One-Year Post-Baseline Monitoring and Assessment of Coral Reattachment Success and Coral Recruitment, at the *C/V Hind* Grounding Site, Broward County Florida

Final report

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EXECUTIVE SUMMARY

During a storm in March 1998, the large container ship, *C/V Hind*, broke anchor and damaged 781 m^2 of coral reef and 4,258 m^2 of live hardbottom habitat offshore Ft. Lauderdale, Florida. The grounding dislodged and fragmented many reef-building corals and created flat topped, scarified reef substrate in several places. In May 1998, contractors, Sea Byte Inc and SSR Inc., reattached over 300 stony corals to reef substrate in 12 zones distributed along the path of the damage; they did not record information on the species, size and condition of the reattached corals.

The purpose of this project was to: 1) relocate, categorize the health and physical stability, and photograph each of the 157 reattached corals tagged in 2000; 2) relocate, categorize the health and physical stability, and photograph each of the 30 control corals tagged in 2000 and compare to the health of the tagged, reattached corals; 3) retag all reattached and control corals with missing tags; and 4) re-assess the permanent transects at a scarified reef site and at the nearby undamaged sites to determine and compare recruitment of new stony corals and other sessile invertebrates. Of the 157 reattached corals tagged in 2000, 156 were found in 2001 (1 coral in Zone 12 was missing but the tag was in place). All 30 of the control corals tagged in 2000 were found in 2001. Pooled data (reattached and control) indicated that the corals in this area had significantly more tissue mortality in 2001 than in 2000. No difference in increased tissue mortality was determined between the reattached and control corals. No significance difference in increased tissue mortality between the reattached and control corals was determined for the four species of tagged and control corals examined.

As was found in 2000, the abundance of juvenile corals on the scarified reef substrate was higher (16 recruits/15m^2) than on the similar undamaged substrate (3 recruits/15m^2). However, the abundance of other sessile invertebrates (gorgonians, zoanthids, sponges etc.) was greater on the undamaged site.

Corals that are dislodged and/or fragmented as the result of vessel groundings may be susceptible to tissue death, disease and algal overgrowth. This project demonstrates that dislodged colonies have good survivorship comparable to naturally attached corals if they are firmly reattached to the substrate. In addition to simply saving the loose colonies and fragments, reattaching corals may facilitate the recovery of a damaged area by releasing larvae for recruitment, attracting recruits, and maintaining substrate complexity for fisheries. The reattachment of corals as a restoration method may be especially appropriate for the high latitude reefs found off southeast Florida where coral cover and recruitment may be low, prolonging reef recovery. The continued monitoring of the damaged area and the tagged corals is vital to evaluate reattachment success, to determine if additional effort is required, and to follow reef recovery.

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1 Introduction

1.1 Statement of Report Purpose

This report discusses the one-year post-baseline assessment and monitoring of reattached corals associated with the grounding of the vessel *C/V Hind* in 1998 offshore Broward County (Figure 1). This report also addresses the completion of field sampling Tasks 1 through 4.

The Statement of Work describes Task 1 as:

- Relocating each of the 157 reattached corals that were tagged in 2000.
- Categorizing the general health of each of these 157 reattached corals to include bleaching, tissue lesions, tissue mortality and death.
- Categorizing the physical condition of each of these 157 corals to include stable, loose or missing.
- Photographing each of these 157 reattached corals to continue the permanent record of size and tissue condition and for continued comparison measurements.

Task 1 is 100% complete.

The Statement of Work describes Task 2 as:

- Relocating each of the 30 control corals that were tagged in 2000.
- Categorizing the general health of each of these 30 corals to include bleaching, tissue lesions, and obvious tissue mortality for continued comparison to the 157 reattached corals.
- Categorizing the physical condition of each of these 30 corals to include stable, loose or missing for continued comparison to the 157 reattached corals.

- Photographing each of these 30 control corals to continue the permanent record of size and tissue condition and for continued comparison to the 157 reattached corals.

Task 2 is 100% complete.

The Statement of Work describes Task 3 as:

- Retagging all reattached corals that have missing tags.
- Retagging all control corals that have missing tags.

Task 3 is 100% complete.

The Statement of Work describes Task 4 as:

- Re-assessing the three coral recruitment, permanent transects that were established in 2000 on former scarified reef surfaces.
- Re-assessing the three coral recruitment, permanent transects that were established in 2000 on adjacent similar undamaged, natural habitat.

Task 4 is 100% complete.

1.2 Background

The purpose of the contract is to perform a one-year post-baseline assessment of a Broward County coral reef area that experienced grounding damage by the vessel *C/V Hind* in March 1998. The grounding dislodged and fragmented many reef-building corals and created flat topped, scarified, bare, reef substrate in several places (Figures 2-4). Subsequent to the grounding a contractor reattached over 300 stony corals in 12 zones back to the reef surface. The contractor did not, however, provide any information on the species, size and condition of the reattached corals. During summer 2000, NCRI was contracted to identify and assess as many reattached corals as possible. A subset of 157

representative reattached corals as well as 30 naturally occurring reference corals was mapped for future monitoring. The reattachment and health status of these tagged reattached corals and tagged control corals was characterized and underwater photographs taken. In addition, permanent transect locations were established at scarified reef sites and nearby undamaged sites to compare recruitment of new stony corals.

1.3 Rationale

Coral colonies are frequently dislodged and/or fragmented as the result of vessel groundings. Damaged corals may be susceptible to continued tissue death, disease and algal overgrowth. Many of these damaged colonies can be saved if they are reattached to the substrate. In addition to simply saving the loose colonies and fragments, reattaching corals may facilitate the recovery of a damaged area by releasing larvae for recruitment, attracting recruits, and maintaining substrate complexity for fisheries.

The assessment and continued monitoring of the damaged area and restoration is vital to evaluate the success of the activities, to determine if additional effort is required, and to follow reef recovery. Estimation of the condition of the tagged, reattached corals includes determining their physical stability (secure, loose, or missing) and estimating health (living, % partial mortality, disease, bleaching, dead). To evaluate the success of reattachment procedures, it is important to compare the condition (health and physical) of reattached corals with nearby undamaged corals of similar size and species distribution. Evaluating coral recruitment in damaged and undamaged areas includes identification and counts of juvenile corals.

2 Methods and Materials

2.1. Task 1

2.1.1 Relocating the Tagged, Reattached Corals

Buoys were dropped at each reattachment zone with coordinates supplied by the previous contractor (and verified in 2000) from the research vessel to provide an initial search point for the eyebolt in the center of each zone. When the eyebolt was found the tagged corals were relocated using the distance and azimuth measurements recorded in 2000. Each of the black nylon tags (numbered 1-15) with white engraved numbers used to mark each of the corals (Figure 5) was cleaned of encrusting organisms. Missing tags were recorded.

2.1.2. Categorizing the Condition and Health of the Tagged Reattached Corals

As each tagged coral was relocated, notes on the condition of each coral were recorded by each of the divers. The physical stability for each was recorded as secure, loose or missing. Health characteristics were recorded for each coral including percent tissue loss, disease and bleaching (Figure 6). Corals were recorded as dead if there was no live tissue remaining on the skeleton. Once the assessment was complete for each zone, all notes were compared between divers for quality control.

In an effort to keep monitoring the same number of corals, additional reattached corals were added to the project to replace those corals that had died. In most cases the new corals were the same species and of similar size to the corals that had died. The physical stability and the health characteristics of these corals were recorded.

