HISTORY OF A FRINGING REEF ON THE WEST COAST OF BARBADOS 1974-1992

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ABSTRACT

The northern Bellairs Reef which fringes the west coast of Barbados was surveyed during a $CaCO_3$ budget study in 1974 (Steam et al, 1977, Scoffin et al, 1980). The region was struck by Hurricane Allen in 1980 and the percentages of substrate types were resurveyed in 1981 by Mah and Stearn (1986} using the same transect lines, After the hurricane the percentage coral cover dropped from 37% to 15% whereas dead coral surfaces increased from 22% to 43% and there was a slight increase in crustose coralline algae from 41% to 42%. The fringing reef corals most damaged were Porites porites and Madracis mirabilis, In 1983 the large population of the urchin Diadema antillarum suffered 94% mortality by an unknown pathogen (Lessios et al, 1984, Hunte et al, 1986). The marked reduction in the grazing fauna had major effects on the fringing reef substrates. A resurvey along the same transect lines in 1992 showed that the cover of crustose coralline algae had dropped from 42% to 25% and dead coral surfaces (with algal turf) had increased from 43% to 60%. The live coral cover had changed little since the 1981 survey; there was no recovery of the Porites porites and Madracis mirabilis populations but the Porites astreoides, Agaricia agaricites and Millepora spp populations showed slight increases. The reported increase in eutrophication may contribute (with the demise of Diadema) to the success of algal cover. The recent seaward extension of sea defences causes seiche waves which further increase inshore turbidity.

INTRODUCTION

During the summer of 1974a study was undertaken of the calcium carbonate budget of a discrete fringing reef on the west coast of Barbados (Steam and Scoffin 1978). The object of the study was to compare quantitatively the rate of production of calcium carbonate by the dominant reef-builders (Steam et al 1977) with the rate of destruction by the major bioeroders (Scoffin et al 1980). The reef chosen was the Northern Bellairs reef (Figure 1) which is about 150m x 150m and isolated from neighboring reefs on the sides and on the seaward margin by an apron of sand.

The Bellairs fringing reefs have been described and zoned by Lewis (1960) and Steam et al (1977). The distribution of the reef-builders follows a zonation which roughly parallels the reef front. Consequently for quantitative analysis the reef was subdivided into equal areas by semi-elliptical boundaries each approximately paralleling the reef front. Counts of reef cover were made along six roped transects, taking readings every 10cm for 50cm of each metre of rope. The attributes recorded were dead coral, crustose coralline algae, living coral, sand and rubble. The living corals present in greater than 1% areal cover of rock surface were: Porites porites, Porites astreoides, Agaricia agaricites, Montastrea annularis, Siderastrea siderea, Millepora spp. Madracis mirabilis and Favia fragum. The counts {total 2175) of substrate type were totalled for each elliptical increment. To take account of the variation in biota with depth and distance from shore the normalised density for each substrate type was calculated for each ellipse and then the trapezoidal integration (Morton 1964) of the ellipses gave the percentage areal cover on the whole reef for each substrate type. The actual areal cover of the various corals and encrusting algae was determined taking into account the planimetric area of the reef and its relief. The rates of growth of the reef builders were determined using stain experiments, planted substrates and skeletal density banding as revealed by x-radiography. The rate of destruction of the reef by bioeroders during fairweather conditions was determined by a variety of techniques (Scoffin et al 1980).

The accessibility of this reef has allowed subsequent surveys to be carried out. Shortly after Hurricane Allen in 1980 Mah and Steam (1981) made a survey of the percentage cover of the various substrate types along the transect lines used earlier. The damage from the impact of the hurricane was assessed by comparison of the two percentage coral cover surveys coupled with a quantitative analysis of the rubble associated with the reef (Mah & Steam 1981).

Bellairs reef was one of the sites used in the comparative study of reefs suffering different levels of eutrophication (Tomascik and San&r, 1985, 1987a,b). In their study, the effects of eutrophication on growth rate of Montastrea annularis, structure of scleractinian coral communities and reproduction of Porites porites were investigated. The authors also recorded (Tomascik and Sander, 1985) the physiochemical and biological conditions of the sea water from this area during the period 1981 to 1982. Wittenberg and Hunte (1992) reported the effects of eutrophication and sedimentation on the abundance, mortality and community structure of juvenile corals on fringing reefs in this area of the west coast of Barbados.

During a visit in 1992 while studying the movement of sand-sized sediment around and within the framework of the reef (Scoffin & Tudhope in press) it was again possible to survey the coral cover on the Northern Bellairs fringing reef using the original lime transects.

