EMERGENCY RESPONSE PROTOCOL FOR THE ATTENTION TO REEFS DAMAGED FROM POTENTIAL SHIP GROUNDINGS AND MARITIME ARTIFACTS

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COMISIÓN CENTROAMERICANA DE AMBIENTE Y DESARROLLO

EMERGENCY RESPONSE PROTOCOL
FOR THE ATTENTION TO REEFS DAMAGED FROM POTENTIAL SHIP GROUNDINGS AND MARITIME ARTIFACTS.

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PREFACE

This regional protocol was prepared for the Mesoamerican Reef Region using various sources and documents, including real-world grounding and reef restoration experience. Also, the document *Manual Coordinador de Procedimientos Ambientales, Administrativos y Legales para la Atención Inmediata a los Arrecifes por Encallamientos* (SEMARNAT 2009) elaborated for Mexico, provided the main foundation for the direction and layout of this protocol.

The purpose of this document is to provide reef managers with the main actions to take to repair the coral reef after damage caused by potential ship groundings or impacts caused by other maritime artifacts.

Not all responsible authorities are listed, as there may be others with different roles and responsibilities, which can vary over time. However, *Appendix A – Responsible Authorities* lists the focal authorities for emergency response. Additional regulations and key authorities with responsibilities relating to vessel groundings, coral impacts and restoration, and legal actions are listed in the document *Identification of applicable legislation for the restoration of reefs in the four countries of the Mesoamerican Reef System and recommendations for a viable legislation to local and regional levels* (Pavón 2019), which can be found on the MAR Fund website.[1]

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[1] www.marfund.org

ACRONYMS

AFS	Antifouling System
AGRRA	Atlantic and Gulf Reef Rapid Assessment
AIS	Automatic Identification System (sistema de identificación automática)
BNCG	Belize National Coast Guard
BPA	Belize Port Authority
CCAD	Central American Commission for Environment and Development
CoC	Chain of Custody
COCATRAM	Central American Maritime Transport Commission
CONANP	National Commission of Natural Protected Areas
CONAP	National Council of Protected Areas
CSI	Crime Scene Investigation (Escena del Crimen)
DiBio	Dirección General de Biodiversidad
Fondo SAM	Fondo para el Sistema Arrecifal Mesoamericano
GIS	Geographic Information System
GPS	Global Position System
ICF	National Institute of Forest Conservation and Development, Protected Areas and Wildlife
IMO	International Maritime Organization
LADS	Laser Airborne Depth Sounder
LIDAR	Laser Imaging, Detection and Ranging
MAR	Mesoamerican Reef
MAR Fund	Mesoamerican Reef Fund
MARN	Ministry of the Environment and Natural Resources
NEBA	Net Environmental Benefit Analysis
NEMO	National Emergency Management
RP	Responsible Party
SEMARNAT	Secretariat of the Environment and Natural Resources
SMP	Synoptic Monitoring Program
UAV	Unmanned Aerial Vehicle

QUICK ACTION GUIDE

INCIDENT – VESSEL RUNS AGROUND OR IMPACTS REEF

INITIAL RESPONSE AND ASSESSMENT (SECTION 3)

EMERGENCY ACTIONS (SECTION 3.1)

Step 1. Identify any potentially dangerous situations and contact the appropriate agency.

Step 2. Provide medical assistance, if necessary.

Step 3. Observe and gather as much information as possible regarding the incident.

INITIAL INCIDENT REPORT (SECTION 3.2)

Step 1. Complete the initial incident report based on observations, discussions with others, interviews, and *in-situ* measurements.

Step 2. Submit the initial incident report to proper authorities.

Step 3. Submit the initial incident report to regional contacts.

ASSIGNING BIOLOGICAL PRIORITIES OR TRIAGE (SECTION 3.3)

Step 1. Turn dislodged corals so their polyps face upwards.

Step 2. Place corals in a protected area: in baskets, plastic boxes, or sediment-free reef depressions.

Step 3. Avoid placing corals in sandy areas.

Step 4. Record numbers, types and locations of triaged organisms.