2.1.3 Photographing the Tagged, Reattached Corals

All tagged, reattached corals were photographed to provide a permanent image record, which may aid in future identification and evaluation. The corals were photographed using a Nikonos V underwater camera fitted with a 20mm lens or a digital camera in an underwater housing with a wide angle lens. To provide consistency and a scale in each of the images either a 0.75 m^2 PVC framer or a 0.17 m^2 PVC framer was used (Figure 7). Each photograph included a plan view image of the coral, the coral identification tag, and a reattachment zone tag and a scale (in 10 cm size increments for the 0.75 m^2 framer and 1 cm or 5 cm size increments for the 0.17 m^2 framers) on the framer.

2.2 Task 2

2.2.1 Relocating the Tagged, Reattached Control Corals

For reattachment zones that included tagged control corals, the tagged control corals were relocated using the distance and azimuth measurements recorded in 2000. Each of the black nylon tags (numbered C1-C30) with white engraved numbers used to mark each of the corals was cleaned of encrusting organisms. Missing tags were recorded.

2.2.2. Categorizing the Condition and Health of the Tagged, Control Corals

Each of the tagged, control corals was categorized in the same manner as the tagged, reattached corals (Figure 6).

2.2.3 Photographing the Tagged, Control Corals

Each of the tagged, control corals was photographed in the same manner as the tagged, reattached corals.

2.3 Task 3

2.3.1 Retagging Reattached Corals with Missing Tags

Reattached corals with missing tags in each zone were noted as the zones were assessed. These missing tags were replaced with the same type of tag and the same number. Type II Portland cement was used to attached the tags to the substrate.

In addition to replacing missing tags, tagged corals that were loose were also reattached with cement. The additional monitored corals that were added to the project to replace most of the monitored corals that had died were tagged in the same manner and with the same type of tags.

2.3.2 Retagging Control Corals with Missing Tags

Control corals tags were replaced and attached in the same manner as described above.

2.4 Task 4

2.4.1 Re-assessing Coral Recruitment Transects on the Former Scarified Reef Surfaces

In order to compare coral recruitment on scarified reef substrate against that on non-impacted reef substrate, permanent transects were installed in September 2000. Three transect locations were permanently installed on scarified substrate between Zones 7 and 9. Three control transect locations were permanently installed on non-impacted substrate in similar habitat north of Zone 8. Each transect was 10 meters long, running in a north–south direction, with 6" long, 1/4" stainless steel nails marking each meter and the north and south endpoints. Endpoint nails were tagged with identification numbers.

Transects were positioned three meters apart in parallel. The transect nails were installed by hammering into holes made with a hydraulic drill fitted with a 3/16" bit. Each nail protruded 3-4 inches above the substrate.

During assessment, a 10-meter line was strung along the nails between each end nail to serve as a guide for quadrat alignment. Each transect consisted of 20 assessed quadrats and a total area of 5 m^2. A total of 15m^2 was assessed. The quadrats were constructed of 1/2" PVC pipe and are 0.5m on a side (0.25 m^2). Each quadrat was further divided into 10 cm^2 subunits with line. The five 10 cm columns were labeled A-E and the five 10 cm rows were labeled 1-5. These 10 cm X 10 cm subunits within each quadrat were used to record the location of each organism identified during the assessment. Each quadrat was placed along the transect so that each transect nail was in the bottom left corner of the quadrat (Figure 8). Corals were identified to genera and species (if possible) and measured (length x width) to the nearest 0.5 centimeter. Fleshy sponges were measured (length x width x height) to the nearest 0.5 cm. Octocorals were identified (if possible) and measured (length x width x height). Other fauna (e.g. zoanthids) present within the quadrats were noted. All loose sediment on the substrate was fanned away to aid in visually locating organisms within the quadrat.

2.4.2 Re-assessing Coral Recruitment Transects on the Undamaged Reef Surfaces

Three transects on similar but undamaged reef substrate were installed in September 2001 as described above. These transects were just north of the three transects on the damaged substrate. These transects were assessed in the same manner as the transects on the scarified substrate.

2.5 Data Analysis

Tests for normality with the tissue mortality data failed. Therefore, ranked data was used in a generalized linear model (GLM) to compare differences in tissue mortality between years (2000 and 2001), treatments (reattached versus control), and species (*M. cavernosa*, *D. clivosa*, *S. bournoni*, and *D. stokesii* only). Pairwise comparisons of the means were completed. All statistical analyses were completed using SAS online statistical software in batch mode (SAS Institute Inc., Cary, North Carolina).

3 Results

3.1 Task 1

Progress on Task 1 began in June 2001 and was completed in September 2001.

3.1.1 Relocating the Tagged, Reattached Corals

Each of the 12 coral reattachment zones (see Figure 1) was visited. Each of the stainless steel eyebolts and numbered tags (1-12) marking the center of each of eight zones are still in place. Table 1 provides the location (latitude and longitude) of each zone. Table 2 indicates the total number of corals reattached in 1998, the number identified in 2000 and the number tagged in 2000 at each zone. Table 3 provides the distance and azimuth form the eyebolt for each tagged coral in each zone. We were successful in relocating 156 of the 157 tagged corals in the eight zones (tagged coral 12 in Zone 12 was missing).

3.1.2 Categorizing the Condition and Health of the Tagged Reattached Corals

The health and physical condition of all the corals in all 12 zones was categorized. The additional reattached corals added to the project to replace the dead corals were also

categorized. Table 4 summarizes information on the general condition of each of the tagged, reattached corals.

3.1.3 Photographing the Tagged, Reattached Corals

All of the tagged, reattached corals in all 12 zones were photographed. Figure 9 is an example of a tagged coral image. Images of all the tagged corals are included in Appendix A.

3.2. Task 2

Work on Task 2 began in June 2001 and was completed in September 2001.

3.2.1 Relocating the Tagged, Reattached Control Corals

The tagged, control corals in Zones 2, 5, 7 and 8 were located along with the tagged, reattached corals in the same Zones. Table 5 provides the distance and azimuth form the eyebolt for each tagged coral in each zone.

3.2.2 Categorizing the Condition and Health of the Tagged, Control Corals

The health and physical condition of all 30 control corals in the four zones was categorized. Table 6 summarizes information on the general condition of each of the tagged, control corals.

3.2.3 Photographing the Tagged, Control Corals

All of the tagged, control corals in Zones 2, 5, 7 and 8 were photographed (see Figure 10). Images of all the control corals are included in Appendix B.

3.3 Task 3

Work on Task 3 began and was completed in August 2001.

3.3.1 Retagging Reattached Corals with Missing Tags

All zones except Zone 4 had at least one coral with a missing tag. A total of 19 tags were replaced. Type II Portland cement was used to attached the new tags to the substrate adjacent to the corals.

3.3.2 Retagging Control Corals with Missing Tags

Two control coral tags were missing, and they were replaced.

3.4 Task 4

3.4.1 Re-assessing Coral Recruitment Transects on the Former Scarified Reef Surfaces

The coral recruitment transects in the scarified areas were assessed on 7 August 2001. Within each quadrat all hard and soft corals and fleshy sponges were measured. The location of each of the organisms within the quadrat was also recorded on data sheets that included an outline of the quadrat with its 10 cm X 10 cm subunits. Appendix C provides a complete set of the data sheets indicating the location and relative size of all fauna recorded.

3.4.2 Re-assessing Coral Recruitment Transects on the Undamaged Reef Surfaces

The coral recruitment transects in the undamaged area were assessed on 7 August 2001. Within each quadrat all hard and soft corals and fleshy sponges were measured. The location of each of the organisms within the quadrat was also recorded on data sheets that included an outline of the quadrat with its 10 cm X 10 cm subunits. Appendix C provides a complete set of the data sheets indicating the location and relative size of all fauna recorded.

4 Discussion

4.1 Coral Reattachment Success

4.1.1 Physical Stability

Coral reattachment success in terms of physical stability was found to be high in 2000. In 2000, after more than two years, 322 of the 385 originally reattached corals (84%) were still securely attached to the substrate. In 2000, 157 of these 322 reattached corals were tagged for continued monitoring. In 2001, 156 of these tagged corals were found secure to the substrate (one coral was missing in Zone 12). In terms of physical stability, concrete appears to be a very effective material to use when reattaching loose and fragmented corals back to the substrate.

