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DAMAGE SURVEY AND RESTORATION OF M/V WELLWOOD GROUNDING SITE, MOLASSES REEF, KEY LARGO NATIONAL MARINE SANCTUARY, FLORIDA

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ABSTRACT

Grounding of the M/V WELLWOOD on Molasses Reef in the Key Largo National Marine Sanctuary on August 4, 1984, resulted in massive destruction to living corals and underlying reef framework. A precision survey of grounding damage to the reef was done with a light weight aluminum frame subdivided with elastic cord into 1-m^2 "search" grids that enabled divers to examine and photograph each m^2 of disturbed substrate. Accuracy was controlled by tightly stretched nylon transect lines spaced 4 m apart across the long axis of the grounding site. The survey revealed that a 1,282-m^2 area of the reef had sustained a 70-100 percent loss of live coral cover as a result of the grounding. Within this major damage zone, 644 m^2 of underlying reef framework had been fractured by the great weight of the 400-ft- long (122 m) ship.

Pilot studies were undertaken at the grounding site to test the feasibility of transplanting hard and soft corals, stabilizing widespread fracturing, and rebuilding reef topography with dislodged, massive corals. All three mitigation experiments have proven to be a practical means of restoring a coral reef area severely damaged by a ship grounding.

INTRODUCTION

An assessment of reef framework damage and reef restoration methodology was conducted at the WELLWOOD grounding site on Molasses Reef between April and September 1985 by personnel of the U. S. Geological Survey, Fisher Island Station, Miami Beach, Florida. Molasses Reef is located at 25°00'7"N and 80°25'5"W and is part of the Key Largo National Marine Sanctuary, an underwater preserve that is administered by the Marine Sanctuary Programs Division of the National Oceanic and Atmospheric Administeration, U. S. Department of Commerce (figure 1).

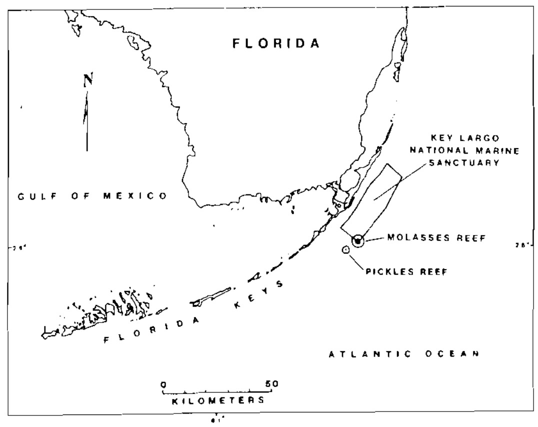

Figure 1. Map of study area.

For purposes of this report, the term "reef framework" will be used to denote that portion of a coral reef that is composed of naturally cemented accumulations of living and dead carbonate materials that resist movement or destruction by severe natural forces, such as hurricanes or winter storms. In addition, the term "framework damage" shall refer to cracked, crushed, split, or otherwise mechanically altered portions of reef framework created by grounding of the WELLWOOD on Molasses Reef on or about midnight of August 4, 1984.

CONSTRUCTION OF "SEARCH" FRAME

Due to the large area of bottom to be examined (1,500 m^2, estimated from aerial photographs and underwater measurements), a 16-m^2 "search" frame was fabricated from 7.6-cm-diameter (3 in.) aluminum irrigation pipe (figure 2). To achieve a square and rigid unit, stainless steel plate stock was welded to form 90°-angle braces that were bolted to each corner of the frame. Elastic shock cord was used to subdivide the frame into a "search" grid of 16 squares of 1 m each (figure 2). To facilitate handling, the frame was cut in half. Splints of split aluminum pipe and hose clamps were used by divers to reassemble the frame after it was lowered from the boat to the seabed. It should be noted that all survey field work was done by scuba divers from an 8-m-long powerboat.

