T/V *PORT STEWART* PRELIMINARY SITE ASSESSMENT PLAN AND EMERGENCY RESTORATION PLAN

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Introduction

The T/V PORT STEWART, a 176 meter tank vessel was reported to strike bottom on October 27, 2009 on the southeast side of Puerto Rico near the entrance to Yabucoa Channel at 18° 2.781'N, 65° 48.268'W , 0942 local time. The natural resource trustees from the National Oceanic and Atmospheric Administration (NOAA) and the Puerto Rico Department of Natural and Environmental Resources, (PRDNER) reported injury to benthic resources at approximately 17° 39.734'N, 64° 49.554'W (Figure 1).

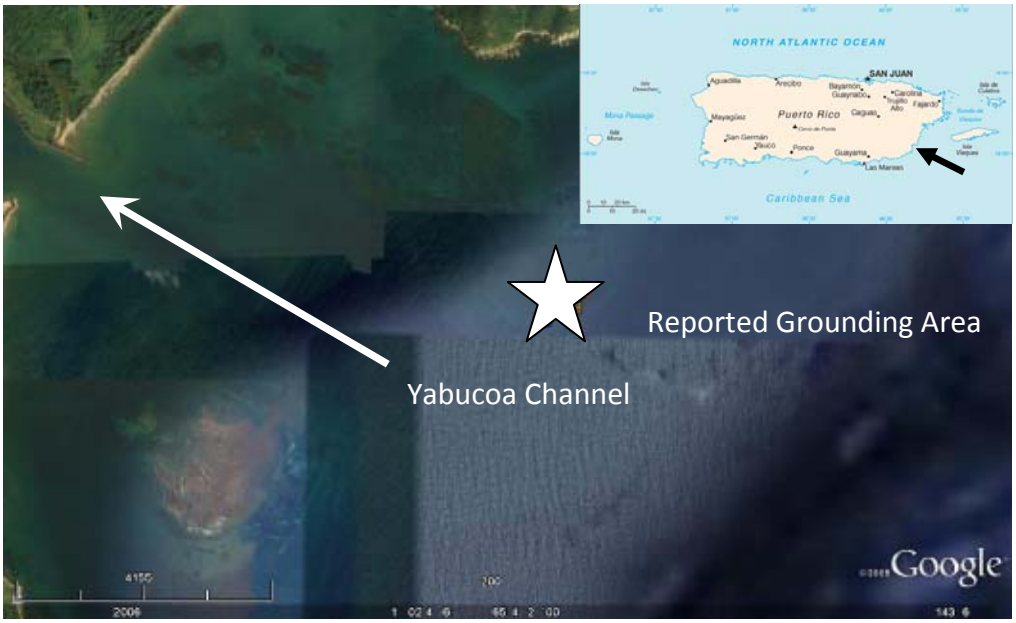

Figure 1. Reported grounding position.

Polaris Applied Sciences, Incorporated (Polaris) was retained to work cooperatively with natural resource trustees from NOAA and the PRDNER to map the alleged injury areas, assess the degree of injury and develop an emergency restoration plan. This report presents preliminary injury information from site surveys conducted on December 3 through 6, 2009. This document also presents comprehensive emergency restoration recommendations for the affected area.

Assessment Surveys

Preliminary information from NOAA and the vessel indicate the position of the reported grounding and reef damage is approximately 100 meters apart, or the distance from the GPS transducer on the bridge to the location of hull contact (Figure 2). A visual assessment with personnel from NOAA and PRDNER was conducted December 3, 2009. The area was mapped and reference data were collected on December 4, 2009. On December 5, 2009, work began to triage corals and plan emergency restoration at the grounding site.