VESSEL SALVAGE CONSIDERATIONS (SECTION 3.4)

- ☐ Conduct pre-removal survey to identify the preferred extraction route.
- ☐ Use floating tow lines.
- ☐ Towing activities should be carried out during high tide.
- ☐ Avoid the use of the stranded propeller and rudder of the vessel.
- ☐ Track the movement of the bow and stern of the stranded vessel to identify areas for further assessment.
- ☐ Avoid the discharge of bilge and cooling water.

COLLECTION OF EVIDENCE & CRIME SCENE INVESTIGATION (SECTION 3.5)

Step 1. Document evidence: location, depth, temperature, date, and collector's name.

Step 2. Photograph evidence and surrounding habitat before and after collection.

Step 3. Transfer information to a chain of custody (CoC) form.

Step 4. Place each piece of evidence in a separate bag or container.

Step 5. Photograph the evidence bag and CoC form.

Step 6. Store evidence and CoC form in a secure location.

DETAILED ASSESSMENT AND EVALUATION (SECTION 4)

ASSESSMENT OF PHYSICAL IMPACTS (SECTION 4.1)

Step 1. Assessment of physical impacts:

- detailed assessment of the extent and severity of physical impacts to the reef.

VALUATION AND ASSESSMENT OF FUNCTION AND RESOURCE LOSS (SECTION 4.2)

Step 2. Valuation and assessment of function and resource loss:

- coral cover, coral density, classes of coral size, species diversity,
- rugosity,
- and restoration potential.

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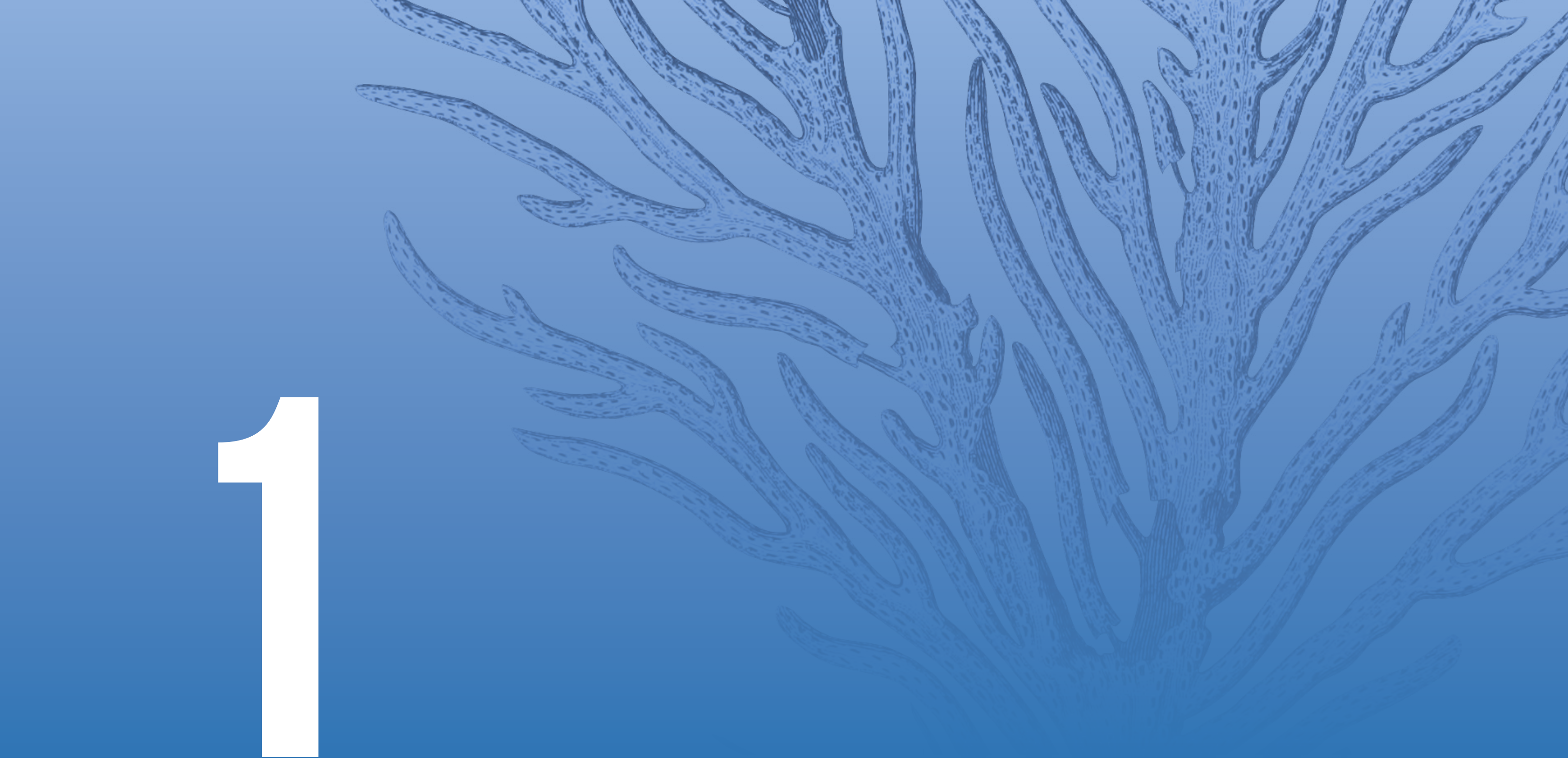
LONG-TERM MONITORING (SECTION 6.2)



