



*M/V WAVE WALKER*  
Coral Reef Restoration  
Baseline Monitoring Report – 2004  
Florida Keys National Marine Sanctuary  
Monroe County, Florida

**U.S. Department of Commerce**  
National Oceanic and Atmospheric Administration  
National Ocean Service  
Office of Ocean and Coastal Resource Management  
**National Marine Sanctuary Program**



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September 2006

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## **COVER**

Restored *M. annularis* described in report—Photo credit: Jeff Anderson

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## **ABSTRACT**

This document presents the results of baseline monitoring of a repaired coral reef injured by the M/V *Wave Walker* vessel grounding incident of January 19, 2001. This grounding occurred in Florida state waters within the boundaries of the Florida Keys National Marine Sanctuary (FKNMS). The National Oceanic and Atmospheric Administration (NOAA) and the Board of Trustees of the Internal Improvement Trust Fund of the State of Florida, (“State of Florida” or “state”) are the co-trustees for the natural resources within the FKNMS. This report documents the efficacy of the restoration effort, the condition of the restored reef area two year and four months post-effort, and provides a picture of surrounding reference areas, so as to provide a basis for future comparisons by which to evaluate the long-term success of the restoration.

## **KEY WORDS**

Coral, Florida Keys, National Marine Sanctuary Program, grounding, restoration, monitoring, *Montastrea annularis*.

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## INTRODUCTION

This document presents the results of baseline monitoring of a repaired coral reef injured by the M/V *Wave Walker* vessel grounding incident of January 19, 2001. This grounding occurred in Florida state waters within the boundaries of the Florida Keys National Marine Sanctuary (FKNMS). The National Oceanic and Atmospheric Administration (NOAA) and the Board of Trustees of the Internal Improvement Trust Fund of the State of Florida, (“State of Florida” or “state”) are the co-trustees for the natural resources within the FKNMS and, thus, are responsible for mediating the restoration of the damaged marine resources and monitoring the outcome of the restoration actions. The restoration monitoring program tracks patterns of biological recovery, determines the success of restoration measures, and assesses the resiliency to environmental and anthropogenic disturbances of the site over time. To evaluate restoration success, reference habitats adjacent to the restoration site are concurrently monitored to compare the condition of restored reef areas with “natural” coral reef areas unimpacted by the vessel grounding.

The monitoring program of the *Wave Walker* site included an assessment of the structural stability and biological condition of the repaired coral colony, an installed restoration module, and reattached coral fragments performed on the following schedule: immediately (i.e., baseline), 1, 3, and 6 years after restoration and following a catastrophic event (Table 1).

Restoration of this site was completed on March 22, 2002. Due to unavoidable delays in the settlement of the case, the monitoring schedule was adjusted accordingly and the “baseline” monitoring event for this site occurred in 2004.

