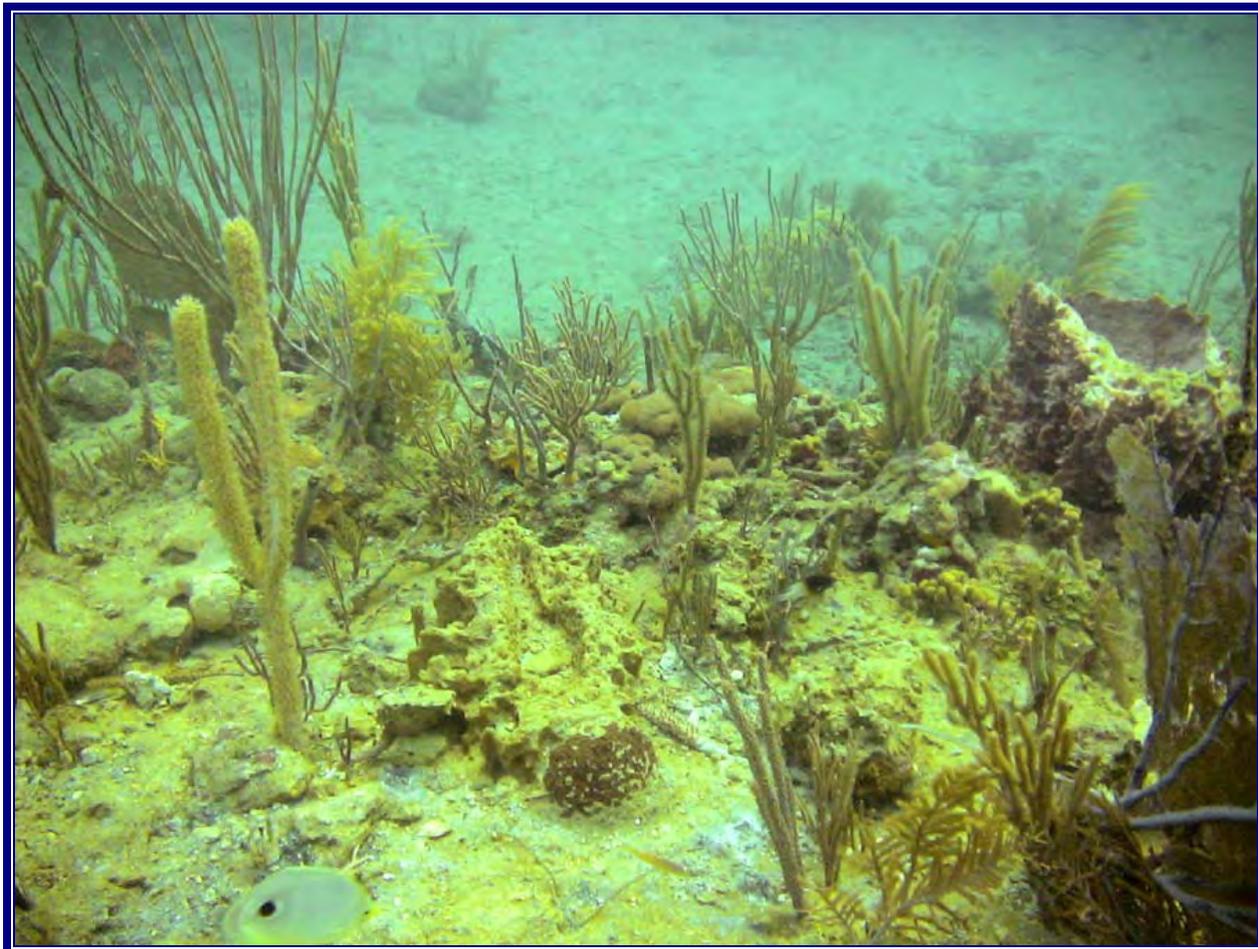


Emergency Restoration Strategy: *M/T Margara* Grounding Offshore South Coast of Puerto Rico



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1.0 INTRODUCTION

The *M/T Margara*, a 228-m (748-ft) tanker, went aground on a hard bottom formation off the southwest coast of Puerto Rico on 27 April 2006. The freighter was reportedly under its own power when it grounded in a water depth of approximately 10.5 m (34 ft). The *M/T Margara* was refloated and removed from the grounding location the following morning on 28 April 2006. The impacted hard bottom formation is located along the outer portion of the relatively narrow insular shelf south of Bahia de Tallaboa (**Figure 1**). The hard bottom bank feature is designated as reef habitat (National Oceanic and Atmospheric Administration, 2001) and supports an epifaunal assemblage visually dominated by soft corals, sponges, and hard corals.

