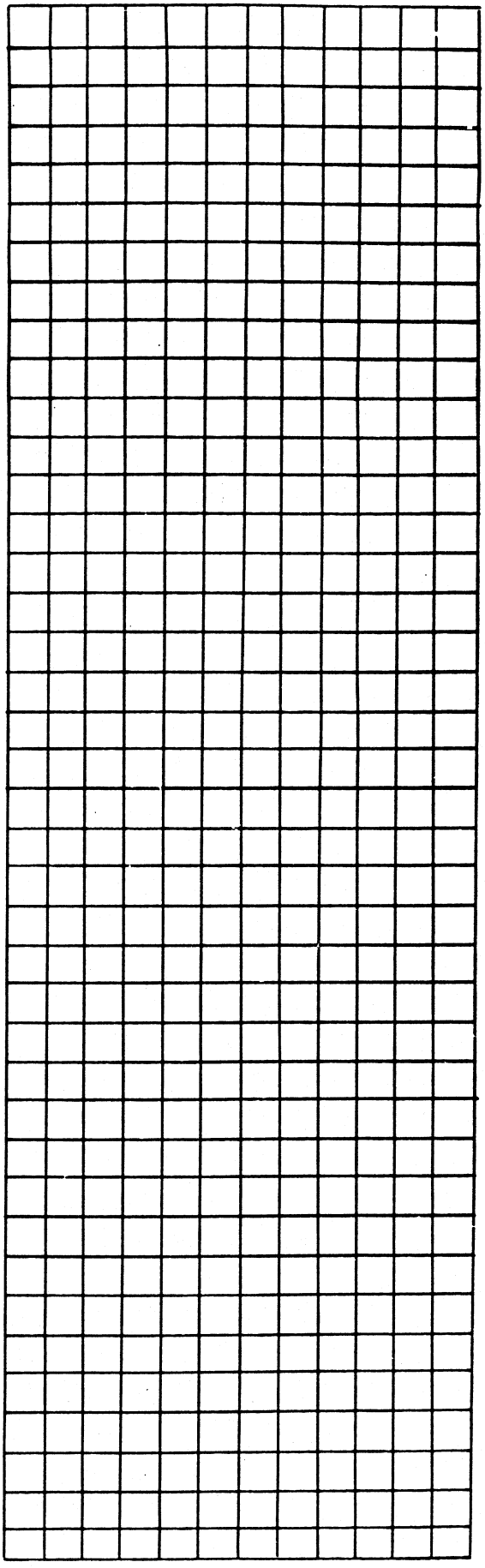
Metropolitan Dade County, Florida

Department of Environmental Resources Management

Sunny Isles Beach Restoration Project: Mechanical Damage to the Reefs Adjacent to the Borrow Area



DERM Technical Report 88-14

SUNNY ISLES BEACH RESTORATION PROJECT: MECHANICAL DAMAGE TO THE REEFS ADJACENT TO THE BORROW AREA

by

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INTRODUCTION:

On August 25, 1988, while conducting biological monitoring, the Metro Dade Department of Environmental Resources Management (DERM) first noted mechanical damage on a portion of the third reef, adjacent to the borrow area used for the Sunny Isles Beach Restoration Project. The location and characteristics of the damage led DERM personnel to believe that it had been caused by the impact of the hopper dredge's (Hopper Dredge LONG ISLAND) drag head(s) on the reef. Subsequently, a survey of the reefs surrounding the borrow area was conducted by DERM biologists to determine the extent and degree of the damage. Nine separate areas of damage were identified. This report details the location of the areas, characteristics of the damage, the communities affected, and quantification of the area of impacted hard bottom at two of the nine locations.

STUDY AREA:

The areas of damage are located on two of the three reef terraces found off Sunny Isles, northern Dade County (Figure 1). Between the first and second, and the second and third reef terraces are deposits of sand. Specific regions of the sand deposits have been identified as borrow areas for use in beach renourishment or restoration projects. The borrow area used for the present project (Sunny Isles Beach Renourishment Project) is located between the second and third reefs (Figure 2).

The damaged areas were found along the edges of the reefs adjacent to the borrow area. The borrow area lies between 2700

and 3000 meters (~9000 and 10000 feet) offshore, with approximate bordering latitudes and longitudes of 25° 57.50'N, 80° 05.75'W and 25° 55.25'N, 80° 05.25' W).

A total of nine areas of damage were identified on the reefs. Two sites were on the eastern edge of the second reef, and seven sites on the western edge of the third reef. The most severely damaged sites were damage sites 2 and 3 on the east side of the second reef. The approximate location of the damage sites relative to the borrow area are shown in Figure 2.

GEOLOGICAL AND BIOLOGICAL FEATURES OF THE REGION:

The general geological and biological features of the reefs found off the southeastern coast of Florida have been described by Goldberg (1973), Jaap (1984) and Shinn (1988). The features found off northeastern Dade County are similar to those described by the above cited authors, but differ with respect to the depth of formations, and, to a lesser degree, with the biotic components of the reef. A brief summary of the specific features found off Sunny Isles is presented here, outlining the pertinent topographic features and biotic communities.

Geology. Three distinct reef platforms, or terraces, are found between 1.1 and 1.5 miles off the northeastern Dade County coast (Figure 2). The reefs are formed of pleistocene reef rock with a "cap" of geologically recent coral reef, which can be up to eight feet thick (Shinn 1988). Shoreward of the first (western-most) reef is a large sand area with scattered patch reefs. The

first reef is a low profile, non-continuous reef believed to be formed by the convergent growth of smaller patch reefs (Goldberg 1973). The second reef is a relatively narrow reef (125-200 m wide), which crests at 11 to 13 m (~35 to 45 ft). The western edge of the second reef shows a mild relief, of 1 to 1.5 m (3 to 4.5 ft), rising out of a sand plain at a depth of 14 to 15 m (46 to 49 ft). The eastern edge shows a greater, and steeper, relief dropping 1 to 3.5 m to 17 m (56 ft) onto the sand plain which makes up the borrow area. The western edge of the third reef, adjacent to the borrow area, has a relief of 1.5 to 3 m, rising from between 18 and 19 m (60 and 63 ft) to ~16.5 m (~54 ft). The eastern edge of the third reef forms the outer reef slope, sloping to +60 m (+200 ft) (Figure 3).

Characteristics of surrounding live bottom communities: A diverse and abundant assemblage of benthic plants, hard corals, soft corals, sponges and fish can be found on the reefs offshore in northern Dade County. The communities found on the second and third reefs (those showing mechanical damage from the dredge's drag head) are categorized by Goldberg as the "Offshore Reef Platform" assemblage. The most abundant organisms are the soft corals (i.e., Eunicea spp., Pseudopterogorgia spp., Plexaura spp.) with numerous massive hard coral colonies (i.e., Dichocoenia stokesii, Siderastrea siderea, Agaricia spp., Montastrea spp.) ranging in size from 2 cm to 1.5 m diameter.

Information collected from DERM biological monitoring stations located around the borrow area show 28 species of hard corals and over 120 species of pelagic fish in the immediate

region. Also, numerous species of sponges (i.e., Xestospongia muta [barrel sponge], Cliona spp. [boring sponge], Callyspongia spp. [tube and vase sponges], Ircinia spp. [tube and cannonball sponges], Haliclona spp. [finger sponges]), anemones (i.e., Palythoa caribbea, Batholomea annulata, Ricordia florida) and algae (i.e., Halimeda goreauii, Dictyota bartayresii, Peyssonnelia spp., Hydrolithon spp.) cover the bottom.