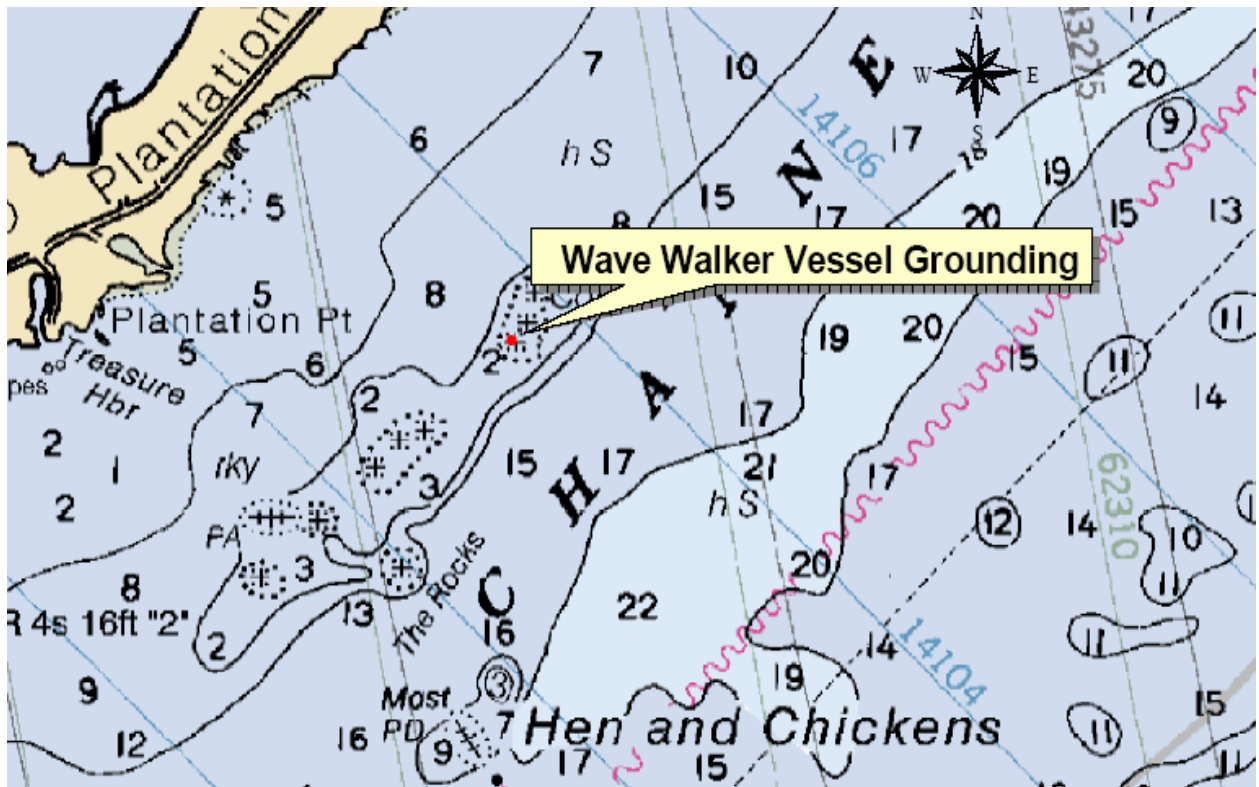
**Table 1.** Event timeline for the M/V *Wave Walker* grounding site restoration.

<b>Event</b>	<b>Date</b>
Vessel Grounding	January 19, 2001
Assessment	January 26, 2001
Restoration	March 22, 2002
<i>Baseline Monitoring</i>	<i>July 23, 2004</i>
Year One Monitoring	Summer 2005
Year Three Monitoring	Summer 2007
Year Six Monitoring	Summer 2010
Post-catastrophic Monitoring (once)	Summer 2004-2010

## Damage Assessment

[Note: The information in this section was adapted from the Discussion section of the *Walker Vessel Grounding Assessment* prepared by William B. Goodwin]

The *Wave Walker*, a 52-foot motor vessel, struck and damaged a large coral colony at “The Rocks,” a patch reef offshore of Plantation Key, Florida, on January 19, 2001 (Figure 1). The vessel suffered significant hull damage and sank as a result of the grounding (Figure 2). The Rocks are a cluster of sizeable *Montastrea annularis* colonies located 1 nautical mile inshore of the much more highly developed “Hen and Chickens” reef. Typical for large specimens of this species, the injured colony displayed a “volcano-like” shape, in which the top central area was mostly dead and sunken due to bioerosion, with a crown of living tissue encircling the rim of the depression. When the hull and running gear of the vessel struck the colony, much of the live tissue along the colony rim was broken into relatively large pieces. These pieces sheared off and landed either in the colony’s central depression or on the surrounding substrate. Additionally, a large (1.5 m<sup>2</sup>) portion of the colony’s sidewall was broken off, exposing the interior framework (Figure 3). In total, 10 m<sup>2</sup> of coral cover was lost as result of this grounding incident.



**Figure 1.** Approximate location (shown on NOAA Chart 11452) that the M/V *Wave Walker* ran aground on a large coral colony offshore of Plantation Key on January 19, 2001.



**Figure 2.** The remains of the M/V *Wave Walker* following damage suffered from grounding on a large coral colony offshore of Plantation Key.



**Figure 3.** Dislodged portion of the colony sidewall of a *Montastrea annularis* damaged by the grounding of the M/V *Wave Walker*. Photo view is towards the northwest.