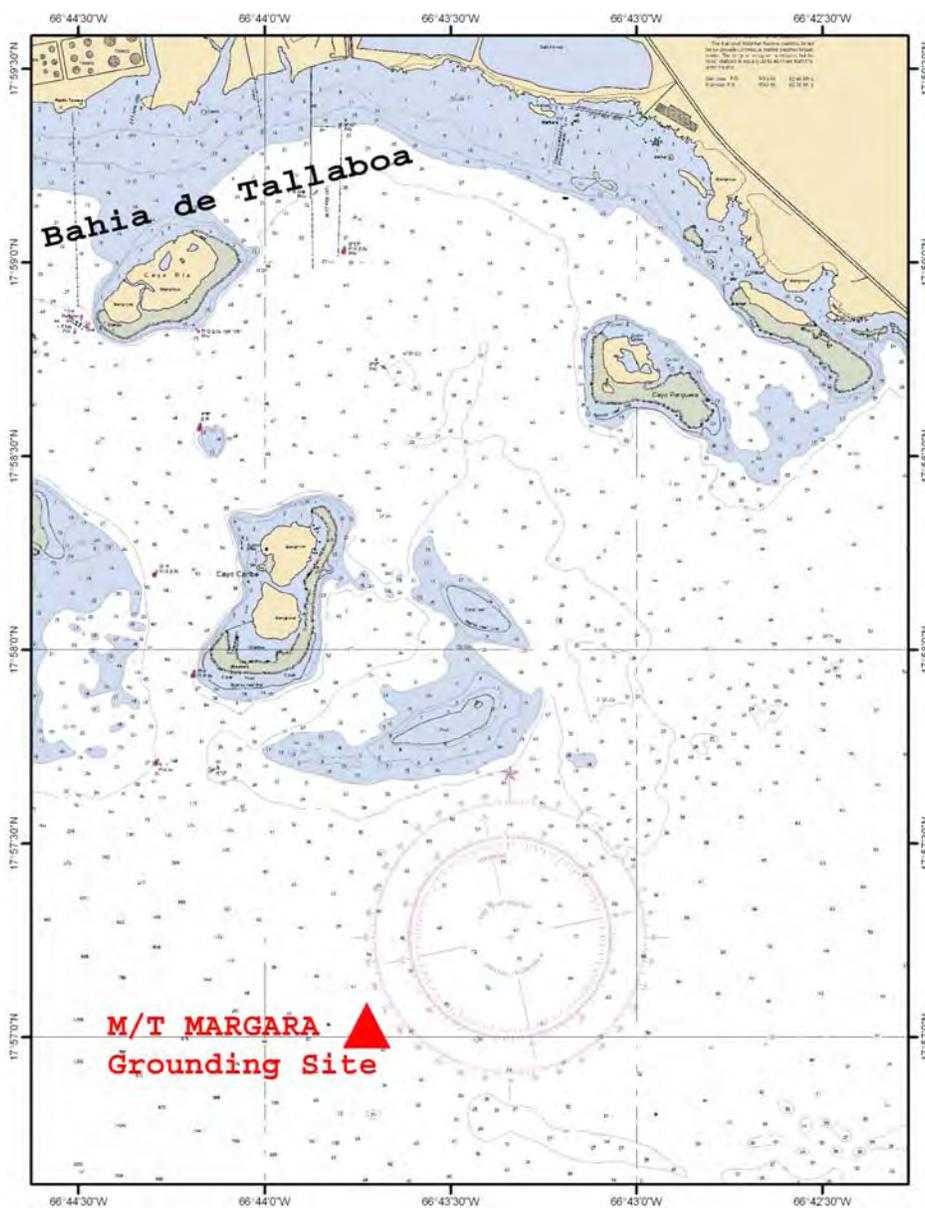


Figure 1. Location of *M/T Margara* grounding site relative to Bahia de Tallaboa, Puerto Rico.

