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MONITORING OF CORAL REEFS WITH LINEAR TRANSECTS: A STUDY OF STORM DAMAGE[1]

CAROLINE S. ROGERS, MARCIA GILNACK and H. CARL FITZ, III

West Indies Laboratory, Fairleigh Dickinson University, Teague Bay, Christiansted, St. Croix, VI 00820, U.S.A.

Abstract: Monitoring of coral reefs in the U.S. Virgin Islands through repeated sampling of linear transects revealed that Hurricane David (August 1979) caused significant changes in the amounts of live and dead hard coral cover on these reefs, i.e., cover by scleractinians and the hydrozoan *Millepora*. Mean percent cover of the most abundant coral species, spatial indices (a measure of bottom topographical complexity), the number of species within transects, the diversity index (H'), and the evenness (J'), did not, however, change significantly as a result of this storm. Mortality in corals did not appear to be species specific. Monitoring of established transects proved to be an effective way of quantifying storm damage. With the increasing interest in management of coral reefs, this technique could also be useful for assessing other types of reef destruction.

INTRODUCTION

Alarm over degradation of the world's coral reefs has led to increased interest in management of these beautiful, complex ecosystems and in documentation of the impact of stresses which are affecting them (Johannes, 1975). Objective assessment of human impact on reefs requires baseline information on natural variations and knowledge of the effects of the natural destructive forces which range from boring sponges (Hein & Risk, 1975; Bak, 1976) to hurricanes (Woodley *et al.*, 1981; Rogers *et al.*, 1982). For example, smashing of coral colonies from careless anchor tosses may be insignificant compared to the damage from storm swells. Reefs, like other ecosystems, are dynamic, not static, and changes in reef structure do not necessarily indicate that a reef is being stressed (see Bak & Luckhurst, 1980; Porter *et al.*, 1981).

The most effective monitoring requires collection of data before, during, and after an impact of known magnitude. Baseline data provide an estimate of natural variability. Because of time constraints, methods which are rapid and which maximize information obtained per unit time are preferable.

Line transects have proven to be particularly effective for studies of coral reef structure (see review by Loya, 1978). Transects can provide data on the number of coral species present, their relative abundance or percent live cover, and the percent of dead and live coral. Diversity indices and evenness can also be calculated, as well as the topographical complexity of the reef.

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Most scientists have used transects to compare different reef areas or to describe a particular reef at a given point in time (e.g., Loya & Slobodkin, 1971; Loya, 1972; Porter, 1972, 1974; Bouchon, 1981). There have been relatively few long-term, quantitative studies where the same transects or quadrats were resurveyed in an attempt to relate changes in reef structure to natural stresses or human impact and to document recovery (see review by Pearson, 1981). Connell (1973, 1976, 1978) documented storm damage and subsequent recovery within permanent reef quadrats at Heron Island, Australia, noting changes in the number of coral species and in the percent of live coral cover. Dahl (1981) described the results of resurveying quadrats along transects done by Mayor (1924) in 1917 and successive surveys of transects on other reefs in American Samoa within a 10-yr period. He concluded that coral community composition can shift greatly over time even in areas without conspicuous human influence, and emphasized that identification of human impact, other than obvious devastation, requires more knowledge of variations in the distributions of reef organisms under normal conditions. Loya (1975, 1976) resurveyed transects to show the adverse effects of oil pollution on coral recolonization on a Red Sea reef recovering after a catastrophic low tide. The use of linear transects allowed quantification of the recovery process, both recruitment and regeneration. Woodley *et al.* (1981) described the impact of Hurricane Allen (1980) on previously studied populations of gorgonians (along line transects), hard corals (within quadrats), and other reef organisms on the Discovery Bay Reef in Jamaica. Porter *et al.* (1981) monitored quadrats with photographs to show the effects of this storm on patterns of coral abundance and mortality. Using similar photoquadrats, Porter *et al.* (1982) documented the death of Dry Tortugas reef corals in shallow water following extremely low water temperatures.