## ***Coral Reef Restoration***

[Note: The following information was adapted from the Wave Walker Restoration Plan prepared by J. Harold Hudson]

The objectives of the M/V *Wave Walker* site restoration were to 1) repair the sidewall and rim of the injured coral colony (Figure 3), and 2) reattach dislodged live coral fragments on the colony's skirt and in an adjacent "reef crown" restoration module. To accomplish these objectives, the damaged rim and sidewall of the colony were stabilized with a layer of 50/50 Portland cement and silica sand grout anchored to the framework with concrete nails. Three large, broken sections of coral were also reattached to the flank of the damaged colony with cement grout. Additional coral fragments were cemented into a reef crown placed on the seafloor approximately 2 meters from the restored colony. The reef crown was a 1.2 m diameter, cylindrical structure created with Portland type II cement, sand, limestone rock aggregate, and boulders and anchored to the substrate with iron reinforcing rods. Short-length (15cm) fiberglass reinforcing rods were used to ensure structural integrity of cement layers with modules. Restoration activities were completed on March 22, 2002.

Project oversight was provided by Harold Hudson, FKNMS, with the restoration performed by Marine Resources, Inc. (MRI). Field operations by MRI during the habitat restoration were conducted using a 9-m (30-ft) MAKO<sup>®</sup> vessel with sufficient deck space to allow transport of reef replacement modules and to accommodate SCUBA and construction equipment. On-board navigation during transit to and from the project site was achieved using a Furuno<sup>®</sup> differential global positioning system (dGPS).

## ***Previous Studies***

Ginsburg and colleagues (2001) recorded the condition of 3,232 coral colonies at 22 shallow patch reef sites throughout the Florida Reef Tract. From their surveys, they distinguished two primary types of patch reef sites: cluster reefs and composite reefs. Cluster reefs consisted of giant and coalesced coral colonies 1-5 m in diameter, typically of *Montastraea annularis* or *M. faveolata* or occasionally *Siderastrea siderea* and *Colpophyllia natans*. The patch reef "The Rocks" where the *Wave Walker* ran aground was identified as a cluster reef by Ginsburg and colleagues (2001). To estimate the live coral cover of large colonies (> 1 m in diameter) at 65 cluster reef sites throughout the Florida Keys, the authors used the line point intercept transect sampling method (Loya 1978) in a radial array on each colony. Among the cluster reefs, sixty percent of coral colonies surveyed had a range of 30-60% coral cover.

## ***Restoration Monitoring***

The purpose of the coral restoration monitoring program is to evaluate the success of trustee actions in achieving restoration goals and to determine if remedial measures are needed. For a grounding site such as the M/V *Wave Walker*, the evaluation of restoration efforts involves the identification of appropriate success criteria and the design and implementation of a sampling and analysis plan. A list of success criteria measures for structural and functional aspects of coral reef restoration as well as a framework for monitoring activities is identified by NOAA (Thayer et al. 2003).

The guiding hypotheses for the evaluation of the “restoration” site reflects the efficacy of the restoration techniques and the condition of the site relative to reference habitats. The monitoring program addresses if the chosen restoration methods are effective and when the site could be considered restored. The structural integrity of the repaired coral colony is evaluated with the following questions:

1. Is the repaired sidewall and installed cement grout cap on the injured colony stable (i.e., firmly attached to the substrate)? Also, are the reattached colonies and the reef crown stable?
2. Are there any visible cracks in the cement grout surface of the repaired colony, reattached fragments, or the reef crown?
3. Is there any noticeable physical damage to the reattached coral colonies?

In addition, the biological condition of the restoration site is evaluated with the following questions:

1. What is the survivorship of the reattached coral fragments?
2. Is there a difference in coral cover between the repaired colony and the reference for cluster patch reefs reported by Ginsburg and colleagues (2001)?
3. Is the coral tissue overgrowing, maintaining, or receding from the interface with the cement grout on top of the colony?

The monitoring program is designed to detect significant changes in coral cover or damage to restoration components (structural enhancements, etc.) as a result of external events, such as major storms or vandalism, and to compare these conditions with the surrounding habitat. In addition, the monitoring assesses the effectiveness of the restoration based upon technical evaluation of appropriate parameters.