Continental Shelf Associates, Inc. (CSA) was contracted by Independent Maritime Consulting, Ltd. (IMC) (the agent for the responsible party [RP]), to conduct restoration-associated activities, which included an initial site survey, biological triage, and a comprehensive assessment at the grounding site. All restoration-associated activities were cooperative efforts between the RP (represented by Continental Shelf Associates, Inc.), the co-Trustees (Puerto Rico Department of Natural and Environmental Resources [PRDNER], and the National Oceanic and Atmospheric Administration [NOAA]). The objectives of the restoration-associated activities were to characterize the biological habitat impacted during the grounding, define the spatial extent of the impact, assess types and variable severity of injury within the impact area, and conduct biological triage of displaced corals and “live rock” at the site. Grounding site information obtained during these activities coupled with previous restoration experience is the basis for evaluating and developing potential restoration/mitigation options.

A comprehensive field assessment, with exception of additional quantitative and qualitative transects, has been completed and provides data that identify impacts resulting from the *M/T Margara* grounding and quantify lost ecological resources. Additional quantitative transects will be collected during emergency reattachment/restoration operations before 31 October 2006. Two spatially distinct grounding locations were identified during the comprehensive assessment and are referred to as 1) initial grounding location and 2) exit grounding location (**Figure 2**).

The purpose of this report is to present additional emergency restoration activities intended to accelerate and facilitate the recovery of injured natural resources. An Operation Plan for these additional emergency restoration activities has been submitted to the Trustees August 2006 and included the following elements:

- Proposed schedule
- Staffing plan
- Staging location
- Vessels
- Room/Board arrangements
- Dive safety plan
- Hurricane demobilization plan

The Operation Plan is intended to provide general information concerning logistics of emergency restoration and guidance for safe dive practices and contingency for tropical storm events which may occur during emergency restoration.