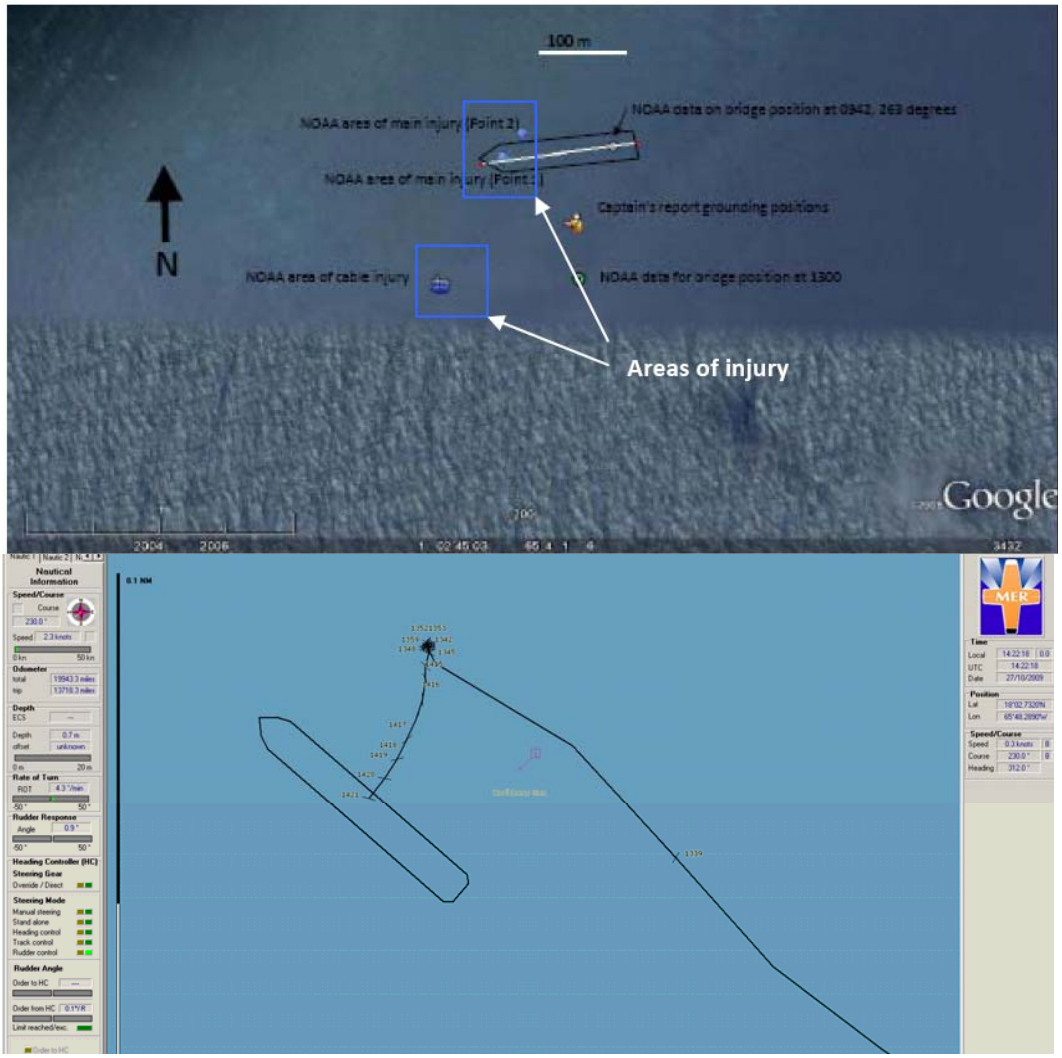

Figure 2. Grounding location, area of injury, and screenshot of vessel path.

The December 3 and 4 surveys were conducted to gather qualitative data of biota presence, injury nature and extent, and general conditions of the surrounding reef to be used in preparation of an emergency restoration plan. The recommended emergency restoration plan is comprehensive and, if successful, will likely satisfy all primary restoration requirements at the site provided the overall site situation and stability do not change by unforeseeable acts. In this instance, the use of local divers from Sea Ventures will enable us to establish a plan and budget and not have to return to the site. A paint sample from the impacted reef bottom and from the vessel were collected under chain of custody for archival purposes.

Coral impact boundary assessments were performed jointly with the Trustees using AquaMap™, a SONAR (Sound Navigation and Ranging) based survey system. The AquaMap™ system consists of three baseline transducers and a diver station. The three baseline transducers are stationary units and are moored to the bottom of the ocean floor around the dive site. The diver station is a mobile transducer and is moved around the dive site to areas of interest. The diver station transmits a brief sonar signal (or sonar code), which travels to all three baseline stations. Upon receipt of a signal, each baseline station transmits a reply back to the diver station. The diver station is then able to compute its distance from each of the baseline stations. A relative coordinate system is developed

and precise positions (about 0.15 m) can be recorded within the dive site. A buoy was attached to one of the baseline stations and was geo-referenced with a Global Positioning System. This position, along with a bearing to another baseline station, was used to produce a chart of the estimated injury. Photographs and video of each survey were recorded to document the outer edges. These data are used to produce an accurate map of the site and features.

Reference transect data were collected for comparison to the injury area to estimate the loss of habitat structure and hard and soft coral organisms. Nine "belt" transects, 10 meters long by 1 meter wide, were marked with an underwater tape and a graduated PVC meter-stick. The long diameter of encrusting and boulder hard corals was recorded and the maximum height of soft corals and branching hard corals were recorded within 50 centimeters of either side of the centerline tape. The meter-stick is moved along the tape until the ten meter section has been recorded. Other observations of sponges and encrusting zooanthids were also recorded. The reference transects locations were jointly selected by an RP/Trustee team. Transects were stratified to represent areas immediately adjacent the injury and in the same depth zone. These data will be analyzed and shared with the responsible party and will be used to estimate "service" loss in addition to structure or measures of relief or habitat complexity. Data was collected by a joint RP/Trustee team.

Affected Area

The affected reef area is a hard bottom of underlying limestone, much of which was not formed by reef-building organisms but supports hard and soft corals as well as numerous other benthic invertebrates. The bathymetry varies from 27 to 31 feet with scattered deeper sand, coral and rubble depressions greater than 31 feet deep. From the injury site offshore, the area quickly exceeds 33 feet (10 meters) in depth. The chart shows the vessel GPS transducer approximately 120 meters from the 10 meter line. We estimate the underside of the forward part of the vessel struck bottom.