## METHODOLOGY

### *Field Methods*

On July 23, 2004, we monitored the *Wave Walker* restoration site using SCUBA from a small vessel (6.4 m). The geographic location of the repaired coral colony was recorded with a dGPS Garmin 76 as latitude 24°57.229 N and longitude 80°32.884 W. To evaluate the physical characteristics of the restoration site, tactile and visual stability assessments were performed by searching for surface cracks and damaged coral fragments while attempting to displace parts of the repaired colony, reef crown, and reattached fragments. To track coral tissue growth or recession on the rim of the repaired colony, the tissue along the edge of the cement cap was mapped with a clear, colorless plastic sheet. The sheet was anchored to the surface of the colony with nails and cut underwater to the exact size and shape of the cement cap along the interface of live coral tissue. A planar photograph of the plastic sheet was digitized and analyzed in the software program Canvas™ to determine the area of the cement grout cap. To determine the biological condition of the site, in situ observations, digital images, and digital videos were recorded for the repaired coral colony, reattached fragments, installed reef crown, and surrounding reef area. Underwater digital images were collected with an Olympus C-5050 digital camera in a Light & Motion Tetra 5050 underwater housing and digital videos were collected with a Sony DCR-DVD200 video camera in an Amphibico QuickView DVD underwater housing.

### *Photographic Analysis*

Digital images were edited with Adobe Photoshop version 7 (Adobe 2002). Edits included hue changes to make water look more blue, brightness changes to compensate for original exposure, and sharpness changes to enhance images not in focus. Coral cover of the repaired colony and two nearby reference colonies was estimated from a set of horizontal digital images of a colony's four sides (i.e., facing north, south, east, and west). The benthic type (i.e., coral or non-coral) was evaluated beneath fifty randomly generated points overlain on each image in the Coral Point Count (CPC) software program (Kohler 2004). Planar images of the quadrat were corrected for barrel distortion of the extreme wide angle image using the Panorama Tools plug-in for Photoshop. Finally, excess image information outside the quadrat boundary was cropped.