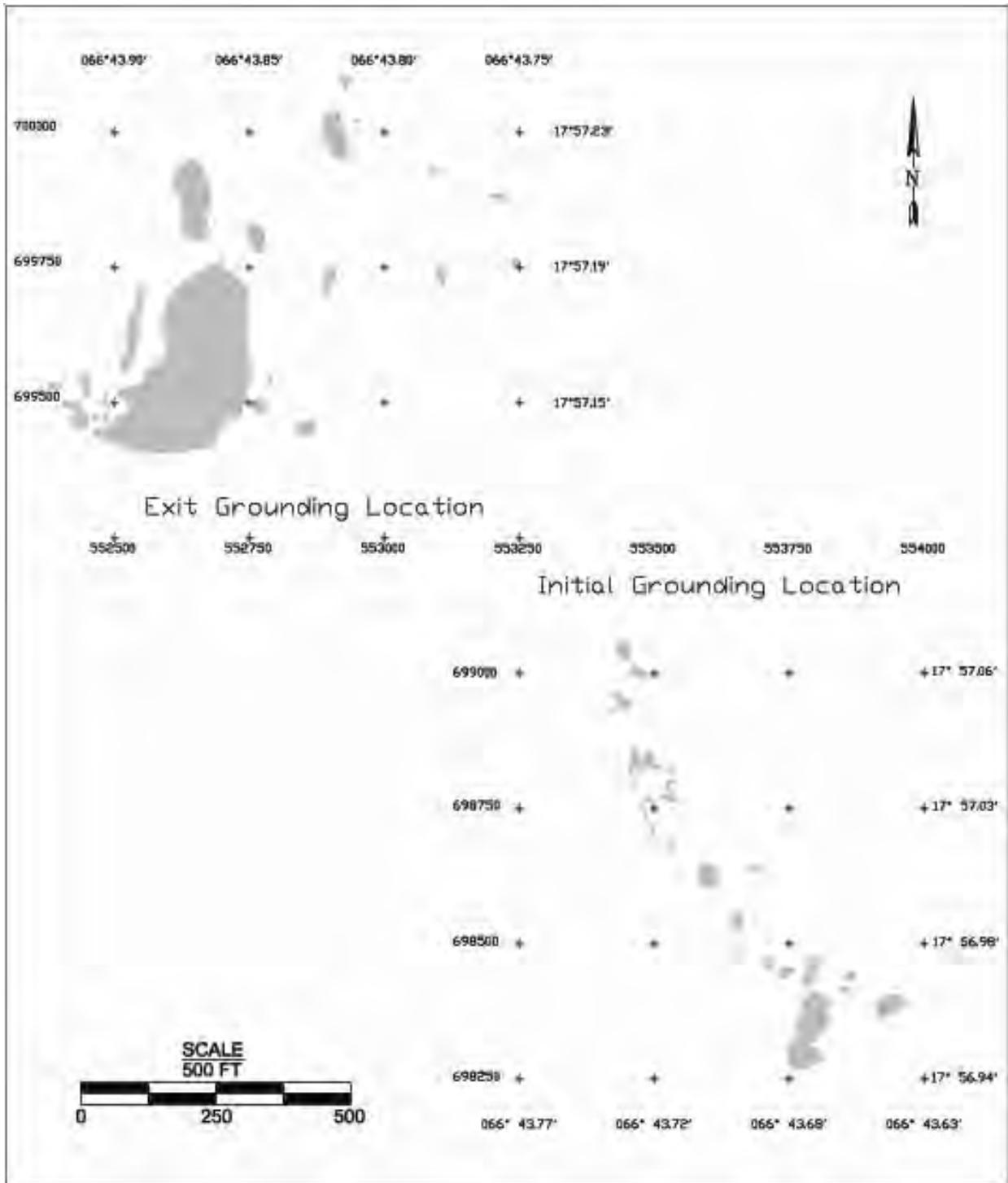


Figure 2. Initial and exit grounding locations identified during the comprehensive assessment.

2.0 SCOPE OF WORK

The proposed plan includes initial actions to recover and reattach viable biological resources (primarily hard and soft corals), and other emergency restoration actions required to minimize additional injury to the habitat associated with the impacted grounding locations. Emergency restoration actions should accelerate and facilitate the recovery of injured natural resources. The immediate recovery and reattachment of viable biological resources will begin as 26 July 2006. The following tasks were identified as emergency restoration during and subsequent to the preliminary RP/Trustee coordination meeting:

- Biological triage
- Mooring installation
- Biological reattachment
- Fouling paint removal/disposal
- Rubble stabilization (various techniques)
- Rubble placement
- Tagging/mapping of reattached biota
- Reporting

M/T Margara grounding locations are to be spatially divided into work units to help guide emergency restoration. A checklist of emergency restoration tasks required at each of the defined work units will be jointly developed by RP/Trustee representatives. The status of work unit tasks will be tracked during operations to facilitate determining completeness of emergency restoration. Trustees will develop a checklist format and required inputs for the emergency restoration work units. The work unit approach for tracking status of emergency restoration operations will most probably require in-field modification due to the novelty of the concept.

2.1 BIOLOGICAL TRIAGE

Biological triage includes repositioning, righting, and caching displaced corals and “live rock” fragments found at and adjacent to the impact areas. Observed biota displaced during the grounding event has been relocated and cached within impact areas pending reattachment. Cached biota comprises whole and fragmented unattached colonies of living biota, and substrate in association with live tissue. Navigational coordinates for each of the cache locations have been recorded to facilitate relocation. Triage and subsequent reattachment of biota, both considered paramount restoration actions, will be very beneficial to the impact areas by preserving significant amounts of live tissue, reducing time for impact recovery, and restoring some of the three-dimensional structure of the habitat.