The objective of this study was to assess reef community structure in certain areas in the U.S. Virgin Islands using linear transects, and, through re-examination of the same transects, to monitor changes in this structure over time. The passage of major storms during the study period allowed an evaluation of the effectiveness of this method in documenting storm damage.

STUDY SITES

Four coral reef areas in St. Thomas and one in St. Croix, U.S.V.I., were the main study sites (Fig. 1a,b). The study site in Perseverance Bay, the largest bay on the southwestern coast of St. Thomas, is ≈6 m deep and part of a submerged barrier reef. Just east of Perseverance, Brewers Bay has submerged barrier reefs in its western and central portions. The smaller western reef is separated from the central one by a distinct sand channel. The Brewers West and Brewers Middle study areas are ≈5 and 6 m deep, respectively. The fourth coral reef site in St. Thomas is a fringing reef off the windward shore of Flat Cay, a small island ≈3 km south of Perseverance Bay. The study area is ≈4 m deep. Salt River submarine canyon is off the north coast of St. Croix. The study area on the sloping west wall of the canyon ranges from 9 to 15 m deep.

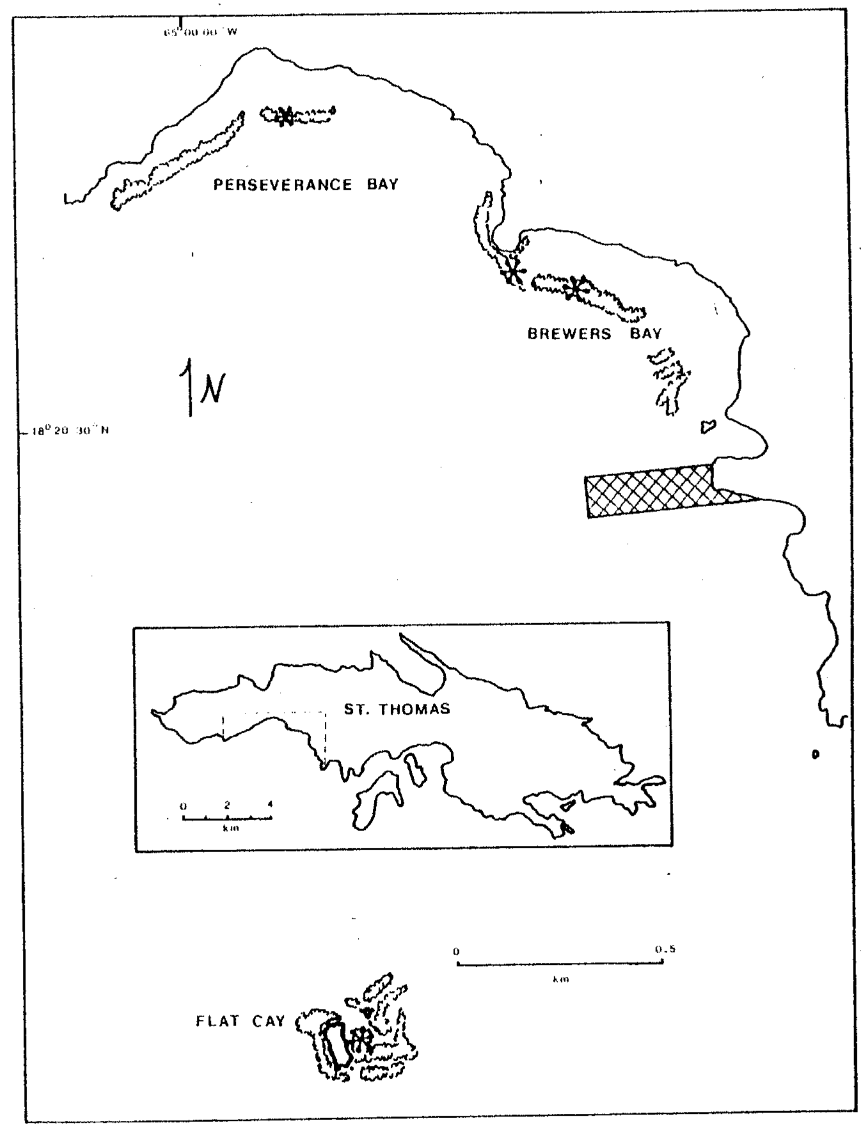

Fig. 1a. Location of Perseverance, Brewers Middle, Brewers West, and Flat Cay study sites in St. Thomas: *, approximate locations of transects.