4.1.2 Health/Survivorship

The original contractor who reattached the loose and fragment corals in 1998 did not supply data on the health of those corals. NCRI assessed the health of 322 reattached corals in 2000. Of these 322 reattached corals, 285 (74%) were still living. In 2000, 157 of these 285 corals were tagged to monitor continued health. In order to accurately discuss the health of these reattached corals, 30 control corals were also tagged in 2000. A comparison of the health of these control corals against the reattached corals increases the understanding on the effectiveness of reattaching corals.

Pooled data (reattached and control corals) indicates that in general corals in this area had significant increase in tissue mortality from 2000 to 2001 ($F = 4.80$, $P = 0.029$). Table 7 summarizes the percent tissue mortality for the reattached corals in each of the zones. All zones (except zone 8) showed increased tissue mortality in 2001. The mean tissue mortality increased from 27% in 2000 to 32% in 2001. A further breakdown of the

data indicates that 54% of the tagged, reattached corals had increased tissue mortality from 2000 to 2001 while 26% had no change in tissue mortality and 19% had reduced tissue mortality (positive growth) (Table 7).

Table 8 summarizes the percent tissue mortality for the control corals in each of the zones. All zones showed increased tissue mortality in 2001. The mean tissue mortality increased from 12% in 2000 to 17% in 2001. A further breakdown of the data indicates that 67% of the control corals had increased tissue mortality from 2000 to 2001 while 27% had no change in tissue mortality and 7% had reduced tissue mortality (Table 7). These tissue mortality trends are similar to those seen in the reattached coral data. Statistical analysis indicates that the reattached corals did not significantly differ from the control corals in the amount of increased tissue mortality ($F = 0.17$, $P = 0.677$).

Table 9 summarizes the percent tissue mortality for four species (*M. cavernosa*, *D. clivosa*, *S. bournoni*, and *D. stokesii*) of reattached corals and their control corals in each of the zones. The mean percent tissue mortality for each of these coral species increased from 2000 to 2001 for both the reattached and control corals. No significant difference was determined between these four species for increased tissue mortality ($F = 0.47$, $P = 0.70$).

4.2 Coral and Other Sessile Invertebrate Recruitment

The scarified area near reattachment zones 7, 8, 9, 10, and 11 was still very obvious even after more than three years of recovery (see Figure 4). A qualitative assessment of the area indicated that there were very few large hard or soft coral colonies present. To examine abundance quantitatively the three, 10 meter long permanent

transects in the scarified and undamaged areas were assessed and compared to the data collected in 2000.

As was found in 2000, the data indicates that the abundance of juvenile hard corals was greater on the scarified area than on the undamaged area (Table 10). The number of hard corals identified on the scarified transects actually decreased from 21 in 2000 to 16 in 2001. The data also show that the scarified substrate has fewer larger, fleshy sponges and soft corals. The abundance of sponges and soft corals did increase in 2001 for both the scarified and undamaged transects. This indicates that the scarified substrate has not recovered fully to an "undamaged" state. The increased juvenile coral abundance in the scarified area may be a function of more substrate available for settlement and less competition from other sessile invertebrates. Because the undamaged substrate has greater coverage of the other sessile invertebrates and a greater coverage of algal/sediment turf, identifying small coral recruits was more difficult. More than three years is required for the sessile community to return to an "undamaged" state. Continued monitoring of the scarified area and undamaged area transects will provide invaluable information on this recovery process.

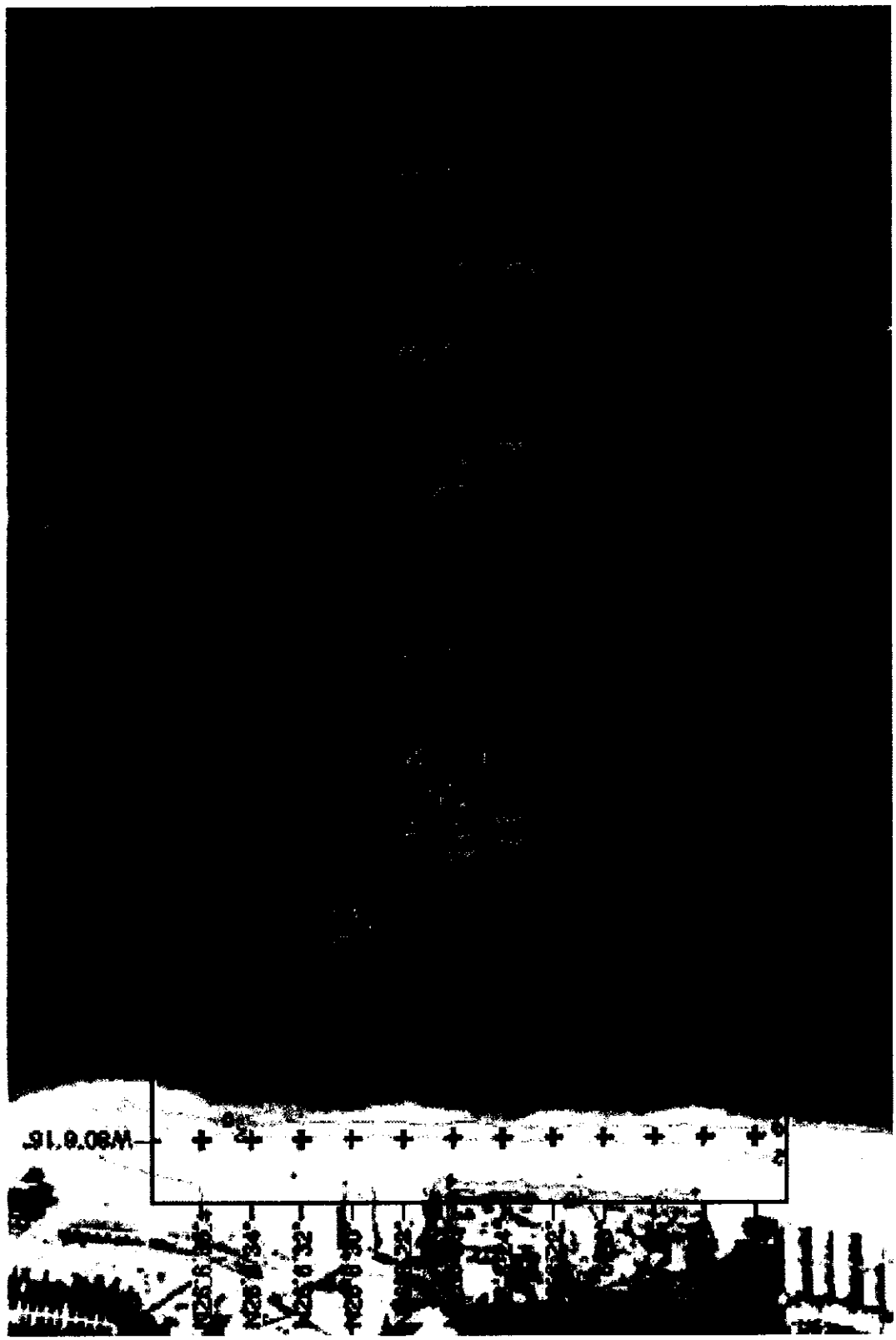

Figure 1. Map of C/V Hind grounding coral restitchment site (yellow square) offshore Ft. Lauderdale.

Figure 2. Fragmentation of *Montastrea* boulders near zones 8 and 9 caused by impact of hull.