The grounding of the *M/T Margara* displaced fragments of staghorn coral *A. cervicornis*. To minimize the loss of live tissue and potentially improve survivorship, fragments should be suspended above the seafloor. Triage will focus on the shorter, single branch fragments which have a relatively high proportion of live tissue in contact with the seafloor and are consequently susceptible to shading and the effects of sedimentation. These fragments will be attached to arrays framed with PVC tubing and/or commercial wire mesh. Arrays will be secured with rebar

stakes to the substrate within the impact site. Coral fragments will be secured to the arrays using plastic cable ties. The stabilized fragments will be available to reattach directly at the impact site and/or to be donated for scientific research.

2.2 MOORING INSTALLATION

Mooring installation will be required in the vicinity of the grounding site to accommodate securing work vessels during restoration operations and will significantly reduce the potential for habitat impact due to vessel anchor deployment and recovery. Vessel moorings will be anchored to the seafloor at selected locations at the grounding site that are hard bottom substrate, relatively devoid of epibiota, and have spatial distribution around the grounding site to facilitate versatile positioning of work vessel(s). Vessel moorings will be marked with surface buoys. Proposed mooring locations relative to the *M/T Margara* grounding features are shown in **Figure 3**.



Figure 3. Proposed mooring locations relative to *M/T Margara* grounding features.

Free anchoring of vessels will be conducted when wind and sea conditions at the *M/T Margara* grounding site preclude the use of installed moorings during emergency restoration operations. The vessel will be maneuvered to a selected location, as based on existing knowledge of the grounding site features, prior to bow anchor deployment. The bow anchor location will be checked by a diver once the vessel is stable. Stern anchor, if required during operations, will be directly deployed by a diver. Free anchoring positions will be selected to minimize impact to the seafloor habitat. Anchor and line will be positioned to prevent impact to known *A. cervicornis* and reattached biotal locations.

2.3 BIOLOGICAL REATTACHMENT

Biological reattachment of cached biota and associated reef substrate will be conducted to rescue viable organisms and promote biological recovery of the grounding site. There are presently 2,300-plus corals that have been cached at the grounding site and are ready for reattachment. To address aesthetics and reduce recovery time, cached biota should be reattached within the injury area. Reattached biota will be spatially distributed in a manner that would mimic natural conditions as closely as possible.

2.3.1 Hard Corals

Hard corals suitable for reattachment will be transported underwater and placed at selected reattachment sites in relative close proximity to their cache location. Prior to attaching displaced hard corals, the reattachment surfaces at the selected sites will be prepared by removing loose sediment, surficial biota (i.e., algae and fouling organisms), and possibly embedded fouling paint. Additional reattachment site preparation may include insertion of 0.6-cm (1/4-in.) rebar stakes to reinforce semi-consolidated surficial substrate and placement of masonry nails in consolidated hard bottom substrate. Both the rebar stakes and masonry nails should have a 2.5- to 5-cm (1- to 2-in.) portion exposed above the substrate to provide structural reinforcement for the bonding agent. Following selection and preparation of attachment sites, a concrete mixture of approximately one part Portland cement to one part silica sand will be prepared utilizing a heavy-duty electric drill equipped with a mixing paddle. Prepared concrete will be lowered from the vessel to near bottom utilizing lift lines and will be transported by divers to attachment sites. Sufficient amounts of concrete will be placed directly on the prepared substrate, and hard coral colonies/fragments to be reattached will be pressed firmly into the concrete mixture and held in position until stable. Reattached hard corals will be checked intermittently during reattachment operations to ensure their stability, address the aesthetic quality of the reattachment matrix, and dissipate cement residue that may have settled on adjacent biota.

2.3.2 Staghorn Coral (*Acropora cervicornis*)

Acropora cervicornis has been designated by NOAA Fisheries Service as Threatened under the Endangered Species Act of 1972 due to dramatic declines in population throughout its range in the last 30 years. While it is increasingly rare to find abundant healthy stands of *A. cervicornis* in the Caribbean, the *M/T Margara* grounding area supported a relatively healthy and dense localized thicket identified during assessment operations. Overall coverage of *A. cervicornis* at

the grounding site is unknown. Approximately 600 to 800 *A. cervicornis* fragments have been cached in temporary holding areas pending reattachment. Fragments range in size from 7.7 to 23 cm (3 to 9 in).