The hard bottom seafloor is estimated to have 15% to 35% cover of soft and hard corals among a variety of other benthic organisms (Figure 3). Reference data will be analyzed to provide more quantitative estimates of biota. The hard corals are dominated by cavernous star coral (*Montastrea cavernosa*), starlet coral (*Siderastrea* spp), smooth brain coral (*Diploria strigosa*), and mustard hill coral (*Porites astreaoides*). Branching calcareous hydroids (*Millepora spp*) and other subdominant hard corals such as knobby brain coral (*Diploria clivosa*), butterprint brain coral (*Meandrina* sp), fungus coral (*Mycetophyllia* sp), grooved brain coral (*Colpolphyllia natans*), elliptical star coral (*Dichocoenia stokesii*) and colonies of staghorn coral (*Acropora cervicornis*) a federally threatened species listed under the Endangered Species Act. There are also numerous branching soft corals at the site, including the sea fan (*Gorgonia flabellum*), and several species of sea rods and sea plumes (*Pseudopterogorgia* sp, *Pterogorgia* sp, *Plexaura* sp, *Plexaurella* sp, *Muricea* sp, *Eunicia* sp).

Biota cover in addition to hard and soft corals includes encrusting and branching sponges and coralline and crustose algae. Many large barrel sponges (*Xestospongia muta*) are scattered throughout the coral community. A large portion of the biota cover includes fleshy algal turf species such as *Dictyota* sp. among others. Benthic invertebrates were also observed and include numerous urchins, sea cucumbers, mollusks, brittle stars and small crustaceans.

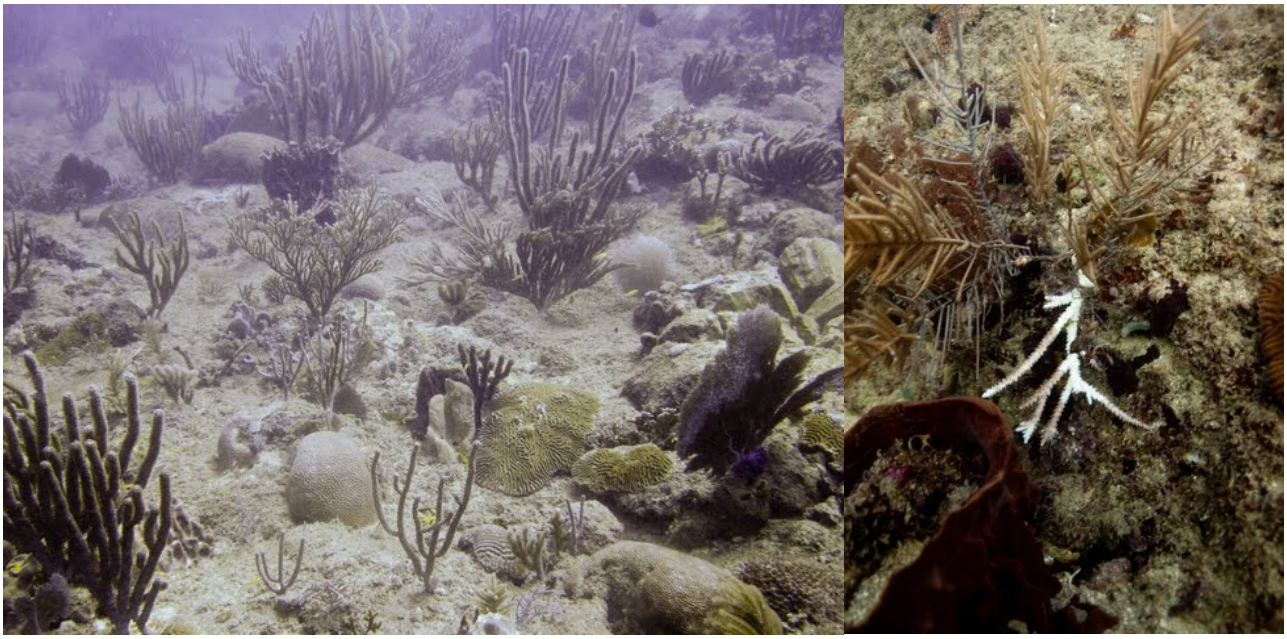

Figure 3. Unaffected hard bottom area showing community composition (left). A sea plume, barrel sponge, and an example of the federally threatened staghorn coral that was broken during the T/V Port Stewart impact and is showing signs of mortality (right).

Preliminary Results

The injured site is variable and includes flat scarring, toppled, broken and crushed rock and corals, scattered rubble, and broken or slumped ledge outcrops (Figure 5). The overall injury boundary of the main scar is estimated to be 512 square meters with the flattened areas scarred by the vessel at approximately 132 square meters or 26 percent (Figure 6). There is substantial bottom paint in chips and infiltrated into cracks and crevices as both soft and hard "plowed" deposits that appear to be pressed into pieces up to several centimeters thick. Although there are not large deposits of rubble, there is considerable rubble in the broken ledges on the outer side of the scar.