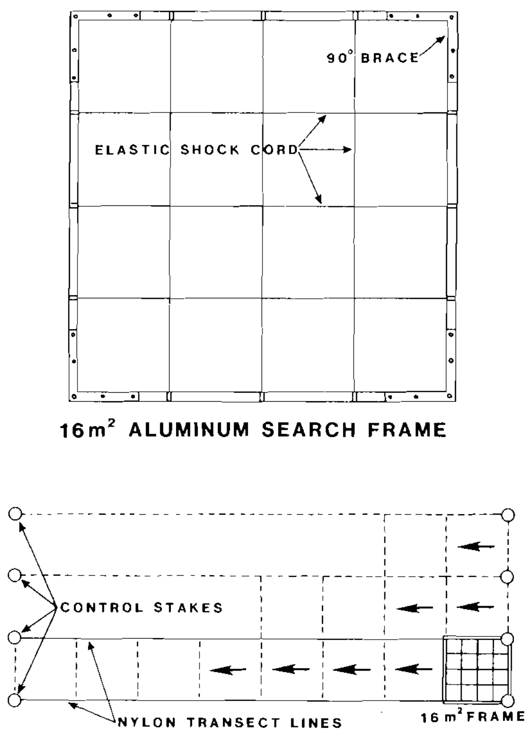

Figure 2. Drawing of 16-m^2 aluminum search frame and diagrammatic sketch of survey procedure using frame.

SURVEY PROCEDURE

Steel survey stakes were installed at strategic points in the grounding area with a hand-held hyraulic drill. Control stakes were placed at 4-m intervals across each end of the largest impact area (figure 2). Transect lines 4 m apart were then created by tightly stretching nylon parachute cord from stake to stake down the long axis of the impact site (figure 2). A master survey line (T-2) was established by extending one of the transect lines almost the entire length of the grounding area (figure 3). Using the T-2 line as a guide, additional stakes were added only where necessary to insure survey accuracy. Exact locations of major survey stakes in the grounding area were determined by placing 1.05-m-wide, circular, white fiberglass targets over the stakes and photographing the entire impact site from a low-flying helicopter (figure 3.) Scale in the aerial photograph was provided by underwater measurement of distance between targets.

Assessment of framework damage was conducted in the following manner: the 16-m^2 search frame was placed at one end of a transect and aligned beneath a pair of tightly stretched nylon transect lines (figure 2). Two or more divers were assigned specific 1-m^2 search areas created within the large frame by the elastic shock cord. Although small pry bars were tested initially, it was quickly discovered that a diver's hands are much more sensitive to loose *in situ* fractured rock than the most delicate hand tool. Thus, every square meter of bottom reported on here received, quite literally, "hands on" examination by one or more persons.

Inspection of impacted substrate was hampered somewhat by the presence of 7 months of natural sedimentation combined with fine and coarse crushed coral debris created by the WELLWOOD at the time of grounding. Divers used their hands in a rapid fanning motion to remove these deposits from portions of each square meter surveyed. Large coral cobbles and other rock debris were shifted by hand to expose the underlying reef framework so that its condition could be determined.

Criteria used to indicate reef framework damage within individual 1-m^2 search grids were as follows: split, crushed, cracked, or otherwise fractured living or dead corals and/or other carbonate rock surfaces, that by visual and tactile inspection were determined to be *in situ* and unstable, were considered damaged (figure 4). If a cracked or otherwise fractured part of the reef framework could be moved by exerting only hand pressure, it was judged to be unstable.

If reef framework damage was found within a 1-m^2 grid, that space was marked with an "X" on an underwater data sheet; if no damage was observed, an "O" was recorded. In addition to basic data on mechanical damage to the reef, information on location of various research tags, stakes, rods, eyebolts, etc., was noted when seen and was drawn in the appropriate place on the data sheet. Surviving stony and soft corals were also drawn on the sheets and identified, in some instances to species.

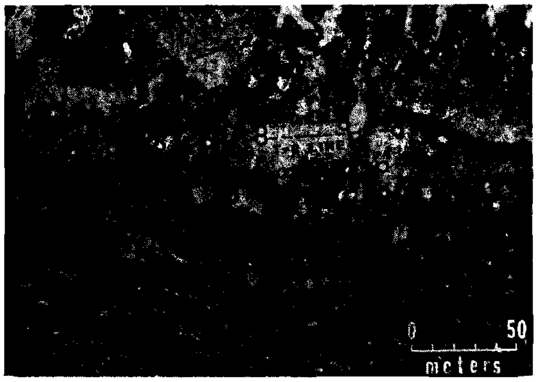

Figure 3. Aerial view of WELLWOOD grounding site. Single circles enclose survey stake targets. Double circles mark grounding site buoys. Black box under "N" denotes grouting and transplant site. Photograph by William J. Harrigan.