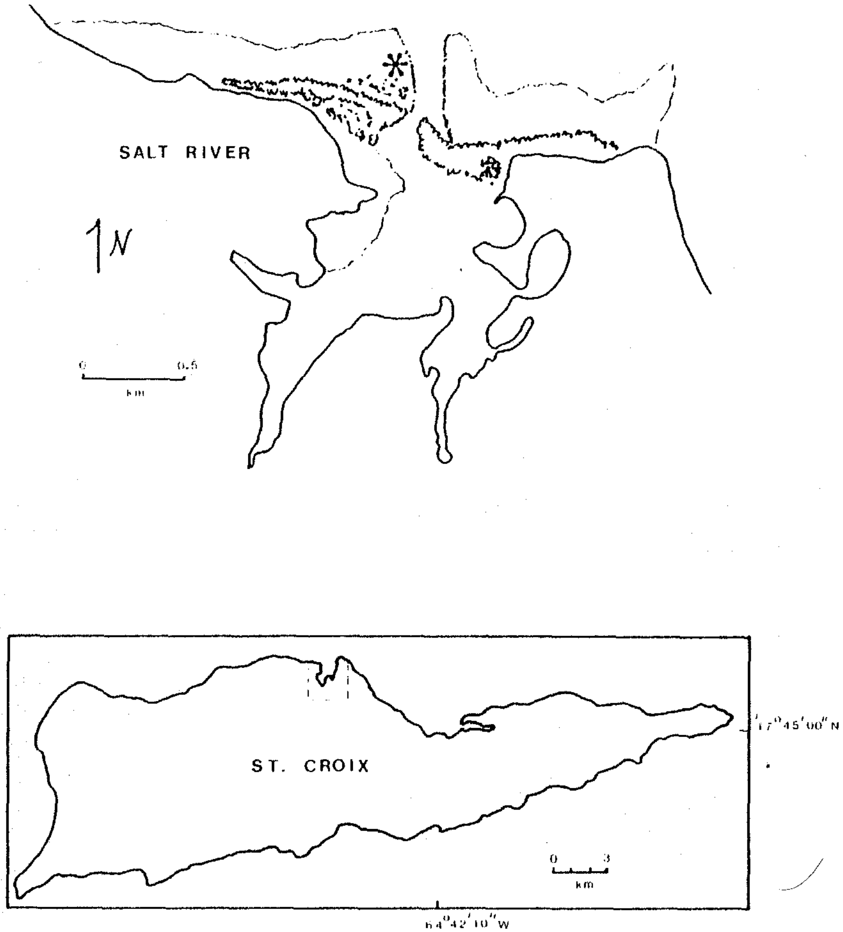

Fig. 1b. Location of Salt River study site in St. Croix: *, approximate location of transects.

Major Storms During the Study Period

The center of Hurricane David passed ≈268 km south of St. Thomas on 30 August, 1979. This was an intense storm with record-breaking winds in the immediate vicinity of the eye. The storm generated waves on the south shore of St. Croix with an estimated average height of 4.3–4.6 m (14–15 ft) and a maximum height of 5.8 m (19 ft) (Blanche, 1980). The main threat from David came from heavy seas and high winds. A few days later, on 4 September, Tropical Storm Frederic went a few km north of St. Thomas, producing much smaller waves and lighter winds. This was a less intense, poorly

organized storm with no well-defined center. Heavy rainfall led to extensive flooding in some areas of St. Thomas and St. Croix, and nearshore waters were turbid for a few days.

One year later, on 5 August, 1980, Hurricane Allen tracked ≈495 km south of St. Thomas. Waves impacting the southern coast of St. Croix were measured at 1.4–1.8 m (5–6 ft) (Hubbard, pers. comm.; Piwonka, pers. comm.). Extremely turbid conditions offshore lasted ≈3 days. Damage to coral reefs in this study appeared to be from heavy swells associated with David with no obvious effects from Frederic or Allen.