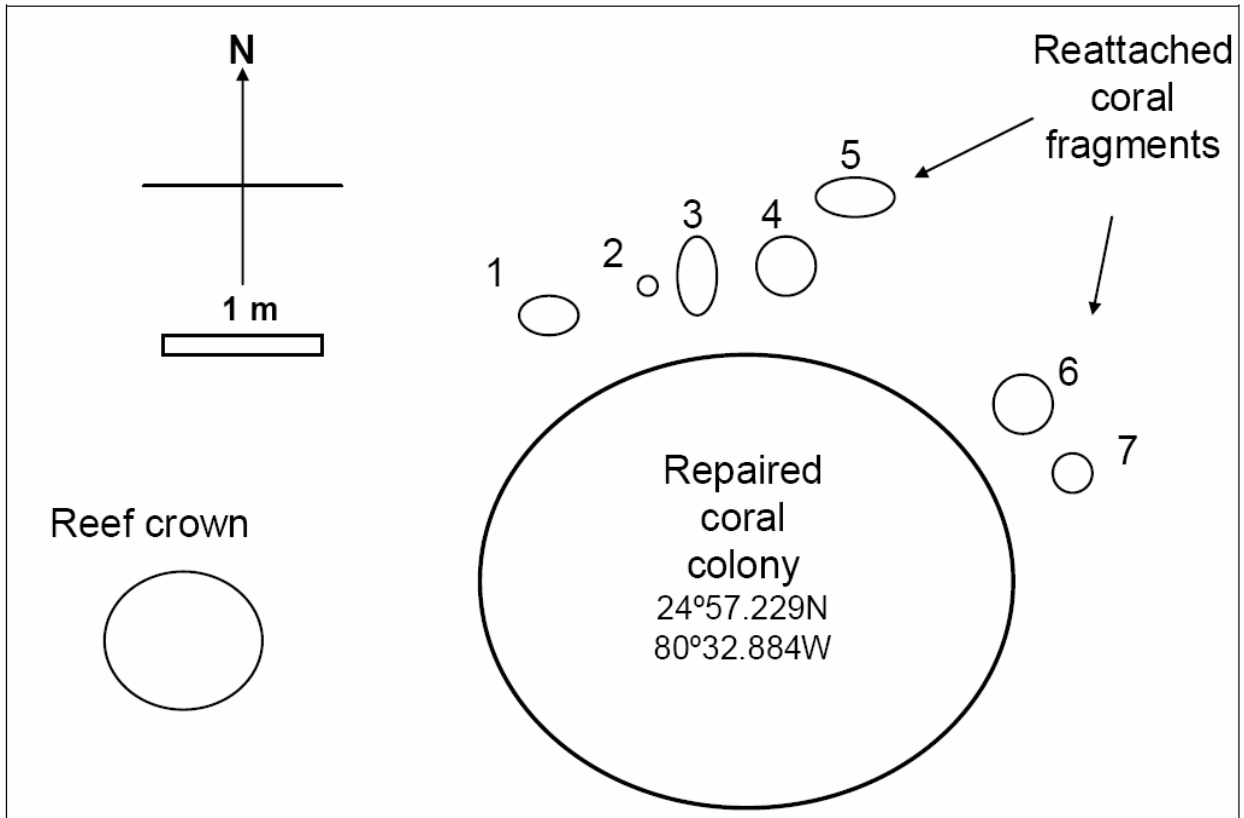
## RESULTS

### *Structural Integrity*

The stability and surface of the coral colony repair and restoration module were found to be visually and tactilely sound (Table 2). The colony cement grout cap and module were found in place with a stable attachment to the substrate and no visible cracks in the cement surface. There was no noticeable physical damage to the reattached coral fragments. The location of the fragments and reef crown were mapped in relation to the repaired coral colony (Figure 4).

**Table 2.** Observed structural characteristics of restoration module and reattached coral fragments in July 2004.

<b>Analysis</b>	<b>Coral Species</b>	<b>Stable Attachment (Yes/No)</b>	<b>Surface Cracks (Yes/No)</b>	<b>Damaged Corals (Yes/No)</b>	<b>Live Coral Tissue (Yes/No)</b>
Colony top	<i>Montastrea annularis</i>	Yes	No	No	Yes
Reef crown	Multiple	Yes	No	No	Yes
Coral 1	<i>Diploria labyrinthiformis</i>	Yes	No	No	Yes
Coral 2	<i>M. annularis</i>	Yes	No	No	Yes
Coral 3	<i>M. annularis</i>	Yes	No	No	Yes
Coral 4	<i>Colpophyllia natans</i>	Yes	No	No	Yes
Coral 5	<i>M. annularis</i>	Yes	No	No	Yes
Coral 6	<i>M. annularis</i>	Yes	No	No	Yes
Coral 7	<i>Porites astreoides</i>	Yes	No	No	Yes