A number of large barrel sponges (*Xestospongia muta*) have bleached on the northwest side of the site in the lee of prevailing swells (Figure 5, Figure 6). Bleaching is an expulsion of symbiotic algae which turns many marine organisms white. It may or may not result in fatality. Bleaching in sponges is not well understood. This event is limited to the areas immediately adjacent the vessel impact footprint and appears to become less severe with distance from the grounding site. An unknown pathogen, toxin, warm water, or excessive turbidity could be possible causes but nonetheless it appears to be related to the incident and is being assessed accordingly.

There is a small separate area of injury approximately 200 meters southeast of the main hull impact area originally thought to be tow cable injury (Figure 2). While local tug boat operators report no tow cables used during extraction, the depth and path of vessel are consistent with this injury being caused by an unknown mechanism during vessel extraction. In addition, it is easy to distinguish the relative timing of injury at both sites, which had consistent white limestone coloration indicating very recent injury. The RP will propose to address this area in the Emergency Restoration Plan without prejudice to the RP's position that such damage may not be its responsibility. The RP understands this injury is relatively minor in comparison.

Figure 4. Clockwise from upper left; 1) Flattened "grated" hard bottom with coral rubble and remnant octocorals , 2 Flattened high spot on the hard bottom coral community, 3) Rubble of broken coral and limestone, 4) fractured *Montastrea annularis* colony, 5) broken fragments of staghorn coral *Acropora cervicornis*, 6) Large overturned colony of giant brain coral *Colpophyllia natans*

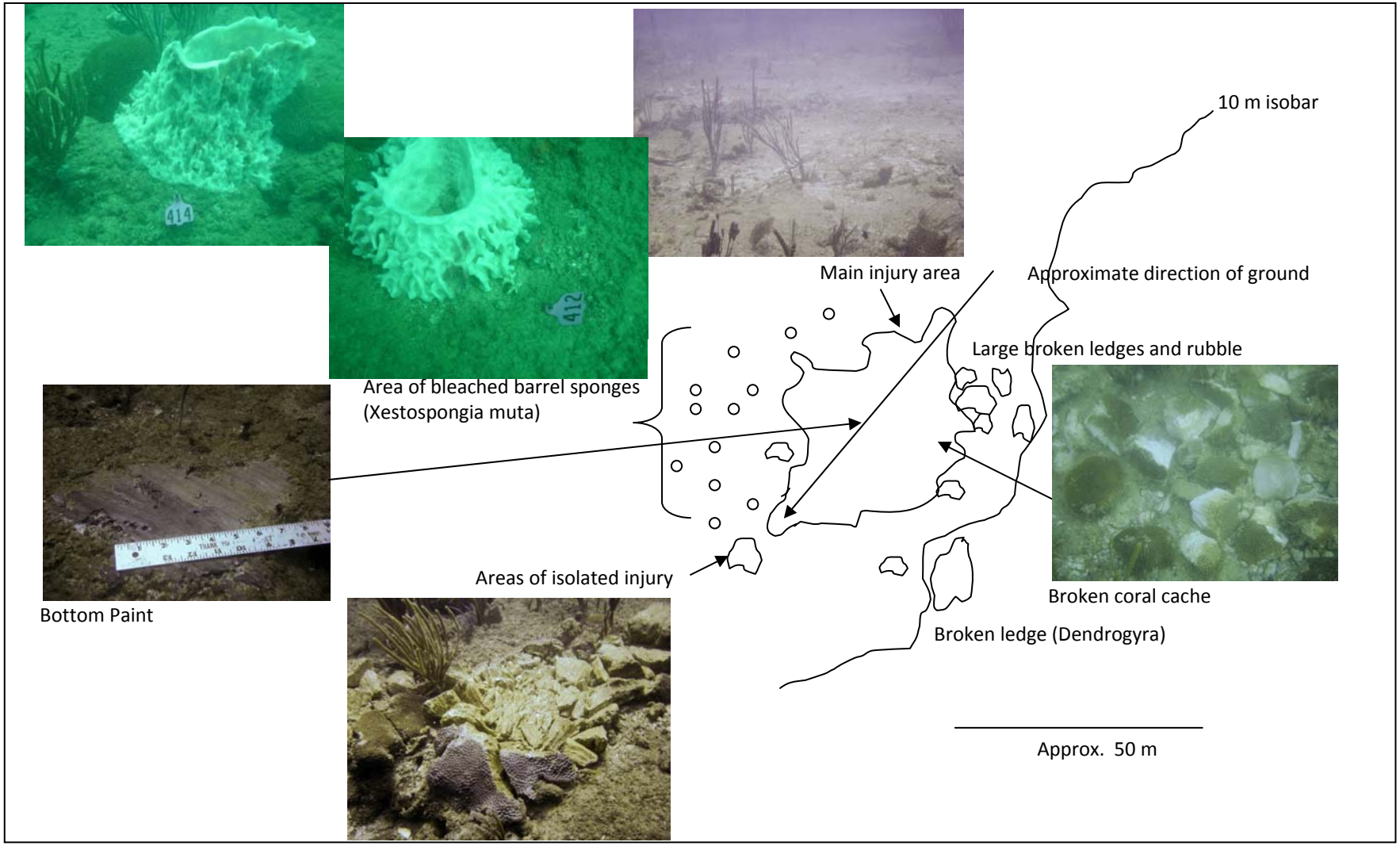

Figure 5. Schematic of injury features, GPS positions are accurate but injury diagram is not to scale and for planning purposes only.