Figure 4. Fractured reef framework exposed by storm surge from Hurricane Kate.

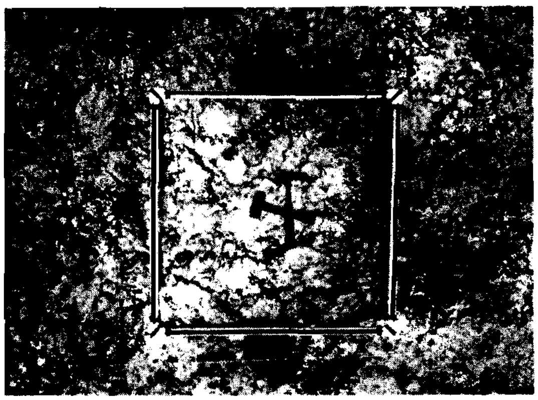

Figure 6. Section of fractured reef framework selected for cement grouting. PVC frame is 1 m^2. Nylon transect line is below frame.

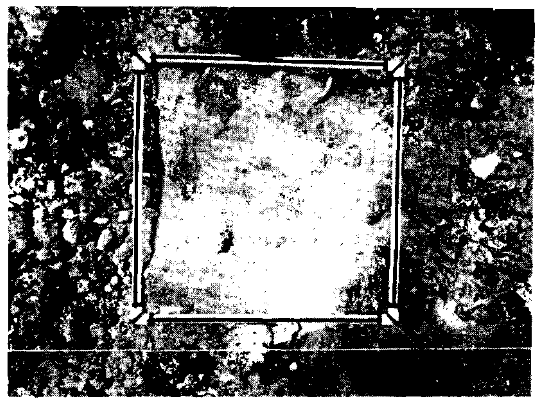

Figure 7. Freshly grouted 1-m^2 test plot.

Figure 8. Airlift bags support a healthy grounding-dislodged head of *Montastraea annularis* that will be used to rebuild reef topography flattened by hull of the WELLWOOD.

Figure 9. Newly transplanted *Montastraea annularis* (shown in figure 8). Note fresh cement (light areas) at base of colony.

Conversely, loose and scattered reef framework debris, regardless of size, was not used to indicate reef framework damage in this survey. Only if an unattached rock or coral fragment could be fitted precisely back into a matching segment of *in situ* substrate was it used as damage evidence.

Obviously, this methodology is conservative in terms of overall damage to the preexisting reef framework. Numerous large *Montastraea annularis* head corals were sheared from their growth position in the reef, overturned, and in several cases shattered into mounds of living and dead coral debris. For most of these corals, their original size and point of attachment will never be known.

Photographic documentation of the entire survey area was done using a Nikonos III camera, Nikkor 15-mm lens, and Kodak Plus X Pan black-and-white film.* The camera was mounted on a specially constructed stainless steel frame that allowed one quarter (4 m^2) of each 16-m^2 quadrat within the search frame to be photographed. A number-letter code board on the frame provided positive identification of individual photographs. Adjustable aluminum legs on the 16-m^2 search frame allowed accurate plan-view photography of deep grooves, overhangs, and large uneven surfaces such as coral heads, etc.

SURVEY RESULTS

This survey covered 1,282 m^2 of substrate at the WELLWOOD grounding site on Molasses Reef (figure 5). Of this amount, 644 m^2 (50 percent) was found to have sustained reef framework fracture damage as previously described. Only where the WELLWOOD came to rest and exerted considerable downward pressure on the reef does there appear to be widespread observable fracturing. Fractured substrate is estimated to have incurred a 90 to 100 percent loss of live coral cover. The remaining 638 m^2 of framework surveyed (50 percent), although intact, sustained an estimated 70 to 90 percent loss of living coral. Photographic documentation of the surveyed area amounted to 342 5" x 7" black-and-white photographic prints, each covering a 4-m^2 portion of each 16-m^2 quadrat.