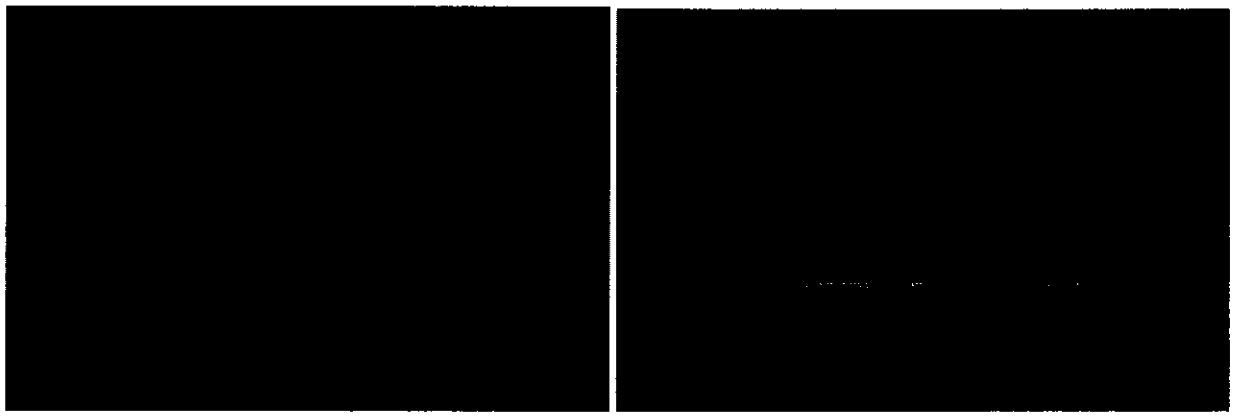

Figure 3. Keel damage after two years looking east (left) and west (right) between zones 7 and 8 and near zones 9, 10, and 11.

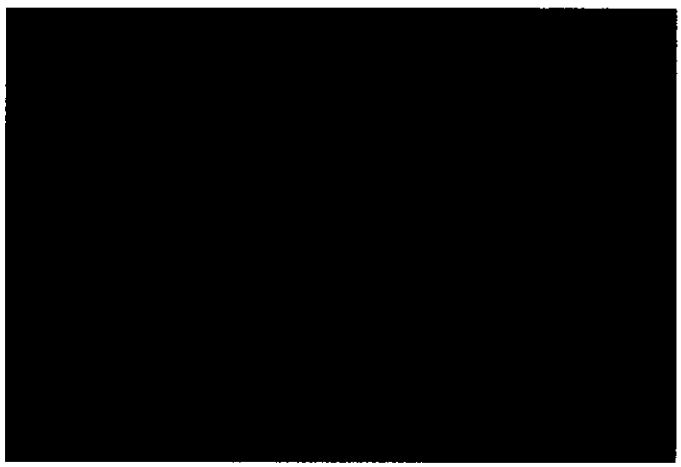

Figure 4. Scarified area near zones 7, 8, 9, 10, and 11 after two years.

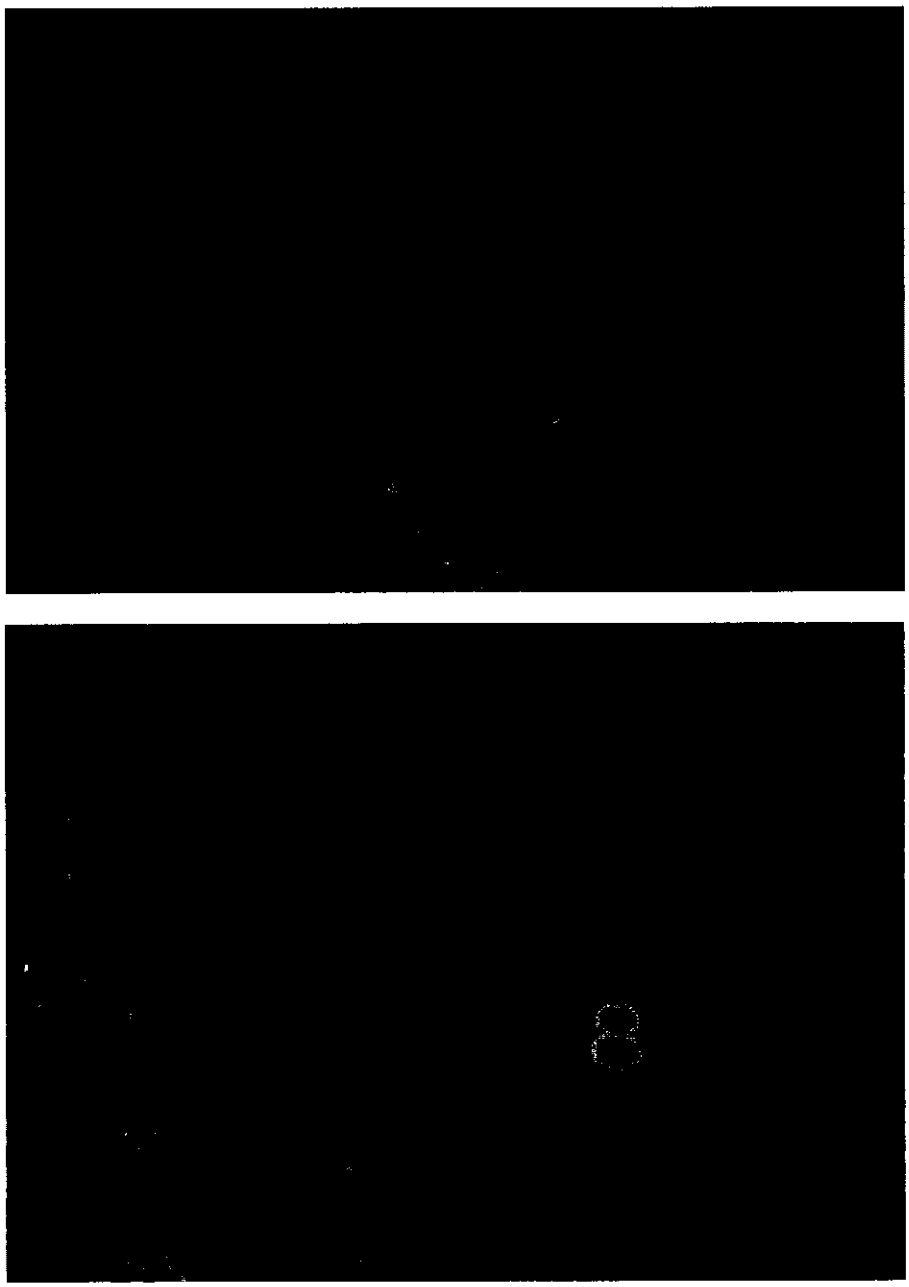

Figure 5. Tagged *Montastrea faveolata* boulder (top) and smaller *Dichocoenia stokesii* colony (bottom).

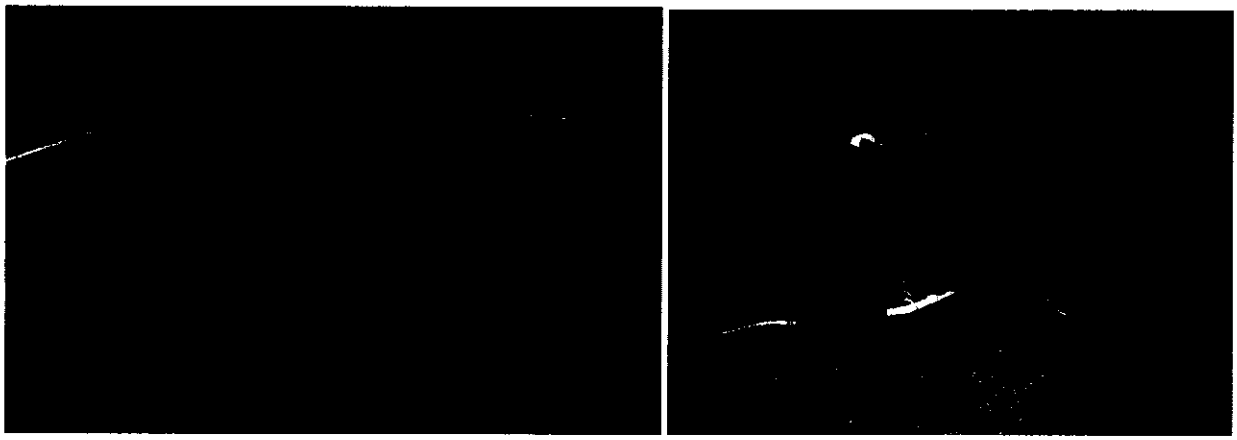

Figure 6. Distance, azimuth (from eyebolt) and size recorded in 2000 were used to relocate each tagged coral; notes on physical condition and health were recorded for each tagged coral.