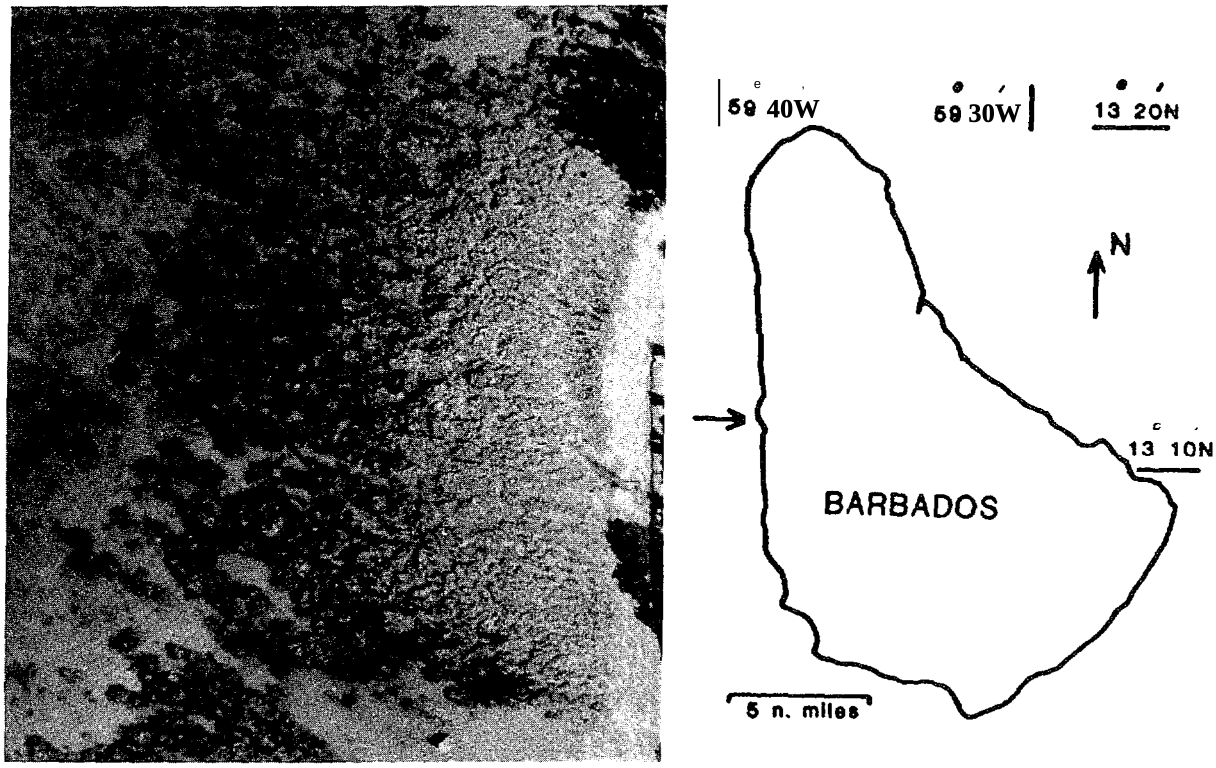

Figure 1 Northern Bellairs reef on the west coast of Barbados

RESULTS

The percentage cover of corals and crustose coralline algae on the rock substrates of the Northern Bellairs Reef during the three periods 1974,1981 and 1992 is given in Table 1.

Table 1. Percentage cover of different substratypes on reef ellipses (1 inshore, 6ffshore) and whole reef, in 1974, 1981 and 1992 surveys.

	ELLIPSE 1	ELLIPSE 2	ELLIPSE 3	ELLIPSE 4	ELLIPSE 5	ELLIPSE 6	TOTAL REEF
	’74 ’81 ’92	’74 ’81 ’92	’74 ’81 ’92	’74 ’81 ’92	’74 ’81 ’92	’74 ’81 ’92	’74’81’92
Dead coral	47 41 70	18 36 77	16 35 69	18 45 50	14 54 55	16 47 41	22 43 60,
Crustose coralline algae	5 0 5 4 3 0	60 49 17	50 50 21	32 47 31	2 8 2 8 2 0	2 6 2 6 2 8	41 42 25
Porites porites	- - -	5 1 -	9 tr tr	17 - 1	2 1 1 1	1 7 1 2	1 2 1 1
Porites astreoides	3 5 -	8 4 4	8 2 5	1 1 2 6	1 0 4 6	9 5 7	8 4 4
Agaricia agaricites	- - -	2 6 1	6 7 3	9 5 8	8 7 8	10 8 14	6 5 6
Montastrea annularis	- - -	1 1 -	5 5 t r	6 - 1	5 4 3	1 2 6 2	5 3 1
Siderastrea siderea	- - -	tr tr -	2 tr -	2 - 1	5 2 6	7 3 2	3 1 1
Millepora spp	- - -	2 3 1	3 1 1	2 1 3	4 3 3	2 3 4	2 2 2
Madracis mirabilis	- - -	tr - -	1 - -	2 - -	3 1 tr	1 - -	1 - -
Favia fragum	- - -	1 tr tr	tr - tr	tr - -	1 - tr	“ - -	tr - -