*Use of brand names does not constitute endorsement by the U. S. Geological Survey.

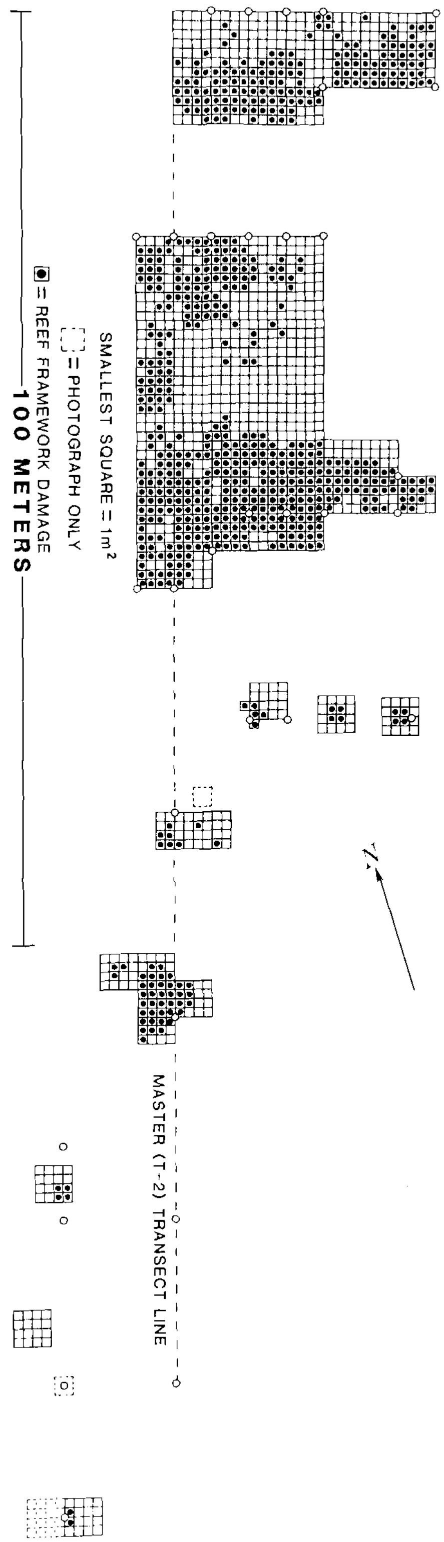

Figure 5. Scale drawing of reef framework damage revealed by underwater survey.

Reef restoration procedure

Upon completion of the damage survey, pilot studies were conducted at the WELLWOOD grounding site between July and September 1985 to test the feasibility of stabilizing fractured reef framework, transplanting hard and soft corals into the major damage area, and rebuilding reef topography. A 1-m^2 area of fractured reef framework (figure 6) was restabilized by grouting with quick-setting underwater cement (figure 7). Removal of loose sand, gravel, and attached algal epiphytes from the site was necessary in order for the cement to bond properly. One bag (94 lbs or 43 kg) of Type II Portland grey cement and 10 lbs (4.5 kg) of molding plaster were used to grout in the damaged 1-m^2 area.

Cement is prepared by adding, by volume, 8 parts Portland Type II cement to 2 parts molding plaster. After combining dry ingredients thoroughly, add only enough (fresh or salt) water to achieve a consistency of firm putty. The cement should be applied immediately as it begins hardening 3 to 6 minutes after mixing. Latex or neoprene-coated gloves should be worn by diver and mixer to protect the skin from lime cement.

Coral transplanting

A 16-m^2 area test plot was selected for transplanting along one edge of the major impact area (figure 3). As a result of the grounding, this plot contained no living hard or soft corals and had sustained only moderate (1 m^2) reef framework fracture damage. Preparation of substrate prior to transplanting was effected by placing a 16-m^2 frame over the plot and removing all loose sediment and rock debris together with attached dead soft coral skeletons. Attached dead hard corals were left in place.