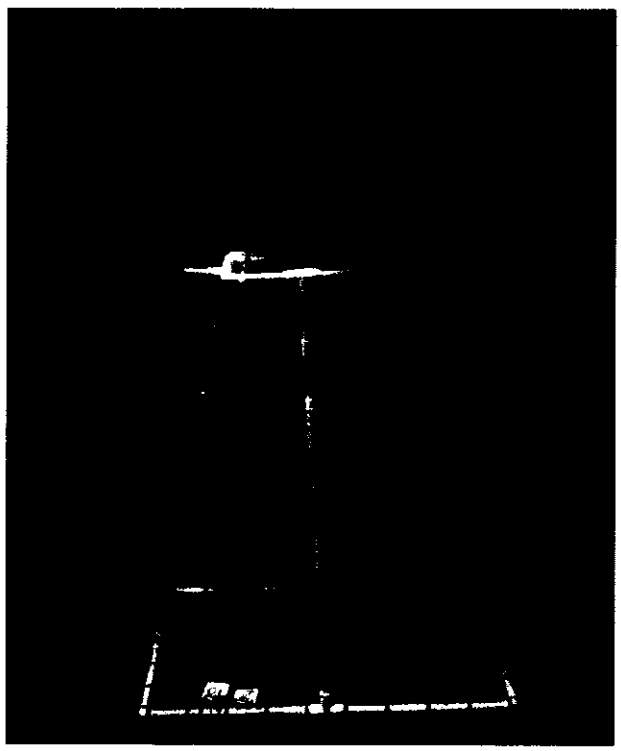

Figure 7. Equipment and technique used to photograph each tagged reattached and control coral. This image shows the 0.75 m^2 with 10 cm increments marked. A 0.17m^2 framer was used to photograph many of the smaller corals.

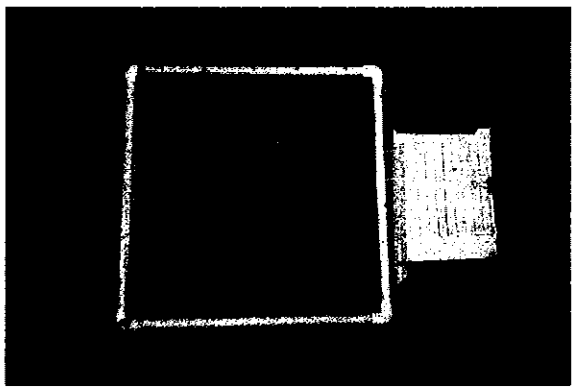

Figure 8. A 0.25 m^2 quadrat and data sheet used for the coral transect surveys. A permanent stainless steel nail is in bottom inside corner.

Figure 9. Image of reattached coral #14 in Zone 3 taken with the 0.75m^2 framer with 10 cm size increments.

Figure 10. Image of reattached coral #10 in Zone 10 taken with the 0.17m^2 framer with 1 cm size increments.

Table 1. Location of Reattachment Zones (NAD 27 Florida East Coast State Plane converted to NAD 83 latitude and longitude.)

REATTACHMENT ZONE	LATITUDE (N)	LONGITUDE (W)
1	26° 06.411'	80° 05.572'
2	26° 06.401'	80° 05.640'
3	26° 06.411'	80° 05.701'
4	26° 06.400'	80° 05.786'
5	26° 06.402'	80° 05.805'
6	26° 06.439'	80° 05.928'
7	26° 06.411'	80° 06.023'
8	26° 06.424'	80° 06.025'
9	26° 06.417'	80° 06.034'
10	26° 06.413'	80° 06.036'
11	26° 06.404'	80° 06.036'
12	26° 06.464'	80° 06.125'

Table 2. The number of corals reattached in 1998 and relocated in 2000 and the number of corals tagged in 2000 and relocated in 2001 in each Zone.

REATTACHMENT ZONE	NUMBER OF CORALS REATTACHED IN 1998	NUMBER OF REATTACHED CORALS FOUND IN 2000	NUMBER OF CORALS TAGGED IN 2000	NUMBER OF TAGGED CORALS FOUND IN 2001
1	15	14	10	10
2	54	53	15	15
3	36	34	15	15
4	27	24	14	14
5	17	14	11	11
6	31	24	14	14
7	4	4	4	4
8	34	33	14	14
9	38	26	15	15
10	39	31	15	15
11	72	61	15	15
12	18	16	15	14
Total	385	334	157	156

Table 3. Reattached corals tagged in 2000 in each zone. Distance and azimuth measurement were taken from eyebolt; width and height are maximum values for colony; * denotes no data. Cells in italics indicate new colonies tagged in 2001.

Zone	Tag #	Species	Distance (cm)	Azimuth (degrees)	Height (cm)	Width (cm)	Whole Colony or Fragment
1	1	*S. siderea*	112	10	5	10	W
	2	*S. michellini*	89	35	10	10	W
	3	*S. michellini*	61	85	10	15	W
	4	*S. siderea*	63	120	10	15	W
	5	*M. cavernosa*	86	145	10	20	W
	6	*S. michellini*	58	180	10	20	W
	7	*S. michellini*	65	240	5	10	W
	8	*S. michellini*	70	265	10	15	W
	9	*M. cavernosa*	111	285	<5	15	W
	10	*M. cavernosa*	70	345	5	25	W
2	1	*D. stokesii*	795	15	5	10	W
	2	*S. siderea*	885	15	5	10	W
	3	*M. cavernosa*	309	15	10	20	W
	4	*P. astreoides*	704	145	15	25	F
	5	*M. faveolata*	450	165	15	40	F
	6	*M. cavernosa*	60	210	20	40	W
	7	*M. cavernosa*	385	270	15	20	W
	8	*M. cavernosa*	330	275	20	25	W
	9	*M. meandrites*	534	300	30	15	W
	10	*M. cavernosa*	300	305	15	25	W
	11	*M. cavernosa*	154	330	20	25	W
	12	*S. bournoni*	41	330	25	30	W
	13	*M. cavernosa*	550	345	15	25	W
	14	*S. bournoni*	440	345	30	30	W
	15	*M. cavernosa*	509	350	20	30	W
	16	*M. meandrites*	*267*	*145*	*25*	*35*	*W*
	17	*M. cavernosa*	*225*	*230*	*15*	*25*	*W*
3	1	*M. cavernosa*	251	15	30	40	W
	2	*M. cavernosa*	56	45	10	20	W
	3	*M. cavernosa*	319	45	10	20	W
	4	*M. cavernosa*	253	60	20	25	W
	5	*M. cavernosa*	372	70	15	20	W
	6	*S. bournoni*	62	120	15	20	W
	7	*M. cavernosa*	153	120	25	40	W
	8	*M. cavernosa*	300	125	10	25	W
	9	*M. cavernosa*	300	135	15	20	W
	10	*M. cavernosa*	352	155	10	20	W
	11	*M. faveolata*	402	155	10	15	F
	12	*C. natans*	269	190	20	50	W
	13	*S. bournoni*	115	200	20	25	W
	14	*M. cavernosa*	351	260	25	30	W
	15	*M. cavernosa*	472	265	15	30	W