ASSESSMENT METHODS:

Perimeter survey. The reefs adjacent to the borrow area were examined for signs of damage (i.e., denuded area of the bottom; overturned, broken or loose hard corals, soft corals or sponges; areas of rubble or large overturned boulders) by DERM biologists, using scuba. The survey began on the eastern edge of the second reef and continued on the western edge of the third reef, until the entire perimeter had been examined. Swimming side-by-side and approximately 3 to 5 meters above the bottom, two divers were able to scan a 20 to 30 meter (~65-100 ft) path of the reef. When an area of possible impact was noted, the divers descended and examined the bottom for indications of contact by the dredge's drag head with the reef. If the area showed markings characteristic of such impact, the area was marked with a buoy and the position noted. Positions were initially noted with "line-ups" (alignment of fixed shore points) and fathometer profiles. The exact location (X, Y co-ordinates) of each region will be determined by a hydrographic surveyor.

Damage assessment: Two areas (damage sites 2 and 3) were quantitatively assessed to determine the area impacted and destroyed. These areas were chosen due to the size (one to two orders of magnitude larger than the combined areas of the remaining sites). At each site, using a compass and following the bearing of the damage path, a metered tape or a 10 meter line, was stretched along the bottom within a damage tract. At 10 meter intervals (5 meter intervals for damage site 2), a second metered line was extended perpendicular to the first, from the western-most point of damage to the edge of the reef. A diver then swam along the perpendicular transect line noting, on an underwater slate, the beginning and end points (i.e., width) of any damage paths and the relative degree of damage within each path. Damage was categorized into one of five levels: 0% (no damage), 0 - 25% (slight), 25 - 50% (moderate), 50 - 75% (heavy), 75 - 100% (severe damage).

It is recognized that this type of quantification can have multiple sources of error. For example, the subjective placement of a region with 25% damage into the 0 - 25% or the 25 - 50% category by a diver, can differ with different divers; the perception of the degree of damage can vary from diver to diver; and the diver's familiarity with the specific area of habitat can affect how he may perceive the degree of damage. Steps were taken to minimize the above sources of error. All the assessments were conducted by two DERM biologists with extensive experience with coral reef communities. Specifically, the biologists conducting the assessments are responsible for conducting the biological

monitoring programs associated with beach restoration and renourishment projects (including the Sunny Isles project) and are familiar with the areas in question. The specific diver's ability to determine levels of damage was verified using photogrammetric techniques. Transect lines, assessed by the divers, were photographed using a Nikonos camera and color slide film. The slides were projected onto a gridded screen (divided into 100 squares). The actual degree of damage was determined by comparison of the percent of bottom cover in impacted areas versus non-impacted areas. The computed values of loss were then compared to the diver's assessment value to insure the diver's estimates were appropriate.

For each site quantitatively assessed, the area impacted and the area destroyed were calculated. The area impacted was determined by multiplying the measured width of the individual damage paths, identified along the assessment transects, by the distance between the assessment transects (i.e., 5 meters for damage site 2; 10 meters for damage site 3). The individual areas were summed to obtain a total area impacted for a specific site (Formula 1). The area destroyed was determined by multiplying the individual area impacted by the decimal equivalent of the mean value of the percent damage category (Table 1) attributable to that area. These values were summed to give the total area destroyed for each site (Formula 2).

Table 1. The decimal equivalents of the mean values for the percent damage categories.

% Damage		Decimal Equivalent
0 - 25%	=	.125
25 - 50%	=	.375
50 - 75%	=	.625
75 - 100%	=	.875

(1) $\sum$ Width Of Damage Path X Distance Between Assessments = Area Impacted

(2) $\sum$ Area Impacted X Decimal Equivalent of Damage = Area Destroyed

As a matter of procedure, areas showing borderline levels of damage (i.e., 25, 50 or 75% damage) were placed into the lower of the possible categories. Areas were assessed as mechanical damage attributable to the drag head only if characteristic scrapes or gouges, described below, were present. Specific areas adjacent to heavily or severely damaged areas may have been assessed a slight damage level (0 - 25%) due to the impact of rubble, generated by the scraping action of the drag head, on the benthic organisms.

DAMAGE ASSESSMENT:

Characteristics of the damage: At each area of damage, DERM divers noted marks, scrapes, or paths indicative of the dredge's

drag head coming in contact with the reefs. Gouges were characterized by smoothed, compressed, flat areas approximately 8 to 10 cm (3 to 4 in.) wide (Figure 4) which cut 0.5 to 5.0 cm (0.25 to 2 in.) vertically into the carbonate rock. The gouged, compressed areas were often seen side-by-side (Figure 5) and correspond precisely to the size and placement of the metal "wear pads" on the underside of the drag head (Figure 6). Scraped areas appeared as flattened surfaces on the higher points of the reef along a damaged path. The scraped surfaces also showed obvious compression, reflecting the considerable weight of the object causing the damage. In the more severely impacted areas (i.e., sites 2 and 3), swaths (multiple paths or tracts) of damage could be seen traversing the reef. The full width of a single path (i.e., one pass of the drag head over the reef) measured 2.5 to 3 m (~8 to 10 ft.), which is equivalent to the width of the dredge's drag head. At sites 2 and 3, due to repeated incidences of the drag head being pulled across the reef, the width of the damage tract was as wide as 20 m. Within the areas of multiple passes, virtually all benthic organisms (i.e., soft corals, hard corals, sponges and algae) were destroyed (Figure 7). Along specific paths at damage site 2 and 3, all sediment and rubble were removed from the damage path (Figure 8), indicating the barge was actively dredging while pulling the drag head across the reef.

In slightly and moderately damaged areas (e.g., sites 1, 4-9), damage was intermittent and limited to the highest points of the reef (Figure 9). In these areas it appeared as though the drag head of the dredge was suspended, or partially raised, and

held at a constant depth in the water column. The drag head, therefore, only made contact with the portions of the reef that were shallower than the depth at which the drag head was held. Although these areas of damage were not as apparent as the severely impacted areas, the characteristic scrapings and marks were present indicating that the damage was caused by the drag head (Figure 10). Areas of partial damage often showed fractured coral heads (Figure 11) and live bottom (Figure 12), damaged soft corals and sponges (Figure 13).

Description of damage at each sites. Brief descriptions of the specific location and the damage at the sites are given below, followed by the quantitative assessments of sites 2 and 3.

Site 1. The first damage site was found on the western edge of the third reef and crossed over DERM's biological monitoring station "H". The damage is along two converging paths, indicating multiple incidences of impact. The paths are 50-75 m long and involve slight damage (0-25%) of the hard bottom. At this specific site, two large Montastrea annularis coral heads were destroyed (Figure 11), along with a number of smaller colonies of Dichocoenia stokesii and Meandrina meandrites. The bearing of the paths were approximately 350-360/170-180 degrees.

Site 2. Damage site 2 is located on the eastern edge of second reef, approximately 50 m north of DERM's biological monitoring station "I". Numerous paths of damage were found, causing considerable destruction. The damage is detailed later in this report (see Assessed Damage Sites).

Site 3. Damage site 3 is located on the eastern edge of second reef, where the reef projects eastward towards the borrow area, forming an irregularity or notch in the generally rectangular borrow area (Figure 2). As at site 2, the damage at this location consisted of numerous paths of damage. The largest impacted area and degree of destruction was found at this site. The damage is detailed later in this report (see Assessed Damage Sites).

Site 4. The fourth area of damage is located on the western shore of the third reef adjacent to the northeastern most point of the borrow area (Figure 2). This is the region where the dredge turned out of (on northerly passes) or into (on southerly passes) the borrow area. A single damage path was present, approximately 2.5 to 3 m wide and 20 m long, within which an estimated 50 to 75% of the benthic organisms were destroyed. Bearing of the damage path was approximately 45/225 degrees.

Site 5. Damage site 5 is on the western edge of the third reef, southeast of the "elbow" in the north end of the borrow area (Figure 2). Four paths of damage were seen, each 0.5 to 2.5 m wide and 20 to 30 m long. An estimated 25 to 50% of the benthic organisms were destroyed within the damage paths. The bearing of the damage was approximately 35-45/215-225 degrees.