The Co-Trustees/RP have developed a reattachment strategy that utilizes various techniques at multiple locations within the grounding site. Results of the reattachment effort will help determine the relative success of these techniques in order to provide guidance in future restoration projects concerning *A. cervicornis*.

Reattachment Locations:

Three spatially distinct locations for reattachment will be established in the exit grounding location (i.e., northern area). The locations will be jointly selected by the Co-Trustees/RP team meeting the following characteristics:

- Stable impact area,
- Free of anti-fouling paint,
- Healthy stands of *A. cervicornis* adjacent to but not at the site,
- Areas not directly adjacent to other restoration/reattachment activities, and
- Capable of supporting the implementation of the proposed reattachment techniques.

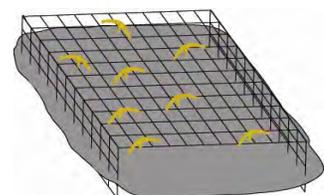
Reattachment Techniques:

Co-Trustee/RP developed techniques for reattachment of *A. cervicornis* fragments utilizing various structural materials that include stainless steel, natural coral rubble, plastic-coated wire mesh, and possibly ceramic.

Stainless steel bolts or screws approximately 15 cm (6 in.) in length will be bound in a pool of cement and be used as a base for fragment reattachment. Pools of concrete with a maximum diameter of approximately 1 m (3 ft) will be prepared within the selected impact locations. Bolts or screws will be inserted into the wet cement base on 30- to 60-degree angles with approximately 10 cm (4 in.) of the bolts/screws remaining exposed above the concrete. The surface of the concrete will be covered with a veneer of natural occurring on-site rubble. Once the concrete is cured, the bolts/screws secure, and other nearby restoration tasks complete the *A. cervicornis* would be attached along the length of the exposed bolts/screws using cable ties. Fragments would be placed 1.3 cm (1/2 in.) above the concrete surface with the majority of growing tips facing downward and spaced approximately 26 cm (10 in.) from other fragments.

Natural coral rubble instead of stainless steel bolts/screws will be used with the aforementioned strategy to help determine if the type of reattachment material affects the relative success of fragment survival. Natural occurring lithified *A. cervicornis* rubble ranging in length from 15 to 26 cm (6 to 10 in.) will be inserted into the wet cement with similar orientation and spatial distribution as described for the stainless steel bolts/screws. Selected rubble should be relatively devoid of encrusting biota.

Plastic-coated wire mesh, (2-m [3-ft] wide and 1.2-m [4-ft] long) will be configured to form a low-relief table for supporting *A. cervicornis* fragments. This method is designed to provide a large area to secure



the fragments in close proximity to the seafloor to facilitate attachment to the underlying natural substrate. The frame is formed by putting a 90-degree bend 10 cm (4 in.) along both sides of the length of the wire mesh. The bends of the frame will be initially secured utilizing rebar stakes. A bed of cement will be placed along the base of the wire mesh bend, which will secure the frame to the seafloor.

Once the frame is secure in the concrete, fragments can then be attached utilizing cable ties. Fragments should be secured so that a small portion of the live tissue is below the mesh and placed at various angles ranging from less than 90 degrees to greater than 30 degrees. Fragments should be placed with the majority of growing tips facing downward and spaced approximately 26 cm (10 in.) from other fragments. A critical factor to consider in the construction of these frames is to ensure that the frame will resist flexing so fragments will not be pulled once they attach to the underlying natural substrate. Pieces of loose rock substrate should be placed between the mesh table top and the seafloor to help stiffen the frame and prevent collapse.

EcoReefs are interlocking ceramic artificial reef modules that mimic the growth form of branching corals and are considered as a suitable platform for reattachment of *A. cervicornis* fragments. Individual modules would be secured to the bottom using a combination of anchors and cement. An array of EcoReefs would be constructed of four to six interlocking modules. Each module could accommodate the reattachment of approximately 10 to 15 *A. cervicornis* fragments. Cable ties would be used to secure the individual *A. cervicornis* fragments to the ceramic modules.