Methods

Eight to ten 10-m linear transects were established at Brewers Middle, Brewers West, Perseverance Bay, and Flat Cay in St. Thomas and at Salt River in St. Croix. During the course of this study (January 1979–July 1981), the authors did the research in St. Croix and the authors plus five others worked in St. Thomas. The data from Salt River provide the best estimate of the precision of the method, as the same investigators performed the transects during each sampling period. Any given transect, however, was not necessarily done by the same person each time.

Transects ran perpendicular to shore or to the reef crest. Depth varied little along each transect, except at Salt River where each transect began in 9 m of water and went down to 15 m. Stakes made from steel reinforcing rods marked the ends of every transect. Plots of cumulative species number against number of meters along the transect indicated that 10 m was a sufficient transect length as, in general, a levelling off of the cumulative number of species occurred after six transects were surveyed. Data were collected four times from the St. Thomas transects and three times from the St. Croix transects.

A modification of the linear transect methods described by Loya & Slobodkin (1971), Loya (1972), and Porter (1972) was used (Adey *et al.*, 1981). A nylon line 10 m long was extended along the reef bottom at the height of the highest corals. A chain was then positioned beneath the line, following the contour of the bottom. The objective was to measure as carefully as possible all surface areas under the line. The number of chain links (each 1.3 cm long) which covered living and dead coral, sand and other reef components (e.g., sponges) was recorded. From these measurements, the percent of live and dead coral and the relative abundance of each of the scleractinian and hermatypic hydrozoan corals (*Millepora* spp.) were calculated. Calculations of live coral cover and dead coral cover were based on the total number of chain links of reef organisms and substratum under the line.

The ratio of the number of meters of chain to the number of meters of line gave an index of bottom topographical complexity, the "spatial index". A spatial index which approaches 1 implies very low relief. Similar calculations of reef bottom topography appear in Risk (1972), and Luckhurst & Luckhurst (1978).

The Shannon formula for diversity (Shannon & Weaver, 1949) was calculated as follows, with a projection of 1 cm under the line being considered as an "individual":

$$H' = -\sum p_i \ln p_i ,$$

where $p_i = n_i/N$, N = total number of centimeters (individuals) of all species under the line, and n_i = the number of centimeters of species i under the line. (This index underestimates the actual value of H' for the whole community (Pielou, 1977), but here we were only interested in comparing indices for the same areas over time.)

Evenness was calculated as $J' = H'/H'_{max}$ (Pielou, 1966), which is the diversity of the total number of meters under consideration divided by the diversity which would exist if all of the species present were distributed equally. A value of 1.00 represents maximum evenness. Diversity and evenness for each sampling period were calculated from the combined data from all transects.

When analysis of variance (ANOVA) indicated that a significant difference in means existed, the Student–Newman–Keuls test was used to determine which means differed significantly (Sokal & Rohlf, 1969). A confidence level of $P < 0.05$ was used for all statistical tests. All percentage data were transformed (arcsine) prior to statistical analyses (Sokal & Rohlf, 1969).

RESULTS

The total number of coral species within transects ranged from 14 at Flat Cay to 25 at Brewers West (Table I). *Porites porites* and *Montastraea annularis* were among the most abundant coral species (those constituting ≥ 10% of total live coral cover) at all St. Thomas study sites, with *Agaricia agaricites* also abundant at Perseverance and Brewers West and *Millepora* spp. abundant at Flat Cay and Perseverance. (See Wells & Lang, 1973, for taxonomic authorities.) *Agaricia agaricites*, *Montastraea cavernosa*, and *Madracis decactis* were the most abundant species at Salt River. Mean percent cover of these species (Table II) did not change significantly at any of the study sites.

TABLE I

Coral species within transects at each study site: * contributes 10% or more of total live coral cover.