Sites 6, 7, 8 & 9. The remaining sites were located on the western edge of the third reef (Figure 2). Each area consisted of a single path of damage, 0.5 to 2.5 m wide and 20 to 30 m long, within which 0 to 25% or 25 to 50% of the organisms were

destroyed. The bearings of the damage tracts were 350-360/170-180 degrees.

Assessed damage sites: In contrast to the damage at sites 1,4,5,6,7,8 and 9, the damage seen at sites 2 and 3 was of greater severity (mostly 50-75% or 75-100%) and involved a much larger area. The width of specific portions of the damaged area indicated that the drag head was pulled over the reef numerous times. The bottom was severly scraped and fractured, producing considerable amounts of rubble. Only very small organisms, that had settled in various small depressions, survived.

Site 2. An area of 1,466 m^2 (15,780 ft^2) was surveyed at site 2. Damage was documented along a 115 m path. Within that area damage varied between 0 and 75-100%, with the latter being most common. Damage to the reef attributable to the drag head was found as far away as 23.8 m (78 ft.) from the edge of the reef (Figure 14). The individual measurements and related areas of destroyed bottom are tabulated in Appendix 1. The areas of slight or no damage represent either sandy areas, low lying areas or regions of irregular contour, which limited the contact of the drag head with the reef. Furrows in the sand adjacent to the reef, caused by dredging action, could be followed out of the sand and onto the reef.

Within site 2 a total area of 938 m^2 (10,096 ft^2) was impacted, of which 663.1 m^2 (7,137.5 ft^2) was destroyed. This is believed to be a conservative estimate of the area of destruction, as the regions assessed at 75-100% damage were most often completely denuded of benthic growth. The true percentage of

destruction was 100%. With the procedures used, however, the relative assessed loss would be calculated at a level of 87.5% (.875; Table 1). This procedure, in light of the degree and mass of damage, errors on the conservative side for the estimates of area destroyed. Figure 14 is a mosaic, generated from the calculated areas of impact and associated degrees of damage. It is apparent from the width of the area, numerous incidences of pulling the drag head over the reef had to have occurred to cause the amount of damage present.

Site 3. Site 3 showed the largest amount of damage. An area of 11,997 m^2 (129,135 ft^2) was surveyed at this site. Varying degrees of damage were documented along a total length of 580 m. The damage tract was interrupted at the 470 meter mark by a large sand area. The tract continued approximately 150 m south of the point of interruption, and continued for an additional 110 m (e.g., total of 580 m). The individual measurements and related areas of destroyed bottom are tabulated in Appendix 1. The total area impacted at site 3 was 7,979 m^2 (85,885 ft^2) within which 5343.0 m^2 (57,511.6 ft^2) was destroyed (Figure 15). Along the main tract of damage, impacted areas were documented on the reef as far as 47 m (154 ft) from the edge of the reef (Figure 15). It is obvious from the extent and intensity of the damage represented in Figure 15, that repeated incidences of pulling the drag head over the reef occurred in this area during dredging operations. Further, some of the damage paths had all rubble and sand removed from the crevasses in the bottom. This indicates that the barge

was actively dredging while pulling the drag head over the reef and not merely holding the drag head at an inappropriate depth.

Summary Of Areas Assessed. A summary of the damage documented is given in Table 2.

Table 2. Summary of the areal extent of impact and damage at sites 2 and 3.

Site	Unit Equivalents	Area Surveyed	Area Impacted	Area Destroyed
	(m^2)	1,466	938	663.1
2	(ft^2)	15,780	10,096	7,137.5
	(acres)	0.362	0.232	0.164
	(m^2)	11,997	7,979	5,343.0
3	(ft^2)	129,135	85,885	57,511.6
	(acres)	2.965	1.972	1.320
	(m^2)	13,463	8,917	6,006.1
TOTALS	(ft^2)	144,915	95,982	64,649.1
	(acres)	3.327	2.203	1.484

The total area impacted was 8,917 m^2 (95,982 ft^2) or 2.203 acres. Of that impacted area, 6,006.1 m^2 (64,649.1 ft^2) or 1.484 acres was destroyed. It should be reiterated that these figures do not include the damage associated with sites 1, 4, 5, 6, 7, 8 and 9. In light of the amount of time and manpower required to do the assessments, and the relatively small amount of damage at the

seven sites listed above, no further quantitative damage assessments are planned by DERM personnel at this time.

SUMMARY:

1) Nine areas of mechanical damage by the hopper dredge's drag head were identified on the reefs adjacent to the borrow area.

2) Seven damage sites (1, 4, 5, 6, 7, 8 and 9), showed slight to moderate damage (0-25% or 25-50%) paths, which were short in length and involved one (usually) to four incidences of the drag head contacting the reef.

3) Two sites (2 and 3) had large areas of severe damage.

4) A total of 8,917 m^2 (95,982 ft^2), or 2.203 acres, of impacted area was documented at sites 2 and 3 (938 m^2 [10,096 ft^2] at site 2 and 7,979 m^2 [85,885 ft^2] at site 3).

5) A total of 6,006.1 m^2 (64,649.1 ft^2), or 1.484 acres, of the impacted area was destroyed (663.1 m^2 [7,137.5 ft^2] at site 2 and 5,343.0 m^2 [57,511.6 ft^2] at site 3).

6) Damage to the reef was found as far away as 23.8 m (78 ft) at site 2 and 47 m (154 ft) at site 3, from the edge of the reef.

7) The magnitude of damage documented could only have resulted from repeatedly pulling the drag head(s) of the hopper dredge across the reef. Indications are that this occurred both during active dredging operations (i.e., sucking material from the bottom) and when the drag head was being held at a constant depth in the water column. This depth was greater than than of the reef, causing the drag head to impact upon, and destroy the benthic life on the reef.

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APPENDIX 1

Damage Assessment Worksheet
Site 2

Distance along damage tract (m)	P-1 * POM	* WOD	%* D.	Area * Dest.	P-2 POM	WOD	% D.	Area Dest.	P-3 POM	WOD	% D.	Area Dest.	P-4 POM	WOD	% D.	Area Dest.	P-5 POM	WOD	% D.	Area Dest.	P-6 POM	WOD	% D.	Area Dest.
0																								
30					6.5	6.0	5.0	26.2																
35					7.5	3.0	5.0	13.1																
40	0.0	2.6	5.0	11.4					9.6	3.3	5.0	14.4												
45	0.0	4.1	5.0	17.9	4.1	4.4	2.0	2.8	9.5	3.0	2.0	13.1	14.9	4.6	5.0	20.1								
50	0.0	3.6	5.0	15.8	3.6	2.5	3.0	4.7	8.2	2.3	5.0	10.1	12.8	4.7	5.0	20.5								
55	0.0	3.5	5.0	15.3																				
60	0.0	2.5	5.0	10.9	5.4	1.6	4.0	5.0	3.0	5.4	5.0	23.6												
65	0.0	3.1	5.0	13.6	5.8	6.8	5.0	29.8																
70	0.0	3.0	5.0	13.1	5.0	5.0	5.0	21.9	10.0	1.8	4.0	5.6	11.8	4.6	5.0	20.1								
75	0.0	2.6	5.0	11.4	4.5	4.1	5.0	17.9					11.4	3.6	4.0	11.2	15.0	3.1	5.0	13.6				
80	0.0	7.9	5.0	34.6					7.9	8.3	2.0	5.2												
85	0.0	3.1	5.0	13.8	3.1	2.4	4.0	7.5																
90	0.0	4.1	5.0	17.9																				
95	0.0	3.0	5.0	13.1	3.0	1.4	4.0	4.4																
100	0.0	2.5	5.0	10.9	2.5	2.8	3.0	5.2					-5.0	2.2	3.0	4.1								
105	0.0	2.6	5.0	11.4									-5.3	2.5	4.0	7.8								
110	0.0	2.9	5.0	12.7	2.9	8.4	2.0	5.2					-7.5	4.2	4.0	13.1	-1.7	1.7	2.0	1.1				
115									12.2	7.7	4.0	24.1												
120									10.9	4.0	4.0	12.5	14.9	1.6	2.0	1.0	16.5	3.7	4.0	11.6				
125													15.5	5.0	4.0	15.6	20.5	3.3	5.0	14.4				
130													13.1	4.4	5.0	19.2								
134									10.6	3.1	5.0	13.6									TOTALS			
Sum Destroyed				223.8				143.7				122.2				132.7				40.7	663.1			
Sum Impacted		255.5				242.0				194.5				187.0				59.0			938.0			

* Abbreviations: POM = Western point of damage noted along the assessment transect. WOD = Width of damage path. % D = Assessed level of damage within the damage path: 1 = 0%, 2 = 0-25%, 3 = 25-50%, 4 = 50-75%, 5 = 75-100%. Area Dest. = Area destroyed (see pp. 6 and 7 of report for method of calculation).