Collecting and transplanting specimens

Using information on species composition and density provided by Thomas Bright of Texas A & M University and Jennifer Wheaton of the Florida Department of Natural Resources, a collection of representative hard and soft corals (table 1) was made at nearby Pickles Reef (figure 1). Selected corals were dislodged from the reef with hammer and chisel and transported by boat to the grounding site in open 30-gallon plastic containers filled with fresh sea water. At the site, divers hand-carried individual specimens from the boat down to the transplant plot.

A decision to limit initial soft coral transplant specimens to 30 was made on the basis of previous experience that most alcyonarians are difficult to relocate without incurring injury to delicate holdfast tissue that often leads to eventual death of the transplant. It was deemed prudent to relocate a moderate number of specimens and adopt a wait-and-see attitude before committing additional time and soft corals to the plot.

Fortunately, hard corals did not pose this problem, due mainly to protection of their tissue by a stony skeleton and our previous experience in transplanting Florida reef-tract scleractinians (Hudson *et al.*, in press).

Table 1. Species composition and number: 4-m^2 transplant plot

Hard Corals

Species	Number
Dichocoenia stokesii	3
Agaricia agaricites	2
Diploria strigosa	1
Diploria labyrinthiformis	1
Montastraea annularis	1
Montastraea cavernosa	1
Meandrina meandrites	1
Siderastrea siderea	1
	11 total

Soft Corals

Species	Number
Pseudopterogorgia americana	14
Gorgonia ventalina	4
Plexaura flexuosa	2
Eunicea mammosa	2
Eunicea tourneforte	1
Eunicea calyculata	1
Eunicea fusca	1
Plexaurella fusifera	1
Plexaurella grisea	1
Muriceopsis flavida	1
Pseudopterogorgia acerosa	1
Muricea atlantica	1
	30 total

Both hard and soft corals were secured to the substrate with the previously described quick-setting underwater cement. Specimens were anchored to the seabed by forcing the attachment base of each coral into a soft ball of cement that had been pressed into a hole in the reef framework. At this writing, all hard corals appear to be in excellent health. A 50 percent loss of soft coral transplants, however, was sustained in late November 1985, as heavy ocean swells generated by fringe winds from Hurricane Kate buffeted Molasses Reef. Loss was not due to cement failure but to twisting off of alcyonarians at the holdfast base.

Rebuilding reef topography

A partial reconstruction of bottom relief in areas flattened by the hull of the WELLWOOD is being accomplished by divers using airlift bags to move large (1 m+), intact head corals (figure 8) and sections of dislodged reef framework back into areas of the reef that were swept clean by the hull. Once in place, each mass of coral is cemented permanently to the reef framework (figure 9).

DISCUSSION

Smith (1985) monitored natural recolonization of hard and soft corals over a 5-year period at a ship grounding site on a Bermuda reef. He found that, although there was active recruitment of hard corals into the damaged area, an average of only 25 cm^2/m^2 per year of coral cover has been generated there by natural means. Surprisingly, he reported that new octocorals (soft corals) have not appeared on the damaged reef despite the fact that they are normally abundant on Bermudan reefs. Dr. Thomas Bright and his associates are presently conducting a study similar to that of Smith at the WELLWOOD site. Thus far, they report only limited evidence of successful new hard coral recruits in the impact area. Conversely, soft corals (primarily *Pseudopterogorgia americana*) have colonized large areas of the impact site. Most individuals noted by us in July 1988 were 10-15 cm high with densities of as much as $5/m^2$. From our previous field experience, age for this size class of *P. americana* is estimated to be between 2 and 3 years.

CONCLUSIONS

It is clear that reef framework fracture damage reported here is confined primarily to elevated segments of the substrate that lay beneath and supported the ship after she came to rest. Thus, damage shown in figure 5 is, in effect, a topographic map of sheared-off and flattened reef projections that bore the major impact and great weight of the stranded vessel. This 644-m area of Molasses Reef is not presently suitable for long-term recolonization by either hard or soft corals.

Each grounding will present a unique set of problems and solutions. In the case of the WELLWOOD grounding, we believe that our efforts at damage assessment and reef rehabilitation have been both practical and effective.

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