The relative coral cover expressed as a percentage is given in Table 2.

Table 2. Relative coral cover percentage

CORAL	1974	1981	1992
Porites writes	**32**	**6**	**7**
Pork astreoides	22	25	27
Agaricia agaricites	16	31	40
Montastrea annularis	14	19	6
Siderastrea siderea	8	6	7
Millepora spp	5	13	13
Madracis mirabilis	3	.	

DISCUSSION

Since the original survey in 1974 there have been both short-lived and prolonged perturbations to this reef at north Bellairs. The dramatic disturbances were the physical damage caused by Hurricane Allen in August 1980 and the mass mortality of Diadema antillarum in summer 1983. The chronic stresses have been the increase in eutrophication as a consequence of nutrient enrichment, sedimentation and toxicity associated with the dumping of domestic and industrial wastes over the last 20 years and an increase in fresh water run off due to man-made modifications of natural drainage streams into major storm drains which empty directly onto most of the fringing reefs. An increase in inshore turbidity at the Bellairs reef has resulted from the reflection of waves from recently extended sea defences which creates nearshore seiche wavea during high tide.

Hurricane Allen

Hurricane Allen, though not passing directly over Barbados produced large waves that affected west coast reefs in 1980. Winds were estimated to be 100 knots. The coral population was dramatically reduced from 37% to 15%. Those branching corals that grew on the tops of spurs in shallow water were the most severely affected, Porites porites coverage was reduced by 96%. This breakage lowered the level of the spur tops creating a substrate of freshly truncated branching coral skeletons and added large quantities of coral stick rubble to the reef grooves. Mah and Steam (1981) noted that the composition of the groove rubble was 40 wt% Porites porites, 32 wt% Acropora cervicornis and 13 wt% Madracis mirabilis The bulk of the rubble made of A. cervicornis and M. mirabilis were swept upon to the fringing reef from their former positions of growth in the reef-front zone of 7 to 20m depth. The percentage loss of the other important corals was as follows Porites astreoides 71%, Agaricia agaricites 25%, Montastrea annularis 54%, Siderastrea siderea 75% (Mah and Stearn, 1981). The coral diversity (recorded as Shannon-Weaver and Simpson indexes) showed the sharpest decline in the zone of the fringing reef where the storm waves broke (Mah & Steam 1981). Prior to Hurricane Allen the Bellairs reef was of relativel y high diversity between the pioneer stage and the stage of dominance by a late successional species (Porites porites). The hurricane damage reset the successional process back to a pioneer stage of low coral diversity. Agaricia agaricites became the dominant coral species on the reef changing from formerly making up 16% of living coral cover to occupying 31% of the living coral cover. Whereas Porites porites formerly the dominant coral dropped from 32% of the coral cover to 6% of the coral cover.

Mass Mortality Of Diadema Antillarum

AS part of the reef $CaCO_3$ budget survey of 1974-1975 the number of bioeroding organisms were determined. The spiny black sea urchin Diadema antillarum was especially abundant on the west coast reefs and the population on north Bellairs reef had art average density of 23 individuals per square metre of rocky reef substrate (Scoffin et al, 1980). It has been suggested (Sammarco, 1980, 1982) that corals settle more readily when grazing by urchins is rapid enough to prevent filamentous non-coralline algae from monopolizing available substrate space. A massive mortality of Diadema antillarum occurred in the Caribbean starting in Panama in January 1983 and spreading throughout the Caribbean by January 1984 (Lessios et al 1984). The major impact in Barbados was in September 1983 after which the Diadema population was reduced by 94% (Hunte et al, 1986). The survey of Bellairs in 1992 showed a marked increase in the area of dead coral substrate at the expense of mainly the crustose coralline algae (Table 1). This dead coral surface had dense algal turf which may well be responsible for the slow recruitment of corals on the fresh substrates exposed during the hurricane two years earlier, as well as this displacement of the calcareous red algae.