Damage Assessment Worksheet
Site 3

Distance along damage tract (m)	P-1 POM	P-1 WOD	P-1 %D.	P-1 Area Dest.	P-2 POM	P-2 WOD	P-2 %D.	P-2 Area Dest.	P-3 POM	P-3 WOD	P-3 %D.	P-3 Area Dest.	P-4 POM	P-4 WOD	P-4 %D.	P-4 Area Dest.	P-5 POM	P-5 WOD	P-5 %D.	P-5 Area Dest.	P-6 POM	P-6 WOD	P-6 %D.	P-6 Area Dest.
0	0.0	2.7	5.0	29.6																				
10	0.0	2.7	3.0	10.1	10.9	3.2	5.0	28.0																
20	0.0	1.8	3.0	6.8	9.0	2.7	5.0	23.6																
30	0.0	2.3	4.0	14.4	2.3	3.9	5.0	34.1																
40	0.0	4.8	5.0	42.0																				
50	0.0	4.7	5.0	41.1																				
60	0.0	5.5	5.0	48.1	6.5	8.0	2.0	10.0																
70	0.0	7.5	5.0	65.6	7.5	5.0	2.0	6.2																
80	0.0	5.4	4.0	33.8	5.4	1.0	2.0	1.2																
90	0.0	4.7	3.0	17.6	4.7	2.4	2.0	3.0																
100	0.0	6.9	3.0	25.8																				
110	0.0	3.5	3.0	13.1	3.5	3.2	5.0	28.0	7.9	3.1	5.0	27.1												
120	0.0	5.9	5.0	51.6																				
130	0.0	4.5	5.0	39.4	6.0	1.9	5.0	16.6																
140	0.0	4.2	5.0	36.8	7.3	0.4	5.0	3.5																
150	0.0	7.7	5.0	67.4	9.4	3.1	5.0	27.1	13.8	2.4	5.0	15.0												
160	0.0	7.5	5.0	65.6	7.5	4.0	4.0	25.0	15.3	2.6	5.0	22.8												
170	0.0	11.0	5.0	96.2					15.3	0.2	5.0	1.8												
180	0.0	3.0	4.0	18.8	4.7	3.0	4.0	18.8	13.8	2.6	5.0	22.8	17.5	6.2	5.0	54.2								
190	0.0	2.8	4.0	17.5	7.9	1.6	3.0	6.0	11.3	2.9	5.0	25.4					20.3	10.9	5.0	95.4				
200	0.0	3.0	4.0	18.8	5.2	6.4	4.0	40.0					17.9	13.3	5.0	116.4								
210	0.0	3.4	5.0	29.8	8.5	3.2	5.0	28.0					15.6	9.4	5.0	82.2								
220	0.0	3.5	2.0	4.4	3.5	3.5	5.0	30.6	10.1	3.4	5.0	29.8	16.5	10.0	5.0	87.5								
230	0.0	8.7	5.0	76.1					10.6	10.5	5.0	91.9												
240	0.0	2.2	2.0	2.8	5.3	16.1	5.0	140.9																
250	0.0	8.3	5.0	72.6	9.4	11.1	5.0	97.1									23.1	1.4	5.0	12.8				
260	0.0	1.7	2.0	2.1	4.8	20.0	5.0	175.0																
270	0.0	2.5	2.0	3.1	6.2	2.3	5.0	20.1	11.2	12.4	5.0	108.5												
280	0.0	2.9	4.0	18.1	7.1	19.0	5.0	166.2																
290	0.0	2.7	5.0	29.6	9.6	2.0	4.0	12.5																
300	0.0	3.9	5.0	34.1					12.6	2.5	2.0	3.1					20.3	9.7	5.0	84.9				
310	0.0	4.4	2.0	5.5	4.4	4.3	5.0	37.6									22.9	7.2	5.0	63.0				
320	0.0	2.7	4.0	16.9	7.1	4.4	5.0	38.5									27.3	8.1	4.0	50.6				
330	0.0	3.0	4.0	18.8	4.4	3.0	3.0	11.2	9.3	4.1	4.0	25.6					29.5	2.3	5.0	20.1	35.0	2.3	4.0	14.4
340	0.0	5.8	4.0	36.2	6.8	2.0	4.0	12.5	15.8	1.6	3.0	6.0					22.2	3.1	3.0	11.6	31.7	4.4	5.0	38.5
350	0.0	5.7	5.0	49.9	5.7	3.7	4.0	23.1	9.4	11.7	2.0	14.6					22.6	4.1	5.0	35.9				
360	0.0	7.0	5.0	61.2	7.0	6.1	3.0	22.9	13.1	3.1	5.0	27.1	16.2	1.8	3.0	6.8	21.1	11.5	5.0	100.6				
370	0.0	4.7	5.0	41.1					15.1	5.8	5.0	50.8					18.0	11.9	5.0	104.1				
380	0.0	7.8	5.0	68.2					13.1	4.7	5.0	41.1												
390	0.0	3.8	4.0	23.8									21.8	3.8	5.0	33.2	25.6	1.9	5.0	16.6	29.8	12.2	5.0	106.8
400	0.0	2.7	5.0	23.6	2.7	8.4	4.0	52.5	11.1	4.7	5.0	41.1	15.8	4.6	5.0	28.8								
410	0.0	3.1	5.0	27.1	3.1	2.1	4.0	13.1	5.2	24.9	2.0	31.1									30.1	15.4	5.0	96.2
420	0.0	1.9	4.0	11.9	7.1	20.1	2.0	25.1													35.6	10.5	5.0	91.9
430	0.0	2.1	5.0	18.4	7.9	3.1	5.0	27.1	14.7	2.4	4.0	15.0	17.1	2.9	5.0	25.4	20.0	3.5	2.0	4.4				
440	0.0	2.5	5.0	21.9	2.5	9.3	2.0	11.6	11.8	5.1	5.0	44.6												
450					7.1	2.0	4.0	12.5																
460	0.0	1.8	5.0	15.8																	35.1	4.5	5.0	39.4
470	0.0	1.5	5.0	13.1																				
480-610																								
620	0.0	2.6	2.0	3.2	9.2	2.7	5.0	23.6																
630	0.0	2.1	4.0	13.1					19.5	2.6	3.0	9.8												
640	0.0	2.3	5.0	20.1					20.4	2.4	4.0	15.0	27.9	5.7	5.0	49.9					30.1	3.9	5.0	34.1
650	0.0	3.3	2.0	4.1									22.7	2.1	3.0	7.9	25.8	8.0	5.0	70.0				
660	0.0	2.6	5.0	22.8									24.4	3.3	5.0	28.9	29.0	4.6	5.0	40.2				
670	0.0	2.4	5.0	21.0					17.9	3.3	5.0	28.9					28.6	34.5	5.0	29.7				
680	0.0	2.6	4.0	16.2					17.5	2.0	5.0	12.5	26.5	3.5	5.0	30.6								
690	0.0	3.5	5.0	30.6	8.7	1.5	5.0	13.1																
700	0.0	7.6	3.0	28.5																				
710	0.0	2.0	3.0	7.5																				
720	0.0	1.3	5.0	11.4																				
Sum Destroyed				1652.7				1265.9				711.4				551.8				739.9				421.3
Sum Impacted		2347.0				1997.0				1210.0				666.0				1227.0				582.0		

TOTAL 5343. 7979.