Table 3. continued

Zone	Tag #	Species	Distance (cm)	Azimuth (degrees)	Height (cm)	Width (cm)	Whole Colony or Fragment
4	1	*M. cavernosa*	140	45	10	35	W
	2	*D. stokesii*	175	45	10	15	W
	3	*M. meandrites*	175	185	10	25	W
	4	*P. astreoides*	112	195	10	20	W
	5	*D. stokesii*	62	220	5	10	W
	6	*M. cavernosa*	163	240	10	30	W
	7	*S. michelinii*	50	245	10	20	W
	8	*M. cavernosa*	146	260	10	20	W
	9	*M. cavernosa*	185	280	5	10	W
	10	*M. meandrites*	36	285	10	20	W
	11	*M. cavernosa*	113	300	30	60	F
	12	*M. cavernosa*	175	325	30	50	W
	13	*M. cavernosa*	55	70	30	50	W
	14	*M. cavernosa*	65	45	30	50	W
5	1	*S. bournoni*	385	0	15	30	W
	2	*D. labyrinthiformes*	330	0	5	15	W
	3	*M. cavernosa*	166	0	5	20	W
	4	*M. cavernosa*	60	20	20	30	W
	5	*M. cavernosa*	130	25	10	20	W
	6	*M. cavernosa*	78	45	15	20	W
	7	*S. bournoni*	45	105	20	25	W
	8	*M. cavernosa*	188	215	10	20	W
	9	*M. cavernosa*	33	240	20	30	W
	10	*S. bournoni*	165	255	30	40	W
	11	*S. bournoni*	134	270	20	20	W
6	1	*D. stokesii*	272	0	20	20	W
	2	*D. clivosa*	237	30	20	40	F
	3	*P. astreoides*	310	60	15	25	F
	4	*D. clivosa*	135	65	10	30	F
	5	*D. stokesii*	194	75	10	20	W
	6	*D. clivosa*	382	100	15	25	W
	7	*M. meandrites*	220	110	25	40	W
	8	*M. cavernosa*	217	130	20	30	W
	9	*M. meandrites*	292	200	10	30	W
	10	*D. clivosa*	340	205	20	40	W
	11	*M. cavernosa*	70	240	20	30	F
	12	*M. cavernosa*	222	310	15	29	F
	13	*M. cavernosa*	182	325	30	60	W
	14	*D. stokesii*	95	330	20	25	W
7	12	*M. faveolata*	197	70	50	90	F
	13	*M. faveolata*	112	105	50	110	F
	14	*M. faveolata*	183	140	60	70	F
	15	*M. faveolata*	209	340	65	60	F

Table 3. continued

Zone	Tag #	Species	Distance (cm)	Azimuth (degrees)	Height (cm)	Width (cm)	Whole Colony or Fragment
8	1	*M. faveolata*	53	15	30	40	F
	2	*M. faveolata*	283	15	30	50	F
	3	*M. faveolata*	229	45	60	70	F
	4	*M. cavernosa*	114	100	40	40	F
	5	*M. faveolata*	192	115	20	30	F
	6	*M. cavernosa*	157	140	50	20	F
	7	*M. faveolata*	160	170	30	35	F
	8	*M. faveolata*	230	195	10	20	F
	9	*M. faveolata*	485	195	25	30	F
	10	*M. faveolata*	231	225	25	40	F
	11	*M. faveolata*	297	240	15	30	F
	12	*M. cavernosa*	75	240	20	70	F
	13	*M. faveolata*	127	315	30	60	F
	14	*M. cavernosa*	259	350	15	30	F
	15	*M. cavernosa*	*373*	*160*	*20*	*20*	*F*
9	1	*M. cavernosa*	665	25	55	60	F
	2	*M. cavernosa*	206	25	25	30	F
	3	*D. stokesii*	205	45	15	20	W
	4	*D. clivosa*	270	55	10	15	F
	5	*M. cavernosa*	107	90	10	15	F
	6	*M. cavernosa*	164	115	20	20	F
	7	*D. clivosa*	186	120	20	20	F
	8	*D. stokesii*	106	120	20	20	W
	9	*M. cavernosa*	36	165	20	10	F
	10	*M. cavernosa*	173	185	15	50	F
	11	*M. cavernosa*	90	185	17	14	F
	12	*D. clivosa*	479	210	15	50	F
	13	*M. cavernosa*	247	230	30	60	F
	14	*M. cavernosa*	139	230	20	20	F
	15	*M. cavernosa*	59	345	30	30	F
	16	*M. cavernosa*	*246*	*215*	*13*	*30*	*F*
	17	*M. cavernosa*	*130*	*0*	*50*	*70*	*F*
10	1	*M. cavernosa*	320	50	10	15	F
	2	*D. clivosa*	257	50	5	10	F
	3	*D. stokesii*	285	60	10	10	W
	4	*D. clivosa*	340	70	5	15	F
	5	*D. clivosa*	235	75	5	15	F
	6	*D. clivosa*	194	75	10	20	F
	7	*D. clivosa*	339	60	9	22	F
	8	*D. clivosa*	432	75	10	15	F
	9	*D. clivosa*	210	50	6	14	F
	10	*D. clivosa*	420	125	10	35	F
	11	*D. clivosa*	335	165	10	35	F
	12	*M. faveolata*	397	180	25	35	F
	13	*D. clivosa*	263	210	10	20	F
	14	*M. faveolata*	107	310	15	30	F
	15	*M. faveolata*	260	355	20	40	F
	16	*D. clivosa*	*235*	*25*	*10*	*40*	*F*

Table 3. continued

Zone	Tag #	Species	Distance (cm)	Azimuth (degrees)	Height (cm)	Width (cm)	Whole Colony or Fragment
11	1	*D. clivosa*	258	15	15	25	F
	2	*D. clivosa*	200	35	15	25	F
	3	*D. clivosa*	302	150	15	15	F
	4	*D. clivosa*	295	155	15	20	F
	5	*S. michellini*	522	185	10	10	W
	6	*M. faveolata*	110	240	15	20	F
	7	*M. faveolata*	275	240	15	25	F
	8	*P. astreoides*	315	275	10	30	W
	9	*D. clivosa*	100	280	10	25	F
	10	*D. clivosa*	380	310	10	25	F
	11	*M. cavernosa*	946	325	30	45	W
	12	*D. clivosa*	494	330	15	30	F
	13	*D. clivosa*	280	340	15	35	F
	14	*M. faveolata*	670	350	15	20	F
	15	*D. clivosa*	526	350	10	15	F
12	1	*D. clivosa*	302	10	10	20	F
	2	*D. clivosa*	197	10	10	35	F
	3	*D. clivosa*	86	10	10	30	F
	4	*D. clivosa*	240	30	10	25	F
	5	*D. clivosa*	181	30	10	25	F
	6	*D. stokesii*	125	90	15	25	W
	7	*D. clivosa*	275	95	10	35	F
	8	*D. clivosa*	280	115	10	25	W
	9	*M. meandrites*	132	120	10	35	W
	10	*D. clivosa*	425	150	10	25	F
	11	*D. clivosa*	223	150	10	18	F
	12	*P. astreoides*	480	160	20	15	F
	13	*D. stokesii*	157	205	10	15	W
	14	*D. stokesii*	125	265	10	20	W
	15	*D. clivosa*	348	325	20	60	F
TOTAL		163 colonies					

Table 4. Health and condition of the tagged reattached corals in each zone. Percent tissue loss estimated in 2000, percent tissue loss estimated in 2001 and bleaching and presence of disease and lesions in 2001. Cells in italics indicate new colonies tagged in 2001.