1 INTRODUCTION

1.1 PURPOSE OF DOCUMENT

This document is intended to be a unified protocol for the Mesoamerican Reef (MAR) region to respond to reef damage from vessels or other marine artifacts. This protocol identifies standard procedures and recommended approaches for assessment, documentation, and restoration of damaged coral reefs, resulting from vessel groundings and other severe physical damage. This document describes the necessary actions to minimize damage during an emergency response, assessment protocols, and possible restoration mechanisms. The intended users of the protocol include government agencies, ship interests/representatives (responsible party), and participating stakeholders.

The document does not address the assessment or the applicability of fines or penalties. Additional information and key authorities with responsibilities related to fines, penalties, and legal actions are listed in the *Identification of applicable legislation for the restoration of reefs in the four countries of the Mesoamerican Reef System and recommendations for a viable legislation to local and regional levels* (Pavón 2019), available at the MAR Fund website.

1.2 MESOAMERICAN REEF SYSTEM (MAR)

1.2.1 Description and importance to the region

The Mesoamerican Reef System (MAR) is a contiguous coral reef ecosystem stretching approximately 1,000 km from the tip of the Yucatan

Peninsula in Mexico to the Bay Islands of Honduras and running across the countries of Belize and Guatemala (Figure 1). It is the largest coral reef system in the Atlantic Ocean and includes over sixty protected natural areas that preserve the region's biodiversity and provide critical feeding, nesting, and nursery habitats for many species of ecological and commercial importance, as well as those threatened or endangered.

The MAR contributes to stabilizing and protecting the coastal landscape, maintains the quality of coastal waters, and constitutes a feeding and breeding ground for marine mammals, reptiles, fish, and invertebrates, many of which are commercially important. The MAR has high socioeconomic importance because it provides employment and represents a source of income for approximately one million persons living in adjacent coastal areas (Mesoamerican Barrier Reef Systems Project 2004).

MAR Fund, Healthy Reefs Initiative

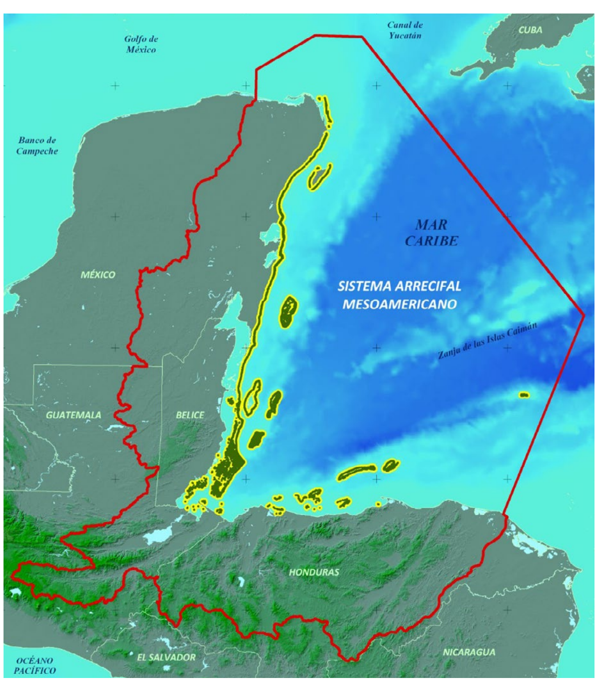


Figure 1. Mesoamerican Reef Region.