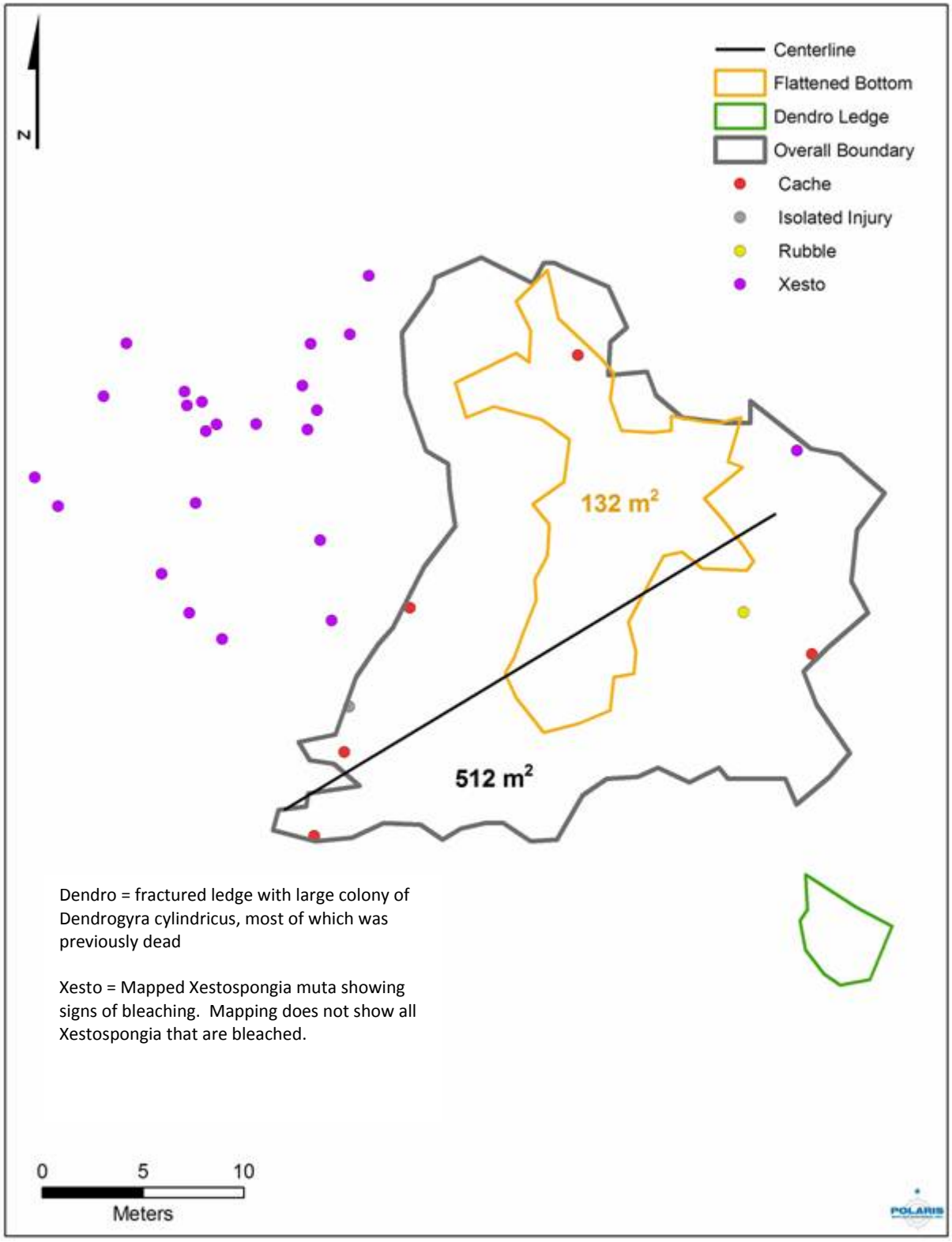

Figure 6. AquaMap of injury area distinguishing scarred areas with broken corals from flattened and fractured areas.

Emergency Restoration

In the aftermath of incidents such as the grounding of the T/V Port Stewart there are two main phases of restoration as part of Natural Resource Damage Assessment under the Commonwealth of Puerto Rico Law for the Protection, Conservation and Management of Puerto Rico Coastal Reefs, (also known as Law #147) and the Oil Pollution Act of 1990 (OPA): primary and compensatory restoration. Primary restoration includes actions necessary to help the site to recover to its former condition. Compensatory restoration includes actions to compensate for lost ecological services until the site recovers to its former condition. Emergency restoration is a form of primary restoration. It is often undertaken in the immediate aftermath of an incident to minimize or prevent ongoing losses and harm to the reef. It is our goal to present and implement a comprehensive emergency restoration strategy. If successful, this strategy is likely to eliminate the need for additional primary restoration at the site. Compensatory restoration will subsequently be developed to address outstanding service losses.