* Abbreviations: POM = Western point of damage noted along the assessment transect. WOD = Width of damage path. %D = Assessed level of damage within the damage path: 1 = 0%, 2 = 0-25%, 3 = 25-50%, 4 = 50-75%, 5 = 75-100%. Area Dest. = Area destroyed (see pp. 6 and 7 of report for method of calculation).

FIGURE 1

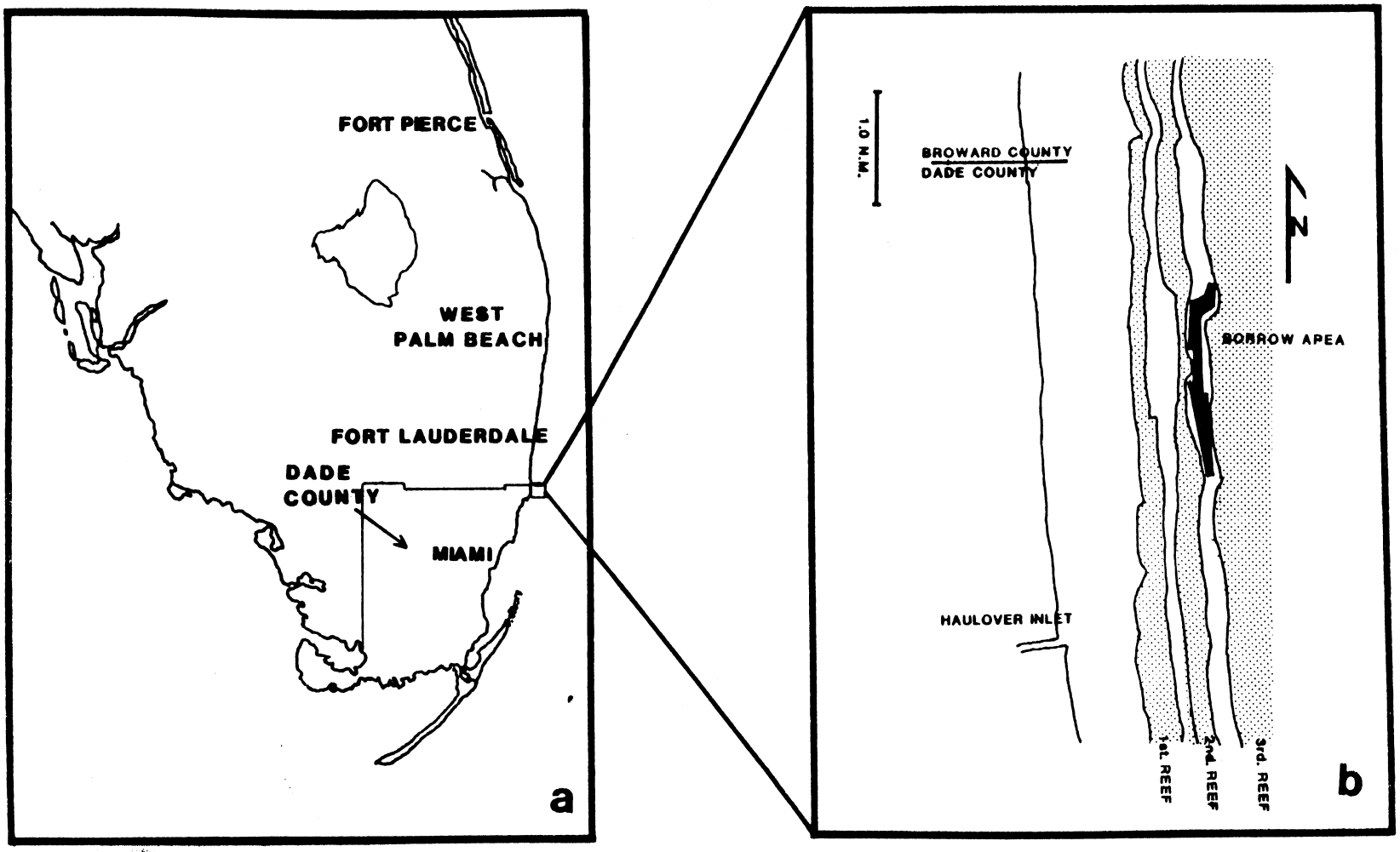

FORT PIERCE
WEST
PALM BEACH
FORT LAUDERDALE
DADE
COUNTY
MIAMI
a
1.0 N.M.
BROWARD COUNTY
DADE COUNTY
HAULOVER INLET
BORROW AREA
1st. REEF
2nd. REEF
3rd. REEF
b