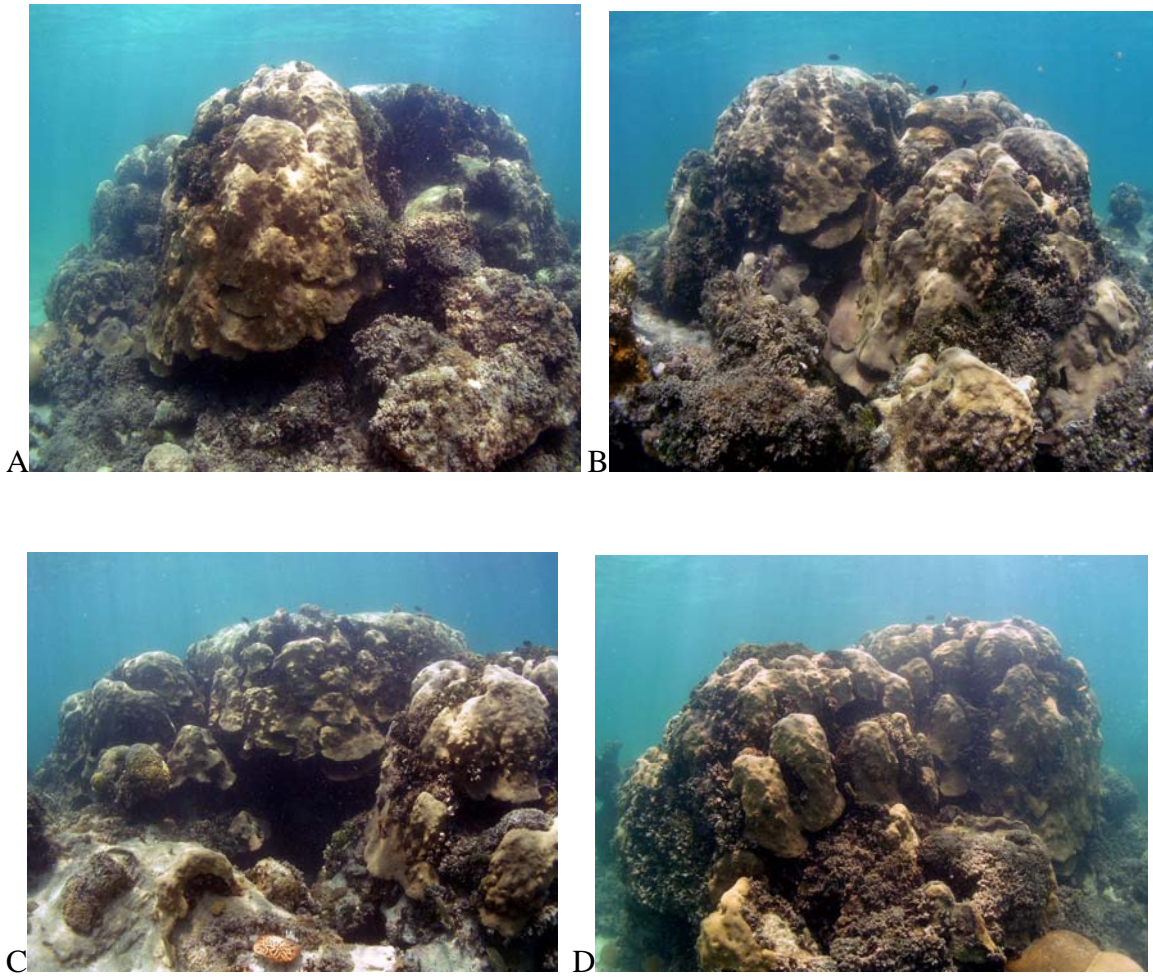


**Figure 4.** Schematic planar view map of the M/V *Wave Walker* restoration site.

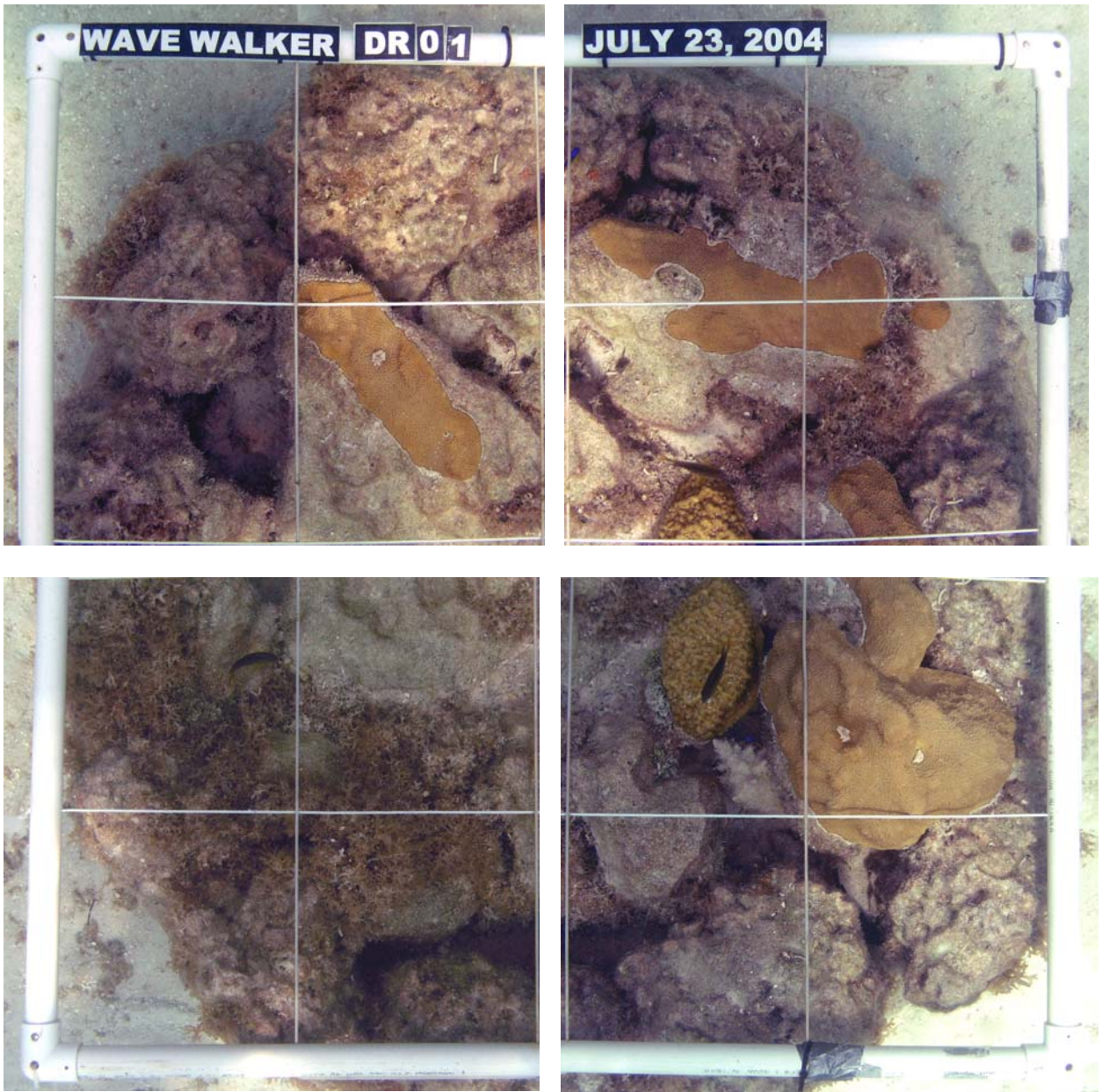
### ***Biological Condition***

The *Wave Walker* restoration site was composed of a large (> 2 m diameter) repaired colony of *Montastrea annularis* (Figure 5) with adjacent reattached coral fragments and an installed reef crown. Reattached coral species included *Colpophyllia natans*, *Diploria labyrinthiformis*, *Montastrea annularis*, and *Porites astreoides* (Table 2). The site and surrounding habitat were defined as a cluster patch reef as described by Ginsburg and colleagues (2001). Live coral tissue was observed on the seven reattached fragments (see photos in Appendix) and five colonies within the reef crown (Figure 6). The tissues of several corals in the surrounding area and one of the reattached colonies (colony #1) were pale or bleached (Figures 7 & 8), but there was no way to determine if these observations were related to restoration activities. In general, the color of the corals appeared “pale” but it was uncertain if this was a common condition for the corals of this patch reef. An estimate of coral cover of the repaired colony was 68%. Coral cover on two nearby, similarly-sized colonies of *M. annularis* were 85% and 67%. The area of the plastic that outlined the cement colony top was 2.66 m<sup>2</sup> (Figure 9).