General Considerations:

The following general considerations are provided for the reattachment of *A. cervicornis* at the site of the *M/T Margara* grounding.

Currently, approximately 600 fragments are temporarily secured on wire mesh and PVC pipe. Other fragments (approximately 200) have been piled together and cached at localized caches within the exit grounding location. It is possible that cached fragments may have naturally attached together and/or to the natural substrate, since *A. cervicornis* is a relatively fast-growing species. If cached fragments have become attached, NOAA oversight personnel will photo document those fragments. Fused fragments will be treated as a single fragment and reattached utilizing the previously described techniques. If the fragment has secured itself to the bottom naturally it will not be moved from the coral cache location unless it is in danger for another reason (e.g., shifting rubble). The attached fragment will be left in place and the Trustee team consulted as to what protective measures may be necessary.

Individual fragments should always be placed in a horizontal orientation or plane. If the fragment has viable buds growing they should be placed so that they will grow in the direction of the substrate. The horizontal placement will promote the growth of multiple shoots and the

orientation of the buds in the direction of the substrate will promote multiple points of attachment.

If visible disease or algae is present on the fragment, its introduction into the reattachment site could compromise the integrity of the other corals at the site. Such fragments should have the questionable area clipped and discarded underwater and the remaining portion of the fragment can be reattached provided it is not placed in direct contact with other *A. cervicornis* fragments.

The annual coral spawning event for *A. cervicornis* and *A. palmata* is expected to occur on or around 12 August 2006. Emergency restoration activities should be limited in the areas that are in close proximity to *A. cervicornis* fragments and unimpacted thickets during the spawning period from 8 to 16 August.

Endangered Species Act (ESA) Requirements:

A. cervicornis has recently been listed as threatened under the ESA and therefore is subject to additional protections. In order to insure compliance with the ESA, the NOAA Restoration Center has initiated emergency consultation activities pursuant to Section 7 of the ESA with the NOAA Fisheries Service Protected Resources Division (PRD). Once this document is completed, NOAA will submit it as part this consultation. During the emergency consultation process PRD has indicated that the following conservation measures will be required to be in place for our activities to move forward.

- A plan to minimize the impact of repetitive boat anchoring at the site during operations. This will be accomplished through the installation of approximately 15 mooring buoys. Additionally, the location of known *A. cervicornis* thickets and caches will be marked with surface buoys.
- Training of all personnel working on the site in the identification of *A. cervicornis* and briefing them on precautions that should be implemented when working around the species.
- The presence of an authorized agency representative during all operations that have the potential to affect *A. cervicornis*. NOAA's Damage Assessment, Remediation, and Restoration Program (DARRP) staff will provide on-site support and oversight for the project and will serve as the authorized agency representative.

In addition to ESA Section 7 requirements, NOAA Fisheries PRD has also recommended that the Trustees and Responsible Party consider providing a small amount (less than 50) of impacted fragments to selected researchers who would otherwise be impacting wild healthy colonies in order to obtain their samples. "Fragments of Opportunity" is the preferred method for coral researchers to obtain samples. During the injury assessment and compensatory restoration scaling the RP would not be penalized for the loss of this coral tissue from the site.

2.3.3 Soft Corals

CSA has successfully reattached soft corals during numerous restoration programs. Soft coral reattachment is more difficult than the reattachment of hard corals. Soft corals are relatively lightweight and their branching morphology creates a high amount of drag in water currents,

which subsequently makes soft corals very prone to movement prior to the set-up of the bonding agent (e.g., concrete). Often, displaced soft corals are basally attached to a piece of substrate, which can be helpful in securing the soft corals during reattachment. The basally attached substrate can be wedged into a natural crevasse or can be weighted with additional substrate to secure the soft corals during reattachment. Metal rebar stakes and/or masonry nails can be used to initially secure soft corals that lack basally attached substrate. Metal rebar 0.6 cm (1/4-in.) can be securely inserted into the substrate and small cable ties used to secure the base of the soft coral to the rebar. Additional cable ties may be needed to further secure the soft coral to the rebar. An adequate amount of cement will be placed at the base of the secured soft coral encasing approximately 5 cm (2 in.) of basal soft coral tissue, exposed rebar, and cable tie(s) closest to the seafloor. Additional cable ties placed higher above the seafloor will be removed once the cement has hardened and the soft coral is stable. Masonry nails could be used to fix the basal tissue directly to the attachment substrate; cement could then be utilized to complete the reattachment. Care will be taken to limit contact of soft coral tissue with cement.