The Proposed Emergency Restoration Plan addresses the following risks to benthic biota:

1) Dislodged or unstable substratum and corals that may be moved by wave action, posing the risk of physical impacts to corals and other benthic biota.

2) Dislodged corals and other biota, themselves, that could be further harmed if moved by wave action, overturned, or buried.

3) Potential toxic effects of bottom paint

4) Structural injuries and lost relief from the flattening effect of the hull, and

5) Injuries to the threatened staghorn coral *(Acropora cervicornis)*

The following are specifications for emergency restoration that we have prepared for the contractor. These actions are proposed to prevent ongoing harm to the reef habitat, in particular to prevent on-going loss of established corals. These actions are also proposed to reduce the magnitude and duration of injury at the site and to promote natural recovery.

<u>Emergency Restoration Tasks</u>

1. Rescuing detached hard and soft corals.

   Collect and store as many re-attachable coral fragments as can be located. This is defined as corals or coral tissue of a size that can be easily manipulated by divers and is in good condition. This is generally a size of greater than 10 centimeters. Smaller corals will be re-attached if in good condition. Small fragments in less than good condition generally have a very low survival rate. Good condition refers to dislodged coral with a large portion of the tissue intact, and sponges and soft corals dislodged with basal structures intact.

   Status: Completed In November 2009

2. Remove Bottom Paint.

Remove and dispose of gross bottom paint contamination. Manually remove large deposits by hand with scraping tools. Small paint fleck accumulations will be either removed by a SCUBA Epibenthic Sampler (small handheld suction device with collection bag) or will be capped under cement and rubble. Opportunistic removal of bottom paint will be ongoing during all activities.

Status: Approximately 75% complete

Performance: Paint is variable in its form and difficulty in extraction. It exists as dust, fragments, chips and clumps and is found in the open, crevices, and wedged intermittently in skeletal coral polyps and is not easily definable in quantitative means. Most of the easily removed bulk paint has been cleaned from the site. Remaining paint residues will be removed to the extent practicable as long as the return on the effort produces a waste stream.

3. Restore site rugosity with limestone boulder rubble.

Loose limestone rubble with limited attached soft or hard coral growth will be gathered and used to re-establish the general site topography and stability and to reduce the potential for additional injury (Figure 7). Large pieces of limestone rubble > 15 centimeters and occasionally a meter across will be used to enhance site complexity in the flattened areas. Concentrations of smaller (<15 cm) dead corals and limestone rubble will be incorporated into reef structures when possible but these and smaller pieces are limited in abundance.. Areas of re-attachment will be the main scar area (Figure 5) Boulder and cement placement will avoid covering existing live biota. An additional 15 yards of limerock will be incorporated to enhance the reef relief. The structures will be arranged to present a variety of sizes and shapes (Figure 8) with special consideration of the following:

- Structures should be close to the existing edges at some point since it appears to aid recruitment and recovery at other sites (edge effect).
- Minimum sizes of approximately 2 square meters will ensure structures are resistant to movement in swells. One cubic yard of reef limestone weighs approximately 1 US ton. We expect most structures to weigh over one half ton. Although weight is especially important when re-attaching materials to an unstable bottom, the purchase to the bottom is most important as demonstrated by many small items attached naturally at the site. We anticipate both large and small attachments at the site as not all corals will be attached to a large structure and some may be attached alone or in smaller groups. Proper cementation to a stable sea floor is as effective as mass in terms of ensuring stability.
- Increased sheer force resistance will be accomplished by placing cut-nails or rebar into the subsurface prior to cementation.

Status: Incomplete

Performance

In order to evaluate the successful restoration of reef structure following emergency restoration, data will be collected to compare reef structure in the restored impact with reference areas adjacent to the impacted site. Data collection will consist of a minimum of 5 – 10 transects in both the restored impact area and adjacent reference areas. Transects of approximately 50m will be used to record traditional rugosity measurements (chain method) as well as the highest structure and lowest depth from the seafloor within a belt transect as described below. It is expected that the data will be collected on one or two dives timed to occur as emergency restoration work is nearing completion.

Replicate rugosity measurements for each transect will be recorded at three random starting locations along each 50m transect using a 10 meter chain by laying the chain along the natural contours of the seafloor. The three replicates will be averaged and then combined with the other transects for an overall average rugosity. Transect locations will follow depth contours and not include any reef sand depressions as they did not occur in the impacted area. Locations will be chosen jointly by the Trustees and RP. Average structure differential or distance between the lowest and highest part of seafloor (including stony corals) will also be recorded along the transect in the following manner. The transect will be broken up into 5 meter increments. The belt transect will consist of 1 m on either side of the transect tape thereby creating ten 2m x 5m blocks along the length of the transect. Measurements will be taken in each increment along the transect. The target values for rugosity and structure differential will be established after the data for reference areas has been established. The goal of the restoration is to establish structure with rugosity and structure differentials similar to that of the reference. Target rugosity and structure differentials are likely to be established within 10% - 20% of the average reference value..