**Figure 5.** Views of the repaired coral colony looking to the north (A), west (B), south (C), and east (D).



**Figure 6.** Photo mosaic of reattached corals in the reef crown installed adjacent to the repaired coral colony. For the photos, the reef crown was overlain with a 1 m<sup>2</sup> quadrat. The smaller squares are 1/16 m<sup>2</sup>.



**Figure 7.** A large (> 1 m diameter) colony of *Colpophyllia natans* that exhibited signs of coral bleaching at “The Rocks” patch reef on July 23, 2004. This colony and several others adjacent to the restoration site were observed in various states of bleaching.



**Figure 8.** Planar view of a section of the repaired coral colony damaged by the *Wave Walker*.



**Figure 9.** Outline (in red) of the plastic sheet cut to delineate the interface of the concrete surface and live coral tissue along the rim of the coral colony.

## SUMMARY

Baseline monitoring suggests that the structural repair of the damaged coral colony was successful. The structural stability of the repaired colony, a restoration module, and several reattached corals was excellent with no sign of displacement or physical damage (Table 2). Among 65 cluster reefs throughout the Florida Keys, Ginsburg and colleagues (2001) found that nearly 60% of coral colonies had between 30-60% coral cover. Coral cover of the repaired colony exceeded this reported range for cluster reef habitat and was similar to two adjacent reference corals colonies. In addition, several pale or bleached colonies were observed within the patch reef habitat surrounding the repaired colony but these conditions were probably not the result of the restoration efforts. The next scheduled monitoring event is during the summer of 2007.