Zone	Tag #	Species	% Tissue Mortality 2000	% Tissue Mortality 2001	Bleaching	Lesions	Disease
1	1	*S. siderea*	0	5			
	2	*S. michellini*	20	20		Y	
	3	*S. michellini*	20	5		Y	
	4	*S. siderea*	0	10			
	5	*M. cavernosa*	0	5	Pale		
	6	*S. michellini*	10	10		Y	
	7	*S. michellini*	10	20		Y	
	8	*S. michellini*	0	20			
	9	*M. cavernosa*	0	30		Y	
	10	*M. cavernosa*	15	20			
2	1	*D. stokesii*	50	60	Pale	Y	
	2	*S. siderea*	0	5			
	3	*M. cavernosa*	0	20			
	4	*P. astreoides*	0	30	Pale		
	5	*M. faveolata*	15	15			
	6	*M. cavernosa*	25	40	Pale edges	Y	
	7	*M. cavernosa*	0	30	Pale	Y	
	8	*M. cavernosa*	0	5			
	9	*M. meandrites*	85	100			
	10	*M. cavernosa*	10	15	Pale	Y	
	11	*M. cavernosa*	10	20		Y	
	12	*S. bournoni*	40	75			
	13	*M. cavernosa*	35	60			
	14	*S. bournoni*	5	10			
	15	*M. cavernosa*	90	95			
	16	*M. meandrites*	*NA*	5			
	17	*M. cavernosa*	*NA*	0			
3	1	*M. cavernosa*	5	5			
	2	*M. cavernosa*	15	20		Y	
	3	*M. cavernosa*	5	10		Y	
	4	*M. cavernosa*	35	55	Pale	Y	
	5	*M. cavernosa*	70	75			
	6	*S. bournoni*	55	55	Pale		
	7	*M. cavernosa*	30	20			
	8	*M. cavernosa*	5	15	Pale	Y	
	9	*M. cavernosa*	5	10		Y	
	10	*M. cavernosa*	30	30			
	11	*M. faveolata*	0	15			
	12	*C. natans*	20	20			
	13	*S. bournoni*	10	5			
	14	*M. cavernosa*	5	10			
	15	*M. cavernosa*	25	30		Y	

Table 4. Continued

Zone	Tag #	Species	% Tissue Mortality 2000	% Tissue Mortality 2001	Bleaching	Lesions	Disease
4	1	*M. cavernosa*	20	20			
	2	*D. stokesii*	0	10			
	3	*M. meandrites*	10	25			
	4	*P. astreoides*	10	10			
	5	*D. stokesii*	0	30			
	6	*M. cavernosa*	40	55			
	7	*S. michelinii*	45	55			
	8	*M. cavernosa*	25	30			
	9	*M. cavernosa*	20	25			
	10	*M. meandrites*	35	65			
	11	*M. cavernosa*	40	30			
	12	*M. cavernosa*	20	25			
	13	*M. cavernosa*	85	85			
	14	*M. cavernosa*	30	30			
5	1	*S. bournoni*	50	35			
	2	*D. labyrinthiformes*	5	35			
	3	*M. cavernosa*	35	30			
	4	*M. cavernosa*	40	35			
	5	*M. cavernosa*	10	30			
	6	*M. cavernosa*	5	5			
	7	*S. bournoni*	5	5			
	8	*M. cavernosa*	10	10			
	9	*M. cavernosa*	30	15			
	10	*S. bournoni*	5	10			
	11	*S. bournoni*	5	5			
6	1	*D. stokesii*	35	50			
	2	*D. clivosa*	40	55			
	3	*P. astreoides*	5	5			
	4	*D. clivosa*	55	55			
	5	*D. stokesii*	40	40			
	6	*D. clivosa*	10	25			
	7	*M. meandrites*	30	30			
	8	*M. cavernosa*	15	15			
	9	*M. meandrites*	5	5			
	10	*D. clivosa*	65	70			
	11	*M. cavernosa*	10	25			
	12	*M. cavernosa*	80	85			
	13	*M. cavernosa*	40	45		Y	
	14	*D. stokesii*	15	15		Y	
7	12	*M. faveolata*	30	40			
	13	*M. faveolata*	50	55			
	14	*M. faveolata*	0	5			
	15	*M. faveolata*	30	20			

Table 4. Continued

Zone	Tag #	Species	% Tissue Mortality 2000	% Tissue Mortality 2001	Bleaching	Lesions	Disease
8	1	*M. faveolata*	10	10		Y	
	2	*M. faveolata*	25	10		Y	
	3	*M. faveolata*	25	30			
	4	*M. cavernosa*	25	30			
	5	*M. faveolata*	15	10			
	6	*M. cavernosa*	75	80			
	7	*M. faveolata*	45	40			
	8	*M. faveolata*	20	10			
	9	*M. faveolata*	25	5			
	10	*M. faveolata*	15	10			
	11	*M. faveolata*	30	20			
	12	*M. cavernosa*	50	50			Y
	13	*M. faveolata*	10	5			
	14	*M. cavernosa*	100[§]	100			
	15	*M. cavernosa*	*NA*	*70*			
9	1	*M. cavernosa*	60	50			
	2	*M. cavernosa*	90	90			
	3	*D. stokesii*	100[§]	100			
	4	*D. clivosa*	40	25			
	5	*M. cavernosa*	10	20			
	6	*M. cavernosa*	100[§]	100			
	7	*D. clivosa*	0	0			
	8	*D. stokesii*	45	40			
	9	*M. cavernosa*	75	70			
	10	*M. cavernosa*	50	35			
	11	*M. cavernosa*	55	80			Y
	12	*D. clivosa*	35	35			
	13	*M. cavernosa*	35	70			
	14	*M. cavernosa*	35	50			
	15	*M. cavernosa*	70	70			
	16	*M. cavernosa*	*NA*	*35*			
	17	*M. cavernosa*	*NA*	*80*			
10	1	*M. cavernosa*	0	30			
	2	*D. clivosa*	0	0			
	3	*D. stokesii*	55	45			
	4	*D. clivosa*	70	100			
	5	*D. clivosa*	0	0			
	6	*D. clivosa*	20	20			
	7	*D. clivosa*	0	5			
	8	*D. clivosa*	75	70			
	9	*D. clivosa*	5	20			
	10	*D. clivosa*	0	10			
	11	*D. clivosa*	0	0			
	12	*M. faveolata*	30	30			
	13	*D. clivosa*	10	15			
	14	*M. faveolata*	70	60			
	15	*M. faveolata*	10	25		Y	
	16	*D. clivosa*	*NA*	*0*			

Table 4. Continued

Zone	Tag #	Species	% Tissue Mortality 2000	% Tissue Mortality 2001	Bleaching	Lesions	Disease
11	1	*D. clivosa*	0	10			
	2	*D. clivosa*	15	10			
	3	*D. clivosa*	30	80		Y	
	4	*D. clivosa*	5	20			
	5	*S. michellini*	10	20			
	6	*M. faveolata*	20	25			
	7	*M. faveolata*	50	45			
	8	*P. astreoides*	55	70			
	9	*D. clivosa*	0	20			
	10	*D. clivosa*	0	0			
	11	*M. cavernosa*	30	35			
	12	*D. clivosa*	35	40			
	13	*D. clivosa*	5	5			
	14	*M. faveolata*	5	10			
	15	*D. clivosa*	0	0			
12	1	*D. clivosa*	0	5	Pale		
	2	*D. clivosa*	60	80			
	3	*D. clivosa*	65	70			
	4	*D. clivosa*	45	40			
	5	*D. clivosa*	90	80			
	6	*D. stokesii*	10	20			
	7	*D. clivosa*	10	0	Pale		
	8	*D. clivosa*	40	50			
	9	*M. meandrites*	0	0			
	10	*D. clivosa*	0	10			
	11	*D. clivosa*	60	75			Y
	12	*P. astreoides*	Missing				
	13	*D. stokesii*	10	10			
	14	*D. stokesii*	55	50			
	15	*D. clivosa*	0	10			
TOTAL		**163 colonies**			**11**	**20**	**3**

Table 5. Tagged control corals and the nearest zone. Distance and azimuth measurements were taken from eyebolt; width and height are maximum values for colony.