2.4 FOULING PAINT REMOVAL/DISPOSAL

Anti-fouling paint and the surficial portion of the embedded substrate will be removed with scraping tools. Anti-fouling paint/substrate lifted from direct impact areas will be placed in plastic Ziploc bags to minimize underwater dispersal of the anti-fouling paint. Ziploc bags with removed materials will be brought to the surface for proper disposal. Anti-fouling paint removed from the grounding site will be containerized and stored onshore. The same procedure for paint removal was successfully conducted during other recent restorations of grounding sites (Marine Resources, Inc., 2003). Anti-fouling paint may have special disposal requirements.

2.5 RUBBLE STABILIZATION

Some loose substrate created during the grounding event may require stabilization to provide lost structural relief. Based on observations made during the restoration activities, there appeared to be some large substrate fragments present at the *M/T Margara* grounding site that would be available for on-site stabilization.

The objective of on-site rubble stabilization is to maximize use of natural materials to provide refuge for mobile fauna and suitable settling habitat for recruitment of epibenthos (Jaap, 2000). The fundamental aim of rubble stabilization is to restore the structural integrity of the impacted habitat and subsequently restore associated biological assemblages. On-site rubble stabilization will increase substrate surface area and availability for epibenthic settlement.

Direct reattachment of large substrate fragments greater than 0.3 m (1 ft) in diameter will help re-establish some of the habitats' three-dimensionality lost during the grounding event. In addition, smaller material (ranging from 15 to 30 cm (0.5 to 1 ft) in diameter) created from the incident will be utilized directly in the reattachment matrix and also used to dress the outside of the matrix. Direct reattachment would use Portland cement to stabilize large fragments onto impacted substrate. Cement pooling would be enhanced by the natural contours of the impacted substrate and also by using a low-slump relatively "dry" mix. Large substrate fragments will be moved by divers with the assistance of lift bags (if necessary). Substrate could be reattached and

aesthetically dressed within a free-form pool of low-slump cement. A thick mix of cement maintains its integrity during placement onto the substrate and during manipulation when bonding substrate fragments/rubble. Natural topographic contours of the impacted substrate also will be utilized in maintaining pooled cement during reattachment of substrate.

Rubble placement will include localized containment of rubble and possible backfilling of scour locations. Grounding-associated rubble within berm formations could be contoured to reduce the slope of the berm formation. Loose rubble can be utilized in reconstruction and stabilization of some impact areas. As discussed previously, some areas of the grounding site have experienced substrate destabilization and may require some reconstruction. A series of metal rebar stakes approximately 0.6 m (2 ft) in length could be inserted into the unstable substrate to provide lateral tensile strength. As with biological reattachment procedures, a 5-cm (2-in.) portion of the rebar stake will be left exposed above the substrate. A small base of concrete would be placed onto the substrate and projecting rebar to provide a stable platform for placement and stabilization of rubble.

2.6 TAGGING/MAPPING OF REATTACHED BIOTA

Tagging and mapping of representative reattached biota relative to on-site reference markers will be conducted to facilitate their relocation for potential monitoring. Uniquely numbered plastic tags will be affixed to the substrate directly adjacent to reattached biota using masonry nails and/or expansion anchors. The distance and bearing relative to a geo-referenced marker will be recorded for representative specimens of the reattached biota. Mapping data will be entered into AutoCAD (a computer-aided drafting program) to produce a scaled map of the reattached biota.

2.7 REPORTING

Reporting will consist of brief letter updates concerning the status of the on-going restoration. During restoration operations, weekly e-mails will be sent to IMC providing information about hours worked, work completed, and a general overview of the on-site weather and sea conditions.

3.0 LITERATURE CITED

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