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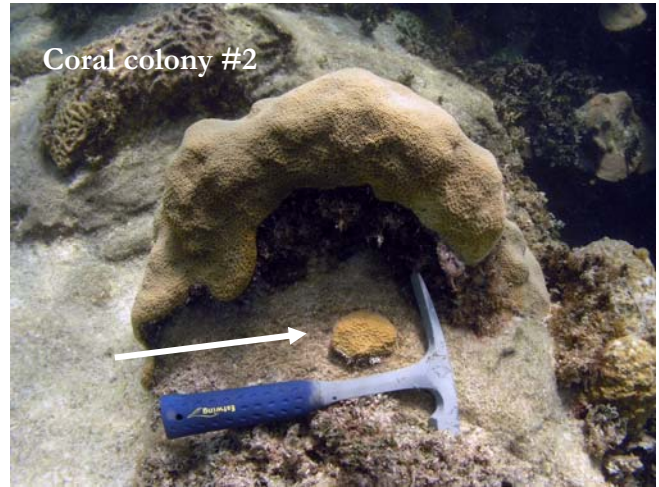
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## APPENDIX

Photographs of coral fragments reattached at the M/V *Wave Walker* grounding site taken on July 23, 2004.



**APPENDIX (CONT.)**



## ONMS CONSERVATION SERIES PUBLICATIONS

To date, the following reports have been published in the Marine Sanctuaries Conservation Series. All publications are available on the National Marine Sanctuary Program website (<http://www.sanctuaries.noaa.gov/>).

Olympic Coast National Marine Sanctuary Habitat Mapping: Survey report and classification of side scan sonar data from surveys HMPR-114-2004-02 and HMPR-116-2005-01 (NMSP-06-07)

A Pilot Study of Hogfish (*Lachnolaimus maximus* Walbaum 1792) Movement in the Conch Reef Research Only Area (Northern Florida Keys) (NMSP-06-06)

Comments on Hydrographic and Topographic LIDAR Acquisition and Merging with Multibeam Sounding Data Acquired in the Olympic Coast National Marine Sanctuary (ONMS-06-05)

Conservation Science in NOAA's National Marine Sanctuaries: Description and Recent Accomplishments (ONMS-06-04)

Normalization and characterization of multibeam backscatter: Koitlah Point to Point of the Arches, Olympic Coast National Marine Sanctuary - Survey HMPR-115-2004-03 (ONMS-06-03)

Developing Alternatives for Optimal Representation of Seafloor Habitats and Associated Communities in Stellwagen Bank National Marine Sanctuary (ONMS-06-02)

Benthic Habitat Mapping in the Olympic Coast National Marine Sanctuary (ONMS-06-01)

Channel Islands Deep Water Monitoring Plan Development Workshop Report (ONMS-05-05)

Movement of yellowtail snapper (*Ocyurus chrysurus* Block 1790) and black grouper (*Mycteroperca bonaci* Poey 1860) in the northern Florida Keys National Marine Sanctuary as determined by acoustic telemetry (MSD-05-4)

The Impacts of Coastal Protection Structures in California's Monterey Bay National Marine Sanctuary (MSD-05-3)

An annotated bibliography of diet studies of fish of the southeast United States and Gray's Reef National Marine Sanctuary (MSD-05-2)

Noise Levels and Sources in the Stellwagen Bank National Marine Sanctuary and the St. Lawrence River Estuary (MSD-05-1)

Biogeographic Analysis of the Tortugas Ecological Reserve (MSD-04-1)

A Review of the Ecological Effectiveness of Subtidal Marine Reserves in Central California (MSD-04-2, MSD-04-3)

Pre-Construction Coral Survey of the M/V Wellwood Grounding Site (MSD-03-1)

Olympic Coast National Marine Sanctuary: Proceedings of the 1998 Research Workshop, Seattle, Washington (MSD-01-04)

Workshop on Marine Mammal Research & Monitoring in the National Marine Sanctuaries (MSD-01-03)

A Review of Marine Zones in the Monterey Bay National Marine Sanctuary (MSD-01-2)

Distribution and Sighting Frequency of Reef Fishes in the Florida Keys National Marine Sanctuary (MSD-01-1)



Flower Garden Banks National Marine Sanctuary: A Rapid Assessment of Coral, Fish, and Algae Using the AGRRA Protocol (MSD-00-3)

The Economic Contribution of Whalewatching to Regional Economies: Perspectives From Two National Marine Sanctuaries (MSD-00-2)

Olympic Coast National Marine Sanctuary Area to be Avoided Education and Monitoring Program (MSD-00-1)

Multi-species and Multi-interest Management: an Ecosystem Approach to Market Squid (*Loligo opalescens*) Harvest in California (MSD-99-1)