While emergency restoration work is ongoing, preliminary rugosity and structure differential measurements will be taken at the site to determine if the completed work is likely to meet target rugosity and structure differential targets. If targets are unlikely to be met with the current amount of material and both parties agree that additional limerock is necessary, the additional material will be brought in and incorporated into the emergency restoration. At the completion of the placement of on-site rubble and limerock, the Trustees and RP will perform a final site inspection and collect final transect data to ensure that the emergency restoration has met the established rugosity and structural differential targets demonstrating the sufficiency of the emergency restoration work in reestablishing reef structure.

To evaluate the continued success of the emergency restoration actions on restoring site structure, follow-up monitoring will occur. Structures are expected to remain intact and corrective action will be necessary if substantial loss of reattached material (approximately 10% or more) occurs or if dislodged or failing structures are likely to cause ancillary damage to the restored area or to adjacent reef.

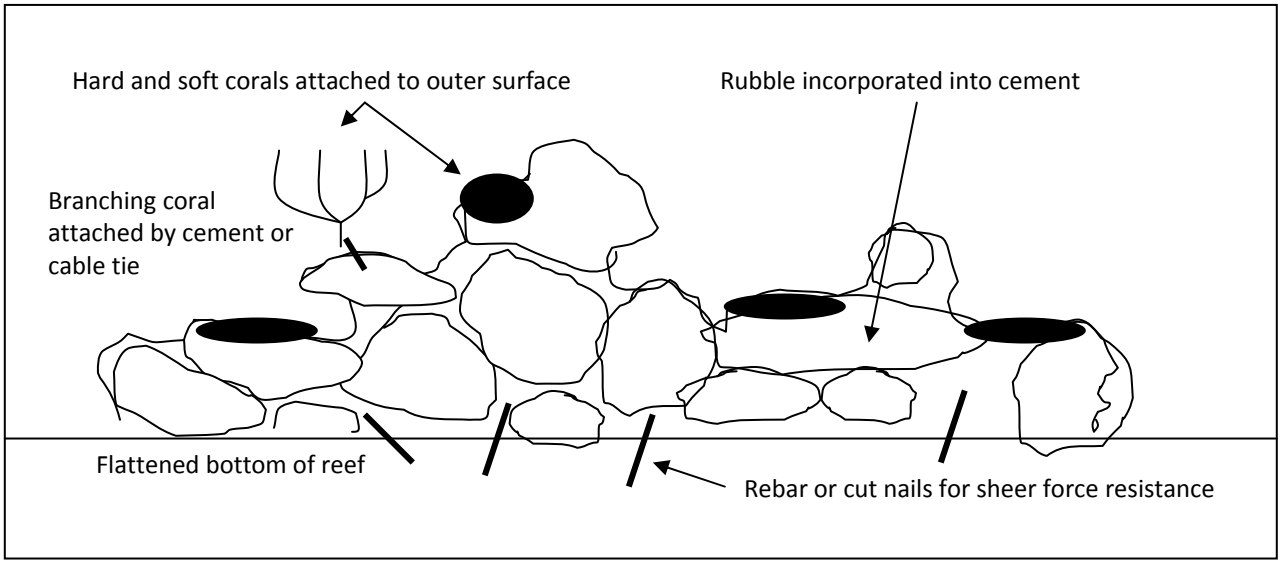

Figure 7. Schematic of rubble/concrete and coral structure.

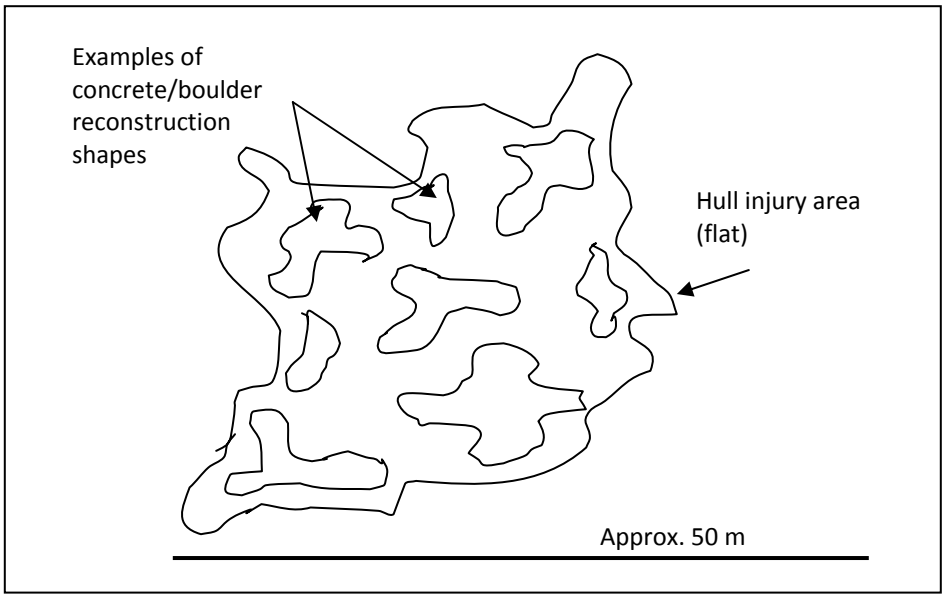

Figure 8. Schematic overview of proposed primary restoration area.

