry and fishers to learn about coral reef ecology, the "experience of Sandy island" could have benefits well beyond its boundaries.**

The descriptions provided in this report, while a reasonable basis for some management initiatives, are only preliminary ones, scientifically. They are a basis for designing a proper scientific study. From that perspective, it would be appropriate to document quantitatively and further elaborate on the qualitative observations given in this report, set up permanent monitoring transects and quadrats extending to deeper water, and to conduct replicated experiments to test the inferred relationships.

The reefs at Sandy Island in themselves constitute a very small proportion of the total reef frontage in Carriacou, and are not particularly important for protection of the mainland (Carriacou proper), although other reefs at Carriacou are in this regard. Obviously, detailed scientific studies cannot be conducted for every inch of coral reef that needs to be managed. The value of doing this at Sandy Island lies in the more general value that would have as a scientific model, and coupled with community based activities, as an educational tool.

Coral reef researchers have emphasized that the support and involvement of communities is required for sustainable coral reef management (40). Sandy Island has already focused attention of islanders on the issue of coral reef health, it is readily accessible, presents the major types of problems of exotic and local origin that have caused degradation of Caribbean reefs, and offers an opportunity for testing/developing some novel approaches to coral reef restoration. Developed in this context, restoration of the Sandy Island reefs could stimulate restoration and conservation of coral reefs more broadly in the eastern Caribbean, and provide new economic opportunities for Carriacouans.

"The conservation of coral reefs and other shallow tropical marine ecosystems depends upon the outcome of a race between the accelerating degradation of these ecosystems and two related areas of human endeavor: the development of ecologically and sociologically sound models for management and the effective education of people to the value of biological conservation" (40).

## FOOTNOTES

1. "Carriacou's Sandy Island. An Asset to Tourism and a Liability to the Environment", in December 1995 Issue of the Caribbean Compass, p. 12.
2. Prof. Patriquin conducted some of his PhD research on seagrass communities in Carriacou in 1968 and 1969, and in 1994 resurveyed the same sites in collaboration with Dr. Hunte as part of a program for monitoring long term changes in coral reef systems. Prof. Patriquin had also visited Sandy Island in 1969 and took underwater photographs of the then thriving *Acropora palmata* dominated reefs, included in this report. Dr. Hunte has researched long term changes in reefs at Barbados and elsewhere in the Caribbean with a particular interest in how the interactions between herbivores, algae and corals influence variation in coral cover over space and time.
3. Where not specifically identified, supporting documentation for this section can be found in (i) Ginsburg, R.N. (Complier). 1994 Proceedings of the Colloquium on Global Aspects of Coral Reefs: Health, Hazards and History, 1993, Rosentiel School of Marine and Atmospheric Sciences, University of Miami. (ii) Sorokin, Y.I. 1993 Coral reef Ecology. Springer-Verlag, Berlin, New York. (iii) Caribbean Conservation Association, 1991. Country Environmental Profile: Grenada. Caribbean Conservation Association, Barbados.
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