When we compare the substrate cover figures for 1981 and 1992 (Table 1) all the coral abundances are relatively unchanged except for Montastrea annularis which shows a considerable reduction. The reduction in this coral is initially surprising as it is the massive Montastrea colonies that are so commonly seen to be infested by Diadema urchins which hollow out the dish-shaped profiles to the large colonies by their collective grazing activities. And so it might have been anticipated that a reduction in Diadema would result *in* recovery of these grazed surfaces and art increase in Montastrea cover on the reef. This is not the case. 1992 is nine years after the mass mortality event and the Diadema population is now increasing and many still actively graze Montastrea heads, for these colonies commonly have lobate surfaces in which discrete 'islands' of living polyps develop separated by channels of dead skeleton which are suitable sites for initial grazing attack. Siderastrea siderea colonies on the other hand, rarely suffer surface grazing by Diadema *on account* of their extensive cover of living polyps. The remaining coral species whose cover is relatively unchanged (i.e. P. porites, P. astreoides A. agaricites, Millepora spp) are essentially new recruits after the hurricane, as is confined by their colony size and their substrate (commonly truncated P. porites branches). The reduction in Diadema may have affected the mortality rate of the juvenile corals of these species (Wittenberg and Hunte 1992) and contributed to the cause for no marked increase in abundance over the twelve years after the hurricane. Hughes (1985) found that the mortality of juvenile corals *rose* sharply following an algal bloom caused by this same event of dramatic reduction of Diadema in Jamaica.

Eutrophication

The effects of the increase in eutrophication along the west coast of Barbados has been described by Tomascik and Sander (1985, 1987a,b) and Wittenberg and Hunte (1992). The main consequence of this eutrophication are reported by the above authors to be:

1) Increase in production at other trophic levels affects the coral community directly through competition for space or indirectly through increased bioturbation or sediment trapping.

2) An increase in eutrophication results in a decrease in the population of Diadema which may contribute to the elevated benthic algae biomass.

3) Increase in phytoplankton biomass affects the coral community indirectly through the reduction of light intensity and/or alteration of spectral quality thus affecting zooxanthellae photosynthesis essential for normal coral function.

4) High turbidity and sedimentation rates have been implicated in severely affecting coral diversity cover, abundance and health. Elevated suspended particulate matter concentrations may be responsible for reduced growth rates of some corals.

5) There is a lower recruitment of juveniles and a higher juvenile mortality with increase in eutrophication and this results in community structure changes from one dominated by low recruitment, low natural mortality corals (such as Montastrea annularis, Siderastrea siderea) to one dominated by high recruitment, high natural mortality corals (such as P. astreoides A. agaricites).

All these trends are supported by the figures of coral cover presented here.

Suspended Sediment

The inshore back-reef zone of Bellairs reef in 1974 was very rich in crustose coralline algae whose skeletogenesis contributed significant $CaCO_3$ to the reef. The strengthening of the sea defences in front of the sea-front property next to the reef has resulted in a seaward extension of the gabion (large limestone boulders) by approximately 2m over the last 15 years. The beach sand has migrated from this shore and now during high tide waves are reflected from the gabion back to sea to form standing waves (seiche wave) where they meet the next advancing wave 10 to 30m offshore. The reinforcement of the wave increases wave height and this causes an increase in the amount and size of suspended sediment particules in this nearshore zone. The crustose coralline algae may have suffered from this sediment loading as well as the other effects that resulted in their greater competition from filamentous algal turf.

CONCLUSIONS

Three surveys of substrate cover on the Bellairs fringing reef of West Barbados were made in 1974, 1981 and 1992 along the same transect lines. The cover of the substrates changed most dramatically after Hurricane Allen struck the reef in 1980. Coral cover dropped from 37% to 15%, with the branching corals living on spur tops (Porites porites and Madracis mirabilis) most severely affected. Dead coral surfaces increased from 22% to 43% during this physical erosion. The dramatic reduction (94%) in the population of the urchin Diadema antillarum in summer 1983 was followed by an increase in filamentous algae and a reduction in crustose coralline algae cover. The increase in non-calcareous benthic algae biomass has also been due to eutrophication and enhanced suspended sediment loading. The relatively unchanged coral population between 1981 and 1992 is thought to be due essentially to the reduction in both recruitment of juvenile corals and reduction in coral growth rate under conditions of increasing eutrophication.

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