	Perseverance Bay	Brewers West	Brewers Middle	Flat Cay	Salt River
Stephanocoenia michelinii	×	×	×		×
Madracis decactis		×	×		*
Madracis mirabilis			×		
Acropora palmata		×		×	
Acropora cervicornis	×	×	×	×	
Agaricia agaricites	*	*	×	×	*
Agaricia fragilis	×				
Agaricia lamarcki	×		×		×
Helioseris cucullata	×	×	×		×
Siderastrea siderea	×	×	×	×	×
Porites astreoides	×	×	×	×	×
Porites porites	*	*	*	*	×
Porites furcata	×	×		×	
Favia fragum	×	×		×	
Diploria labyrinthiformis	×	×	×		×
Diploria strigosa	×	×		×	×
Colpophyllia natans	×	×	×		×
Colpophyllia breviserialis		×	×		
Montastraea annularis	*	*	*	*	×
Montastraea cavernosa	×	×	×	×	*
Oculina diffusa		×		×	
Meandrina meandrites		×			×
Dichocoenia stokesi	×	×	×		×
Dendrogyra cylindrus			×		
Scolymia sp.	×	×	×		×
Isophyllia sinuosa	×				×
Isophyllastrea rigida	×	×		×	×
Mycetophyllia lamarckiana	×				
Mycetophyllia ferox	×	×	×		×
Eusmilia fastigiata	×	×	×		×
Millepora spp.	*	×	×	*	×
Total no. spp.	24	25	21	14	21

TABLE II

Mean percent cover (± SD) of the most abundant coral species within transects.

Perseverance Bay	Jan. 79	May 80	Nov. 80	June 81
P. porites	34 ± 19	26 ± 20	25 ± 18	30 ± 23
M. annularis	28 ± 10	31 ± 12	24 ± 9	26 ± 11
A. agaricites	11 ± 9	12 ± 7	20 ± 13	14 ± 9
Millepora spp.	7 ± 11	13 ± 12	7 ± 9	11 ± 12
Brewers West	Jan. 79	May 80	Nov. 80	June 81
P. porites	36 ± 17	34 ± 16	26 ± 13	34 ± 19
M. annularis	15 ± 18	26 ± 21	30 ± 17	25 ± 20
A. agaricites	14 ± 7	16 ± 12	18 ± 13	16 ± 10
Brewers Middle	Mar. 79	Mar. 80	Sept. 80	Apr. 81
M. annularis	56 ± 25	56 ± 28	54 ± 20	59 ± 20
P. porites	20 ± 13	21 ± 13	21 ± 12	21 ± 9
Flat Cay	May 79	May 80	Nov. 80	June 81
P. porites	51 ± 23	48 ± 22	47 ± 18	56 ± 22
M. annularis	14 ± 12	11 ± 13	11 ± 11	13 ± 12
Millepora spp.	14 ± 8	12 ± 13	14 ± 13	9 ± 8
Salt River		June 80	Jan. 81	July 81
A. agaricites		27 ± 19	25 ± 14	33 ± 18
M. decactis		18 ± 13	21 ± 11	24 ± 10
M. cavernosa		17 ± 12	17 ± 15	12 ± 15

FLAT CAY

There was a significant decrease in the mean amount of live coral and increase in the mean amount of dead coral at Flat Cay from January 1979 (before Hurricane David) to May 1980 (8 months after the storm) ($P < 0.05$, one-way ANOVA) (Table III). A decrease in live coral and an increase in dead coral appeared in every transect. Transect data were remarkably similar for May, November 1980 and June 1981. The diversity indices and evenness showed no consistent trends during the study period. Spatial indices ranged from 1.4–1.8.

BREWERS MIDDLE

At Brewers Middle, the mean percent of live coral did not change significantly during the study, but there was an overall decrease in the amount of live coral. Although the differences in mean percent of live coral for successive time periods were small, the largest drop occurred between March 1979 and March 1980, the interval which included Hurricane David (Table IV). The percent of dead coral was significantly less in March 1979 than in April 1981 ($P < 0.05$, one-way ANOVA) (Table IV). The spatial indices, diversity indices, and evenness followed no particular pattern.