Zone	Tag #	Species	Distance (cm)	Azimuth (degrees)	Height (cm)	Width (cm)
2	C1	*M. cavernosa*	715	20	25	20
	C2	*M. cavernosa*	1120	35	10	26
	C3	*D. stokesii*	1370	45	10	20
	C4	*S. bournoni*	289	95	25	35
	C5	*M. cavernosa*	655	95	10	12
	C6	*M. cavernosa*	264	105	15	20
	C7	*S. bournoni*	722	130	20	30
	C8	*S. bournoni*	747	200	20	20
	C9	*M. cavernosa*	253	215	10	30
	C10	*M. cavernosa*	1019	0	25	35
5	C11	*M. cavernosa*	600	25	10	20
	C12	*S. bournoni*	1296	70	25	20
	C13	*D. stokesii*	1223	70	5	10
	C14	*M. cavernosa*	982	75	15	30
	C15	*M. cavernosa*	706	95	10	20
	C16	*M. cavernosa*	1295	100	13	20
	C17	*M. cavernosa*	778	105	15	32
	C18	*M. cavernosa*	718	130	5	32
	C19	*M. cavernosa*	870	140	15	20
	C20	*D. stokesii*	970	205	10	13
7	C21	*D. clivosa*	411	10	20	30
	C22	*D. clivosa*	758	110	5	15
	C23	*D. clivosa*	428	290	10	20
	C24	*D. clivosa*	203	305	10	40
	C25	*S. bournoni*	592	350	40	45
8	C26	*D. clivosa*	1115	40	20	50
	C27	*D. stokesii*	565	40	10	20
	C28	*D. clivosa*	1390	85	10	35
	C29	*D. clivosa*	385	115	5	15
	C30	*D. clivosa*	595	355	5	30
TOTAL		30 colonies				

Table 6. Health and condition of the tagged control corals in each zone. Percent tissue loss (mortality) estimated in 2000, percent tissue loss estimated in 2001 and bleaching and presence of disease and lesions in 2001.

Zone	Tag #	Species	% Tissue Mortality 2000	% Tissue Mortality 2001	Bleaching	Lesions	Disease
2	C1	*M. cavernosa*	0	5			
	C2	*M. cavernosa*	10	20			
	C3	*D. stokesii*	20	45	Pale		
	C4	*S. bournoni*	0	5			
	C5	*M. cavernosa*	10	25			
	C6	*M. cavernosa*	0	5		Y	
	C7	*S. bournoni*	0	5			
	C8	*S. bournoni*	0	5			
	C9	*M. cavernosa*	10	15		Y	
	C10	*M. cavernosa*	0	5	Pale		
5	C11	*M. cavernosa*	20	30			
	C12	*S. bournoni*	10	10			
	C13	*D. stokesii*	50	55			
	C14	*M. cavernosa*	5	5			
	C15	*M. cavernosa*	35	40			
	C16	*M. cavernosa*	0	5			
	C17	*M. cavernosa*	20	25			
	C18	*M. cavernosa*	10	15			
	C19	*M. cavernosa*	15	15			
	C20	*D. stokesii*	5	5			
7	C21	*D. clivosa*	25	45			
	C22	*D. clivosa*	5	5			
	C23	*D. clivosa*	0	0			
	C24	*D. clivosa*	10	10			
	C25	*S. bournoni*	30	35			
8	C26	*D. clivosa*	20	10		Y	
	C27	*D. stokesii*	10	5		Y	
	C28	*D. clivosa*	0	20			
	C29	*D. clivosa*	20	20			
	C30	*D. clivosa*	10	30			

Table 7. Summary of the mean percent reattached coral tissue mortality (TM) estimated in 2000 and 2001, and the number of reattached corals that showed no change in TM, reduced TM, and increased TM in each zone from 2000 to 2001.

Zone	Mean % TM 2000	Mean % TM 2001	Corals with No Change in %TM	Corals with Reduced %TM	Corals with Increased %TM
1	8	15	2	1	7
2	24	39	1	0	14
3	23	25	4	1	9
4	27	35	4	1	9
5	18	20	4	4	3
6	32	37	7	0	7
7	28	30	0	1	3
8	34	29	3	8	3
9	53	56	6	5	4
10	23	29	5	3	7
11	17	26	3	2	10
12	32	36	2	4	8
Totals	27	32	41	30	84

Table 8. Summary of the mean percent control coral tissue mortality (TM) estimated in 2000 and 2001, and the number of control corals that showed no change in TM, reduced TM, and increased TM in each zone from 2000 to 2001.

Zone	Mean % TM 2000	Mean % TM 2001	Corals with No Change in %TM	Corals with Reduced %TM	Corals with Increased %TM
2	5	14	0	0	10
5	17	21	4	0	6
7	14	19	3	0	2
8	12	17	1	2	2
Totals	12	17	8	2	20

Table 9. Summary of the mean percent tissue mortality (TM) for each tagged, reattached and control coral species.

Species	Number of Individuals	% TM 2000	% TM 2001	% Change in TM
Reattached Corals				
M. cavernosa	56	33	39	6
D. clivosa	36	25	31	6
M. faveolata	22	24	23	-2
D. stokesii	12	35	39	5
S. bournoni	8	22	25	3
S. michelini	7	16	21	5
M. meandrites	6	28	38	10
P. astreoides	5	18	29	11
S. siderea	3	0	7	7
C. natans	1	20	20	0
D. labyrinthiformis	1	5	35	30
Control Corals				
M. cavernosa	13	10	16	6
D. clivosa	8	11	18	7
D. stokesii	5	8	12	4
S. bournoni	4	21	28	7

Table 10. Abundances of sessile invertebrates identified along the scarified and undamaged area transects. The abundances are the pooled values from the 60 quadrats assessed within each area. Sponges (greater than 1 cm width) were counted but not identified.

	Scarified Area Transects			**Undamaged Area Transects**		
	Species	**Abundance**		**Species**	**Abundance**	
		2000	**2001**		**2000**	**2001**
Hard Coral Recruits	*Porites astreoides*	9	1	*Porites astreoides*	1	1
	Siderastrea sp	12	14	*Siderastrea sp.*	1	1
	Porites porites	0	1	*Porites porites*	0	1
Hard Coral Non-recruits		0		*Diploria clivosa*	2	2
				Dichocoenia stokesii	1	1
Soft Coral	Encrusting Soft Corals	18	25	Encrusting Soft Corals	42	43
	Plexaurella sp	1	2	*Plexaurella* sp	0	0
	Pseudopterogorgia sp.	3	3	*Pseudopterogorgia* sp.	2	1
	Eunicea sp.	1	1	*Eunicea* sp.	1	5
	Pterogorgia sp.	0	2	*Pterogorgia* sp.	0	2
	Gorgonia ventalina	0	0	*Gorgonia ventalina*	1	1
	Psuedoplexaurella sp.	0	1	*Psuedoplexaura* sp	3	3
	Unid. Branching Gorgonian	0	0	Unid. Branching Gorgonian	1	0
Zoanthids	*Palythoa caribaeorum*	0	11	*Palythoa caribaeorum*	11	11
	Zoanthus pulchellus	0	16	*Zoanthus pulchellus*	0	13
Sponges		63	80		90	222