1.2.2 Tulum Agreement

On June 5, 1997, in the City of Tulum, Quintana Roo, Mexico, the presidents of Mexico, Guatemala, Honduras, and the Prime Minister of Belize signed an agreement known as the Tulum Declaration. This agreement promoted the conservation of the MAR through its sustainable use, the establishment of work collaborations between authorities, and the development of cooperation programs and projects, setting a historical precedent in conservation matters. In the spirit of said agreement, this Response Protocol has been developed to provide a common regional approach to assess and mitigate vessel-related impacts to the MAR.

1.3 VESSEL GROUNDINGS

When a vessel strikes or runs aground and must be refloated or removed from a coral reef, there are different types of impacts that cause an array of damaging effects. These include:

Physical damage to the reef structure

- **Crushed, broken, and fractured corals.** Corals and other organisms are physically damaged (Figure 2).
- **Rubble berms and piles.** Damaged corals and reef rubble can be formed into berms and piles, which can cover and smother other organisms (Figure 3).
- **Scarred and flattened areas.** Reef areas and upper layers of the substrate can be partially or completely scraped clean of organisms (Figure 4).

- **Propeller scour.** The use of propellers either on the grounded vessel or salvage support vessels can dislodge organisms and displace sand and sediment.

- **Fractured substrate.** Reef structure can be broken off and fractured (Figure 5).

- **Sedimentation.** Fine limestone sediment can form due to vessel contact onto the reef, which can cover and smother organisms and remain unstable for a long time (Figure 6).

- **Anchor and cable damage.** Anchor and/or chain or salvage support vessels and cables for towing can scrape or scar the reef substrate and dislodge organisms (Figure 7).

Hull paint deposition. Antifouling hull paint designed to be toxic to marine organisms can be scraped off the vessel and deposited on the reef as paint chips or fine particulate material (Figure 8).

Oil/hazardous materials. Potentially hazardous cargo or fuel oil may be accidentally spilled from the vessel into the environment.

Man-made debris. A variety of debris and garbage may be lost from a vessel resulting in additional impacts on the reef (Figure 9).

Ballast water release. Ballast water poses the risk of potentially introducing invasive species or diseases that can have long-term implications for coral reefs and other organisms.

Bilgewater release. Bilgewater may contain hydrocarbons or other chemicals, presenting a hazard to coral reefs and other organisms if released. The International Maritime Organization (IMO) has strict guidelines of hydrocarbon concentration in any intentionally discharged bilgewater.

Figure 2. Fractured coral head.

Figure 3. Broken reef substrate and corals can be piled into rubble berms.

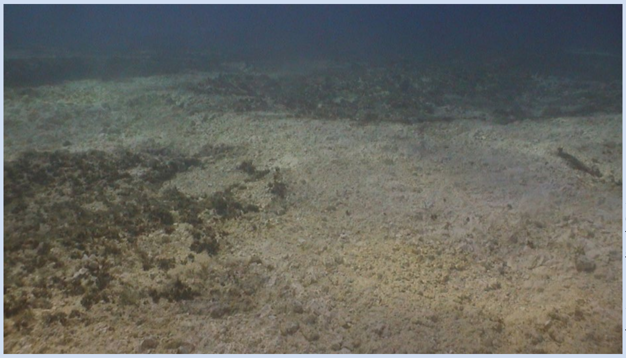


Figure 4. Scarred reef top.