TABLE III

Coral transects: Flat Cay; A, January 1979; B, May 1980; C, November 1980; D, June 1981.

Transect	Live coral (%) A	B	C	D	Dead coral (%) A	B	C	D	Spatial index A	B	C	D	Diversity index, H' (evenness, H'/H_{max}) A	B	C	D
1	68	20	18	15	25	78	77	83	1.3	1.5	1.6	1.3	1.52 (0.63)	1.63 (0.71)	1.66 (0.72)	1.53 (0.73)
2	62	48	44	59	35	48	54	39	1.1	1.1	1.7	1.4				
3	48	42	39	33	51	57	59	65	1.3	1.9	1.3	1.4				
4	56	35	46	33	43	65	53	66	1.3	1.8	2.2	2.1				
5	66	55	46	53	29	41	50	44	1.6	2.7	1.7	2.7				
6	79	52	51	52	18	40	43	41	1.5	1.3	1.5	1.6				
7	65	51	51	54	25	44	39	39	1.3	2.1	1.9	1.6				
8	74	45	52	51	21	46	38	43	1.5	1.5	1.8	2.4				
Mean	65	44	43	44	31	52	52	53	1.4	1.7	1.7	1.8				
SD	10	11	11	15	11	13	13	17	0.2	0.5	0.3	0.5				
n	8	8	8	8	8	8	8	8	8	8	8	8				
Total no. spp.	11	10	10	8												

Note: Data for all transects at all sampling times are presented here and in Table V (Salt River) to show the precision of the technique. Table I summarizes the data from other sites.

TABLE IV

Coral transects: Brewers Middle, Brewers West, and Perseverance: A, March 1979; B, March 1980; C, September 1980; D, April 1981; E, January 1979; F, May 1980; G, November 1980; H, June 1981.

	Live coral (%)				Dead coral (%)				Spatial index				Diversity index, H' (evenness, H'/H'_{max})			
Brewers Middle																
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Mean	45	38	34	33	46	48	53	57	1.8	2.2	2.4	2.3	1.55 (0.53)	1.39 (0.49)	1.55 (0.55)	1.27 (0.44)
SD	8	11	10	10	5	10	7	8	0.4	0.7	0.6	0.8				
n	9	9	9	9	9	9	9	9	9	9	9	9				
Total no. spp.	19	17	17	18												
Brewers West																
	E	F	G	H	E	F	G	H	E	F	G	H	E	F	G	H
Mean	36	25	26	27	38	60	60	59	1.4	2.0	1.8	2.0	1.87 (0.69)	1.77 (0.64)	1.81 (0.65)	1.77 (0.64)
SD	7	6	10	11	7	11	9	9	0.2	0.3	0.3	0.2				
n	8	8	8	8	8	8	8	8	8	8	8	8				
Total no. spp.	15	16	16	16												
Perseverance																
	E	F	G	H	E	F	G	H	E	F	G	H	E	F	G	H
Mean	44	34	32	32	44	54	56	52	1.3	2.2	2.1	2.0	1.79 (0.66)	1.81 (0.67)	1.79 (0.63)	1.77 (0.61)
SD	13	10	10	12	6	11	7	13	0.1	0.3	0.5	0.4				
n	8	8	8	8	8	8	8	8	8	8	8	8				
Total no. spp.	16	15	17	18												

BREWERS WEST

At Brewers West, there was a decrease in the percent of live coral and an increase in the percent of dead coral between the first and second sampling periods (Table IV). The mean percent of dead coral was significantly less in January 1979 (the first time transects were examined) than for the three subsequent sampling times, all of which followed Hurricane David ($P < 0.05$, one-way ANOVA). Analysis of variance indicated a significant difference in the means for percent live coral; the Student–Newman–Keuls test did not indicate a significant difference between individual means. Mean percent of live coral in January 1979 was higher than at any subsequent time ($P < 0.05$, one-way ANOVA). Diversity and evenness were very similar throughout the study period, and spatial indices ranged from 1.4–2.0.