4. Reattach (i.e., cement to substratum) corals following site stabilization and re-attachment of structural features discussed below.

Biota will be re-attached to the bottom in areas that are stable such that re-attachment does not disturb other biota. For live corals, we propose the majority of re-attachment within the main scar area following stabilization of other rubble and creation of structural relief. Corals will be re-attached in groupings on structures but sufficiently apart from one another to allow growth and minimize competition.

Surface preparation will include “cleaning” algae from the limestone substratum and underside of object being re-attached such that cement re-attachment will not fail (Figure 8). Wire brushes will be used to clear the surface of algae. All reef surfaces for re-attachment will include previously injured areas with clear and stable surfaces.

Corals and other biota will be re-attached with Portland (Type II Marine if available) cement with a 50% mix of clean sand. The cement will be mixed on the vessel to a thick consistency to avoid dissolution and sedimentation underwater. Cement will be placed in 5-gallon buckets with lids and lowered carefully to the bottom directly over the work site. Smaller corals may be also attached utilizing a two part underwater epoxy.

Approximately 70 colonies of Acropora cervicornis were impacted and are currently being temporarily held in floating underwater coral arrays. Once all other on-site restoration is complete and *A.cervicornis* corals have had time to heal lesions and/or grow to a transplantable size they will be transplanted into the restoration site under the direction of trustee representatives. Trustee representatives will evaluate reattachment options with the RP representative to determine the best method and location for transplant. Options may include securing the corals with two-part underwater epoxy and/or placing rebar or cut-nails into the cement such that it protrudes sufficiently to attach a colony via a cable-tie or suitable means to avoid movement and abrasion. Based on the success of the current line nurseries, if the environmental parameters at the site are determined to be adequate for successful nursery operations, another cycle of *A. cervicornis* fragmentation, grow out, and transplantation will be performed prior to 2010 hurricane season. Fragmentation and transplantation can occur in February after emergency restoration is complete. The next generation of fragments will be grown out on the line nurseries for 5-6 months. A second transplantation of *A.cervicornis* colonies from the line nurseries to the site can then be performed in May/June.

No material other than the minimum amount of cement and/or epoxy to secure a fast position will be deposited on-site.

Status: Incomplete

Figure 8. 1) Collecting corals. 2) Preparing the surface. 3) Pouring cement. 4) Re-attached group of corals.

Performance: A subset of re-attached corals will be marked for monitoring in consultation with the trustees.

5. Minimizing additional harm to the habitat

All work will be done in a manner to minimize collateral impacts to the surviving biota and habitat structure. This includes care in placement of anchors, vessel operations, diver operations, and placement of materials during removal and disposal. Trustee supervisors may change any activities that they determine to be posing unacceptable risks to the environment in the operations area.

6. Trustee/Biologist supervision

The trustees have requested that at least one scientist be onboard during all restoration activities. The scientist may be Polaris, NOAA, PRDNER, or a Sea Ventures' biologist.

Updates will be provided to the Trustee representatives upon request. Following completion of work, a Trustee diver biologist will conduct a site inspection. Trustee supervisors will discuss any changes with the RP representatives. Agreed upon changes will be incorporated into the work plan with contractors in an expeditious manner.

Potential Additional Actions

The trustees have suggested that there are some dislodged corals from another grounding of a vessel where restoration would have to be funded by the government. These corals are 1 mile from the grounding site and are on the way from the vessel moorage. We propose they be transported to the site for re-attachment to reduce coral cover recovery time. The RP will propose to conduct this work without prejudice to the RP's position that such damage is not its responsibility.

Post-Restoration Assessment

The assessment of service loss and gains assumes that structure and biota provide similar levels of the overall reef service. Measures of structural relief will be completed as discussed above in item 3 under Emergency Restoration Tasks. The biota component of service will be estimated by using the previously collected reference transect data from surrounding areas to estimate the abundance and size distribution of biota that were impacted. After taking into account survival of reattached biota in the injury area, the total surviving reattached corals will be subtracted from the estimates of total impacted corals to quantify the remaining loss of biological resources. Recovery rates will be determined at a later date and will be based on the estimated return of the site to similar biota cover based on growth estimates and other relevant data. Survival of *Xestospongia* that have bleached will also be recorded. The trustees have marked in excess of 84 sponges seemingly affected by the grounding.

Schedule

Initiate Coral Triage – Complete
Remove Bottom Paint – 75% complete
Cement coral and rubble – Present to December 12. Contractor not available again until mid-January.
Re-Attach Coral – January 2010
Restoration Assessment, Credit, and Compensatory Restoration Planing – March-May 2010

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