FIGURE 2

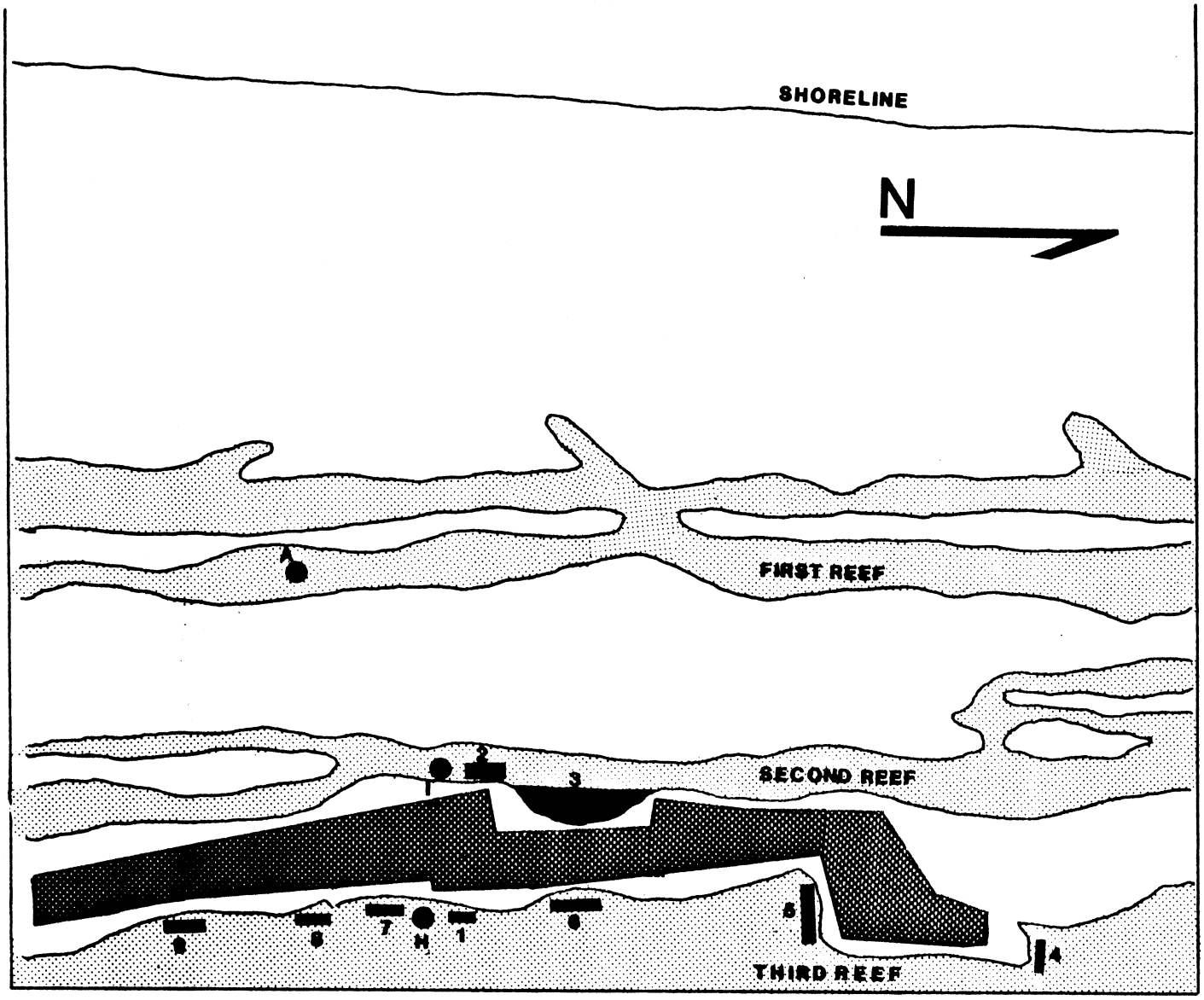


FIGURE 3

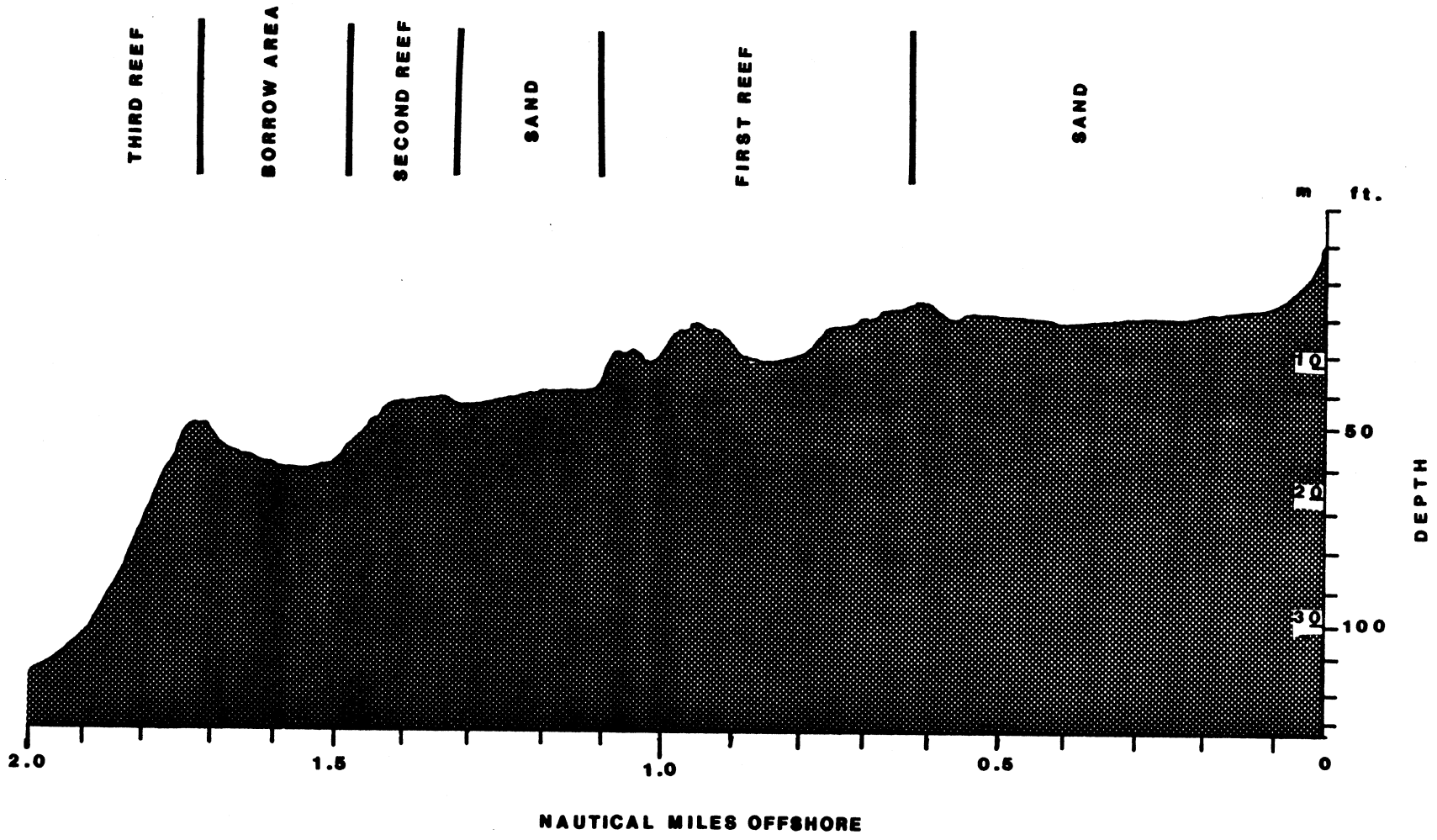

THIRD REEF
BORROW AREA
SECOND REEF
SAND
FIRST REEF
SAND
m
ft.
10
50
20
30
100
DEPTH
2.0
1.5
1.0
0.5
0
NAUTICAL MILES OFFSHORE