PERSEVERANCE

There was a decline in the mean amount of living coral and an increase in the mean amount of dead coral at Perseverance after Hurricane David (Table IV). However, ANOVA showed no statistically significant differences in coral cover. Diversity indices and evenness remained similar throughout the study period, while spatial indices ranged from 1.3–2.2.

SALT RIVER

All transects at Salt River were surveyed after Hurricane David. Species diversity, evenness, spatial indices, and the mean percent of live and dead coral changed little between sampling periods (Table V).

TABLE V

Coral transects: Salt River; A, June 1980; B, February 1981; C, July 1981.

Transect	Live coral (%) A	Live coral (%) B	Live coral (%) C	Dead coral (%) A	Dead coral (%) B	Dead coral (%) C	Spatial index A	Spatial index B	Spatial index C	Diversity index, H' (evenness, H'/H'_{max}) A	Diversity index B	Diversity index C
1	14	18	7	59	53	58	1.6	1.8	1.7			
2	17	15	17	61	61	69	1.7	2.1	1.9	2.12	2.18	2.07
3	19	18	20	60	64	63	1.6	1.8	1.6	(0.71)	(0.72)	(0.70)
4	16	17	13	76	66	75	1.5	1.4	1.5			
5	24	20	18	54	57	65	1.6	1.5	1.3			
6	16	13	14	84	72	74	2.0	1.9	1.9			
7	13	25	15	77	65	68	1.7	1.8	1.4			
8	24	19	24	69	72	69	2.2	1.7	1.7			
9	22	19	19	57	55	66	2.2	1.8	1.8			
Mean	18	18	16	66	63	67	1.8	1.8	1.6			
SD	4	3	5	11	7	5	0.3	0.2	0.2			
n	9	9	9	9	9	9	9	9	9			
Total no. spp.	20	21	19									

DISCUSSION

Hurricane David was most likely responsible for the decreases in the amount of live coral and the increases in the amount of dead coral observed at Flat Cay, Brewers Middle, Brewers West, and Perseverance Reefs. About 2 wk after this storm, extensive physical damage to *Acropora palmata* was seen at Flat Cay. There were many broken branches and shattered colonies. (This species is not abundant in the transects.) Some massive corals had been overturned. At Brewers West, there were numerous overturned colonies of several species including *Dendrogyra cylindrus*, *Montastraea cavernosa*, and *Montastraea annularis*. Similar damage was observed at other sites as well.

There were no significant changes in mean percent cover of the most abundant coral species, total number of coral species within transects, diversity indices or evenness as a result of the hurricane. These data suggest that coral mortality was not species specific. If the hurricane had affected the dominant corals more than any of the others, one would expect to see an increase in evenness and diversity.

For example, if we take the data from Brewers Middle (4/81) and arbitrarily eliminate *M. annularis* which made up 65% of all the living coral found within transects, the diversity index increases from 1.27 to 1.75 and evenness from 0.44 to 0.62. On the other hand, if we examine the Brewers West data (1/79) and eliminate *P. porites* which made up 36% of all live coral, the diversity index changes from 1.87 to 1.90 and evenness from 0.69 to 0.72. In this case, corals were distributed evenly enough that arbitrary elimination

of a single species did not change the diversity index or the evenness. Similarity in diversity indices and evenness over time can occur when (1) there have been no changes in reef structure, (2) there have been equivalent increases or decreases in all coral species, or (3) there has been elimination of species which were not abundant enough (relative to other species) to greatly affect these indices.

Our data indicate that a greater or different impact is required to bring about changes in the diversity indices or evenness components than in the percent of live and dead coral. Community structure as reflected in diversity and evenness did not change although there were statistically significant changes in the percent of live and dead coral.

Diversity indices are useful when based on a sufficient number of transects for comparison of reef areas or for assessment of the status of a particular area before and after an impact, such as a storm or dredging project. There is, however, no direct correlation between diversity and reef "health". Shallow Caribbean reef zones of actively growing *Acropora palmata* have very low diversity. In this study, the area with the lowest percent live coral cover, Salt River, had the highest diversity index.