FIGURE 4

FIGURE 5

FIGURE 6

FIGURE 7

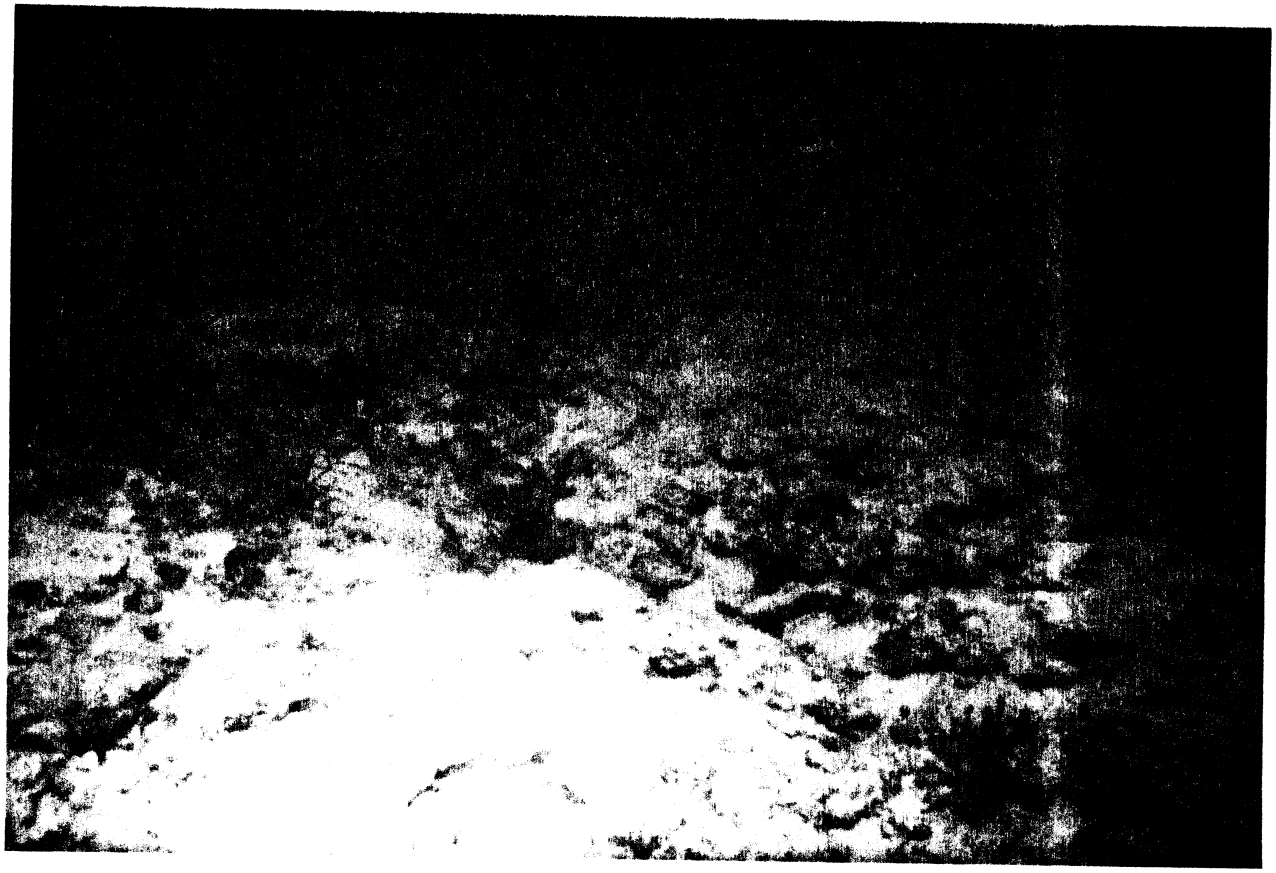


FIGURE 8

FIGURE 9

FIGURE 10

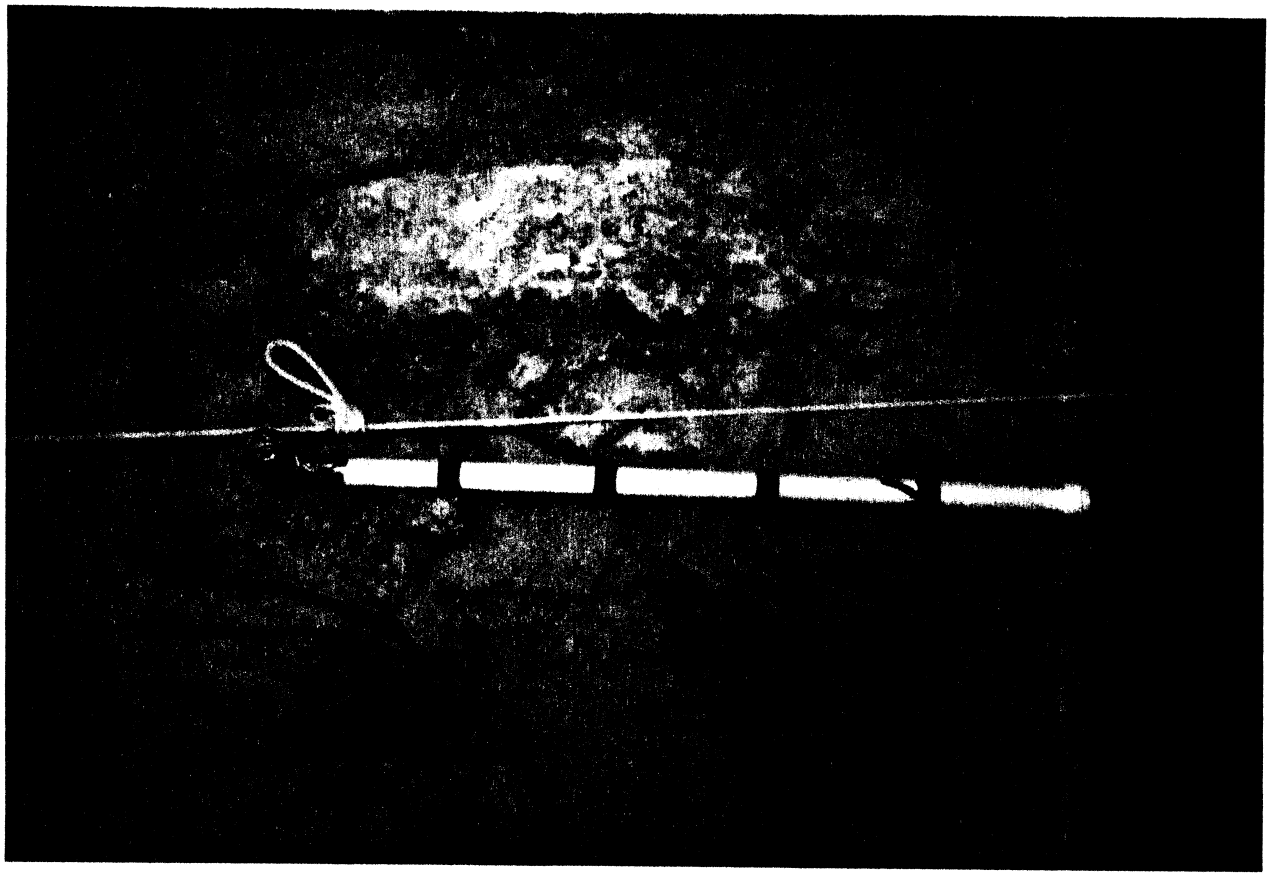


FIGURE 11

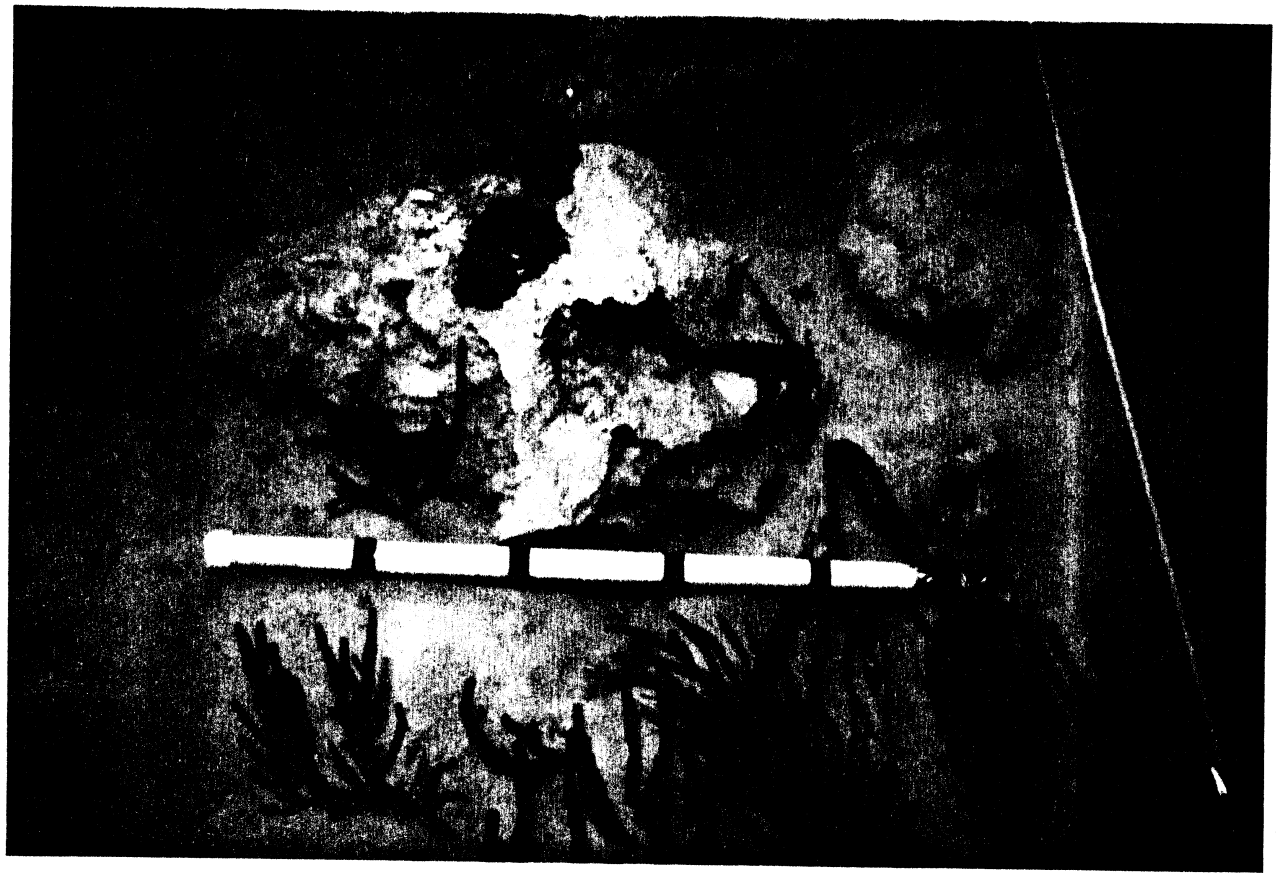


FIGURE 12

FIGURE 13

FIGURE 14

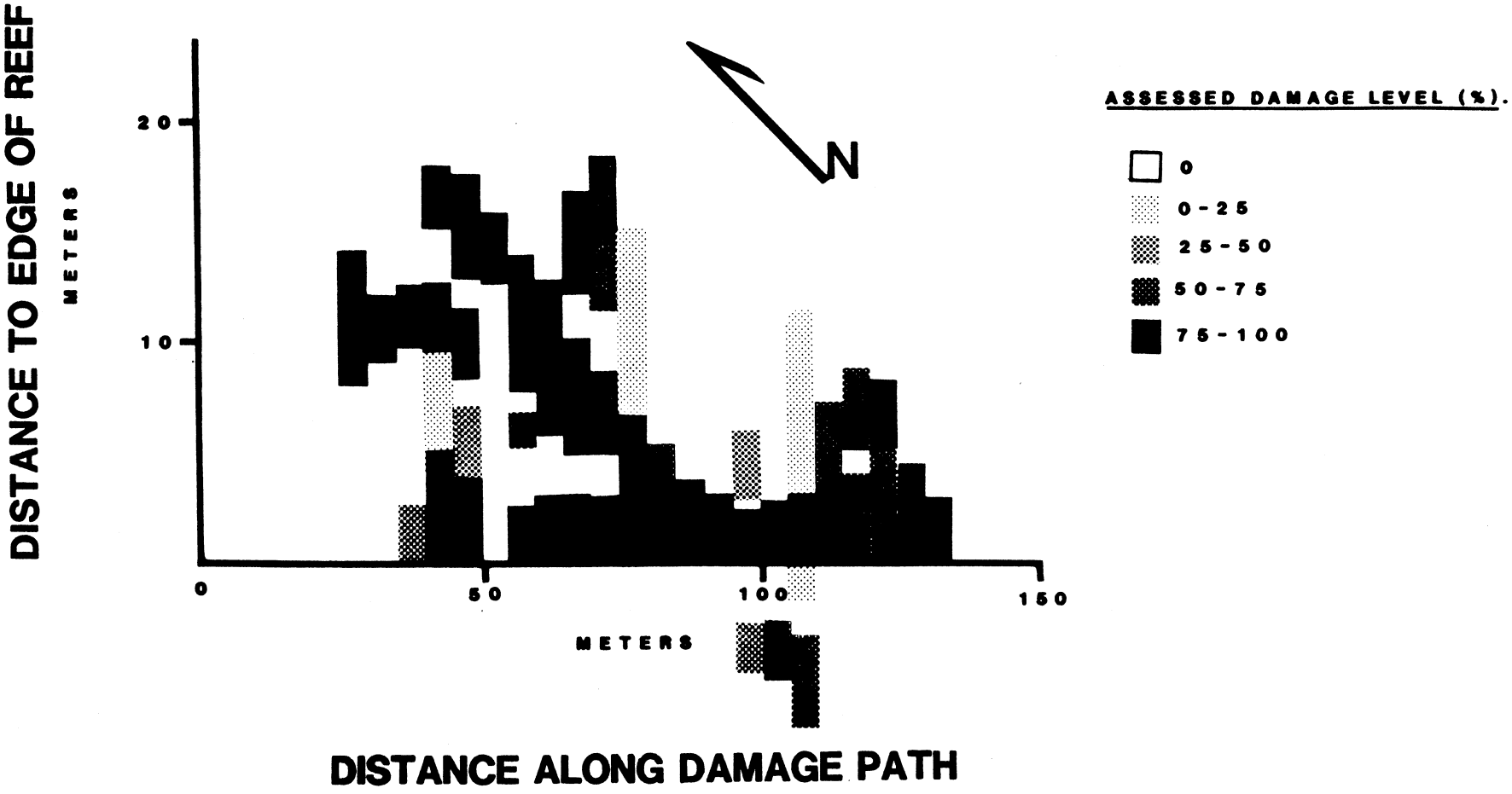
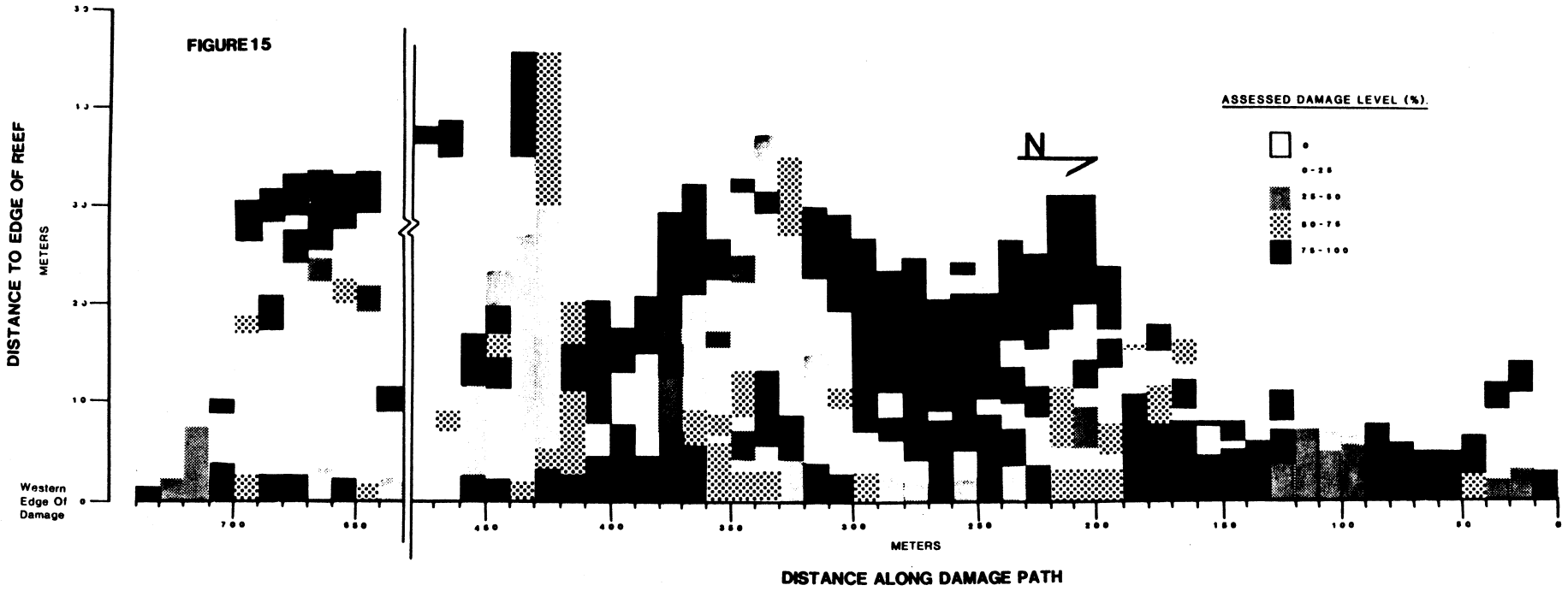

DISTANCE TO EDGE OF REEF
METERS
20
10
0
50
100
150
METERS
N
ASSESSED DAMAGE LEVEL (%).
0
0-25
25-50
50-75
75-100
DISTANCE ALONG DAMAGE PATH

FIGURE 15


DISTANCE TO EDGE OF REEF
METERS
Western Edge Of Damage
0
10
METERS
DISTANCE ALONG DAMAGE PATH
N
ASSESSED DAMAGE LEVEL (%).
0
0-25
25-50
50-75
75-100