The spatial index is a reflection of the topographical complexity of the reef. One would expect this index to change only as a result of stresses which physically (rather than physiologically) damage the corals responsible for the architecture of the reef. Presumably, the index would decrease after storms on very shallow Caribbean reefs where the branching morphology of *A. palmata* is the main contributor to structural relief. Greater susceptibility of branching species compared to massive coral species to destruction by storms is well documented (e.g., see Woodley *et al.*, 1981). With smashing of *A. palmata* colonies and the elimination of several layers of surface area (the coral branches), the index would be expected to decrease. Rogers *et al.* (1982) noted a marked decrease in this index on a St. Croix reef dominated by *A. palmata* after Hurricane David, but transects done before and after the storm were not identical and the data were limited. *A. palmata* was not the most abundant species within transects on any of the reefs in this study, and the main effect of the storm was the overturning of some massive corals and probably the death of some coral tissue from impact with coral fragments and abrasion of sediments carried in storm seas. Our data suggest that the overturning of massive corals such as *Diploria* and *Montastraea* may not affect the spatial index.

The mean spatial index changed significantly only at Perseverance, although there was an increase at the other stations. The most likely explanation is observer subjectivity. With the exception of the senior author who did some of the transects at each sampling period, different people did the transects in 1979 than in 1980 and 1981. Different observers may measure holes, crevices, and coral branches (or layers) in various ways. This subjectivity is more likely to affect spatial indices than the other transect parameters. A more meticulous measuring of the coral layers will lead to an increase in the spatial index but presumably will not affect the percent of live and dead coral as more links of both dead and live coral will be measured.

The Salt River data show that a remarkable consistency is possible when the same people examine permanently marked transects over time (and in the absence of major environmental alterations). The mean percent of live coral for the three sampling periods ranged from 16–18% while the mean percent of dead coral ranged from only 63–67%. The spatial indices, the overall diversity indices, and the evenness also varied only slightly.

Although coral cover appeared to be very constant within transects at Salt River, monitoring took place for only 1 yr. Recent studies by Bak & Luckhurst (1978) and Porter *et al.* (1981) demonstrated that changes in reef structure can occur even in the absence of stresses. Over a 5-yr period, Bak & Luckhurst (1978) found that coral cover within quadrats on a Curaçao reef decreased slightly but significantly at depths of ⩽20 m. Spatial rearrangements of reef components, both living (e.g., corals and sponges) and non-living (e.g., sediments) were substantial down to a depth of ⩽40 m.

Over a 4-yr period in Jamaica, Porter *et al.* (1981) noted that cover by *Acropora palmata* and *A. cervicornis* tended to increase on the shallow reef, with rarer species having a higher mortality. (Hurricane Allen reversed this trend as it caused the greatest mortality among these more abundant branching species.) The design of monitoring programs for coral reefs and subsequent interpretation of data must take into consideration possible changes in cover and spatial arrangement even in the absence of major disturbances.

Quadrats are more suitable than transects for studies of spatial arrangements on the reef or competitive interactions (Porter *et al.*, 1982) while transects seem more effective when the objective is to examine more extensive reef areas for changes in coral cover or other less subtle changes in community structure as a result of stresses.

In summary, the use of permanent transects to monitor coral reef and coral community structure appears to be very effective, having the advantage of minimizing the problems caused by the natural patchiness in the reef environment which can mask environmental alterations. Repeated long-term observation and analysis of the transects will give a measure of variability in the method and will allow documentation of changes.

Initially we suspected that there would be significant differences in transect data only when there were highly noticeable, extensive changes in reef structure at the study sites. We saw isolated, overturned colonies of massive corals, and in the shallowest areas, some fractured *A. palmata* colonies, but we did not observe extensive bleaching, and the increase in the amount of dead coral was not conspicuous. The transect method, therefore, proved to be more sensitive than anticipated in terms of documenting changes in the percent of live and dead coral. Similarity in diversity indices and evenness throughout the study period suggested that the hurricane did not alter these aspects of reef structure and that mortality was not species specific in the reef areas we studied.

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