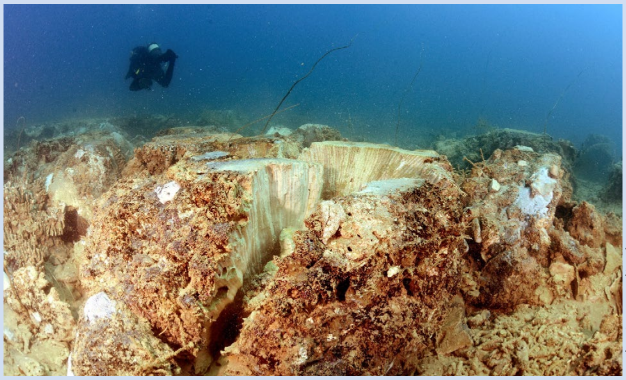


Figure 5. Fractured substrate.


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Figure 6. Sedimentation can cause fine sediments to bury live and undamaged coral.


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Figure 7. Tow cables can scar the reef substrate and dislodge organisms.

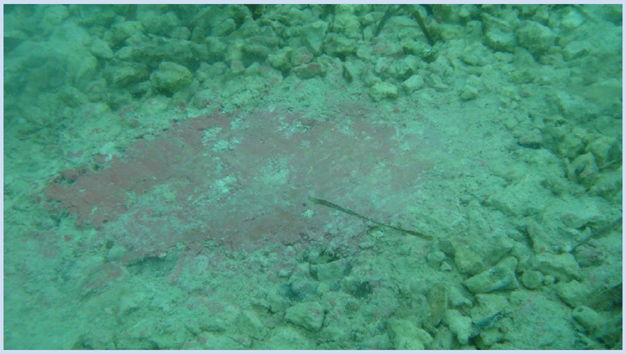
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Figure 8. Hull paint deposited on substrate.


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Figure 9. Debris from the stranded or salvage vessel can be deposited on the reef.

Coral bleaching. If a vessel is aground for an extended period, the shade, increased heat near the hull from internal equipment, or other stressors may cause corals to expel their symbiotic algae and "bleach."

1.3.1 Vessel impacts on the MAR region

There have been several recorded groundings and impacts on reefs caused by vessels in all four of the MAR countries over the years. These incidents have been caused by vessels ranging from small pleasure crafts to large container vessels. Reef restoration has occurred as a result of some of these incidents. It is recommended to develop and maintain a centralized database for documentation and tracking purposes of reef incidents in the MAR, the resulting restoration, assessments, and any other activities that are ultimately carried out. MAR Fund, or COCATRAM, is a logical organization for maintaining and organizing this data repository. A database allows the MAR region to establish a record of precedent and track accomplishments and concerns in order to improve the effectiveness of the program over time.

2

PROTOCOL OVERVIEW

This regional protocol is a recommended guide to assessing, documenting, and restoring damaged coral reefs during the emergency response phase of a vessel grounding incident (or from other marine artifacts). These recommendations are designed to be flexible to provide room for modifications in the field, depending on the extent and severity of each incident. Potential Authority and Responsible Party (RP) actions and responsibilities are discussed in each section. The document workflow follows the initial response and incident assessment, the detailed assessment process to help determine restoration, recommended primary restoration actions, and post-restoration considerations (Figure 10).

Some incidents may not have an identified RP, and the appropriate environmental agency may end up being responsible for the funding, assessment, and potential restoration. For those incidents that do have an RP, early engagement and participation with the RP can be critical for an efficient and effective response. Communication and cooperation with the RP facilitate a mutual agreement on several issues covered in this protocol, including salvage considerations, triage, detailed assessment and evaluation, restoration planning, and post-restoration activities. Since the RP may be responsible for the funding and staffing for these activities, cooperating and participating with the RP can contribute to a potentially quicker access to funds, agreement on impacts and next steps, and ultimately a more effective response and restoration following the incident. Delaying or dismissing the RP's involvement in assessment activities hinders their opportunity to mitigate damages. This limitation potentially leaves agencies and the government open to legal challenges, difficulties, or delays in obtaining reimbursement for response activities. Cooperation should also be the preferred approach of the RP. In addition to promoting understanding and agreement, cooperation efforts reduce effort, expenses of competing assessment teams, and ensuing discussions. Thus, it shortens the time between the incident and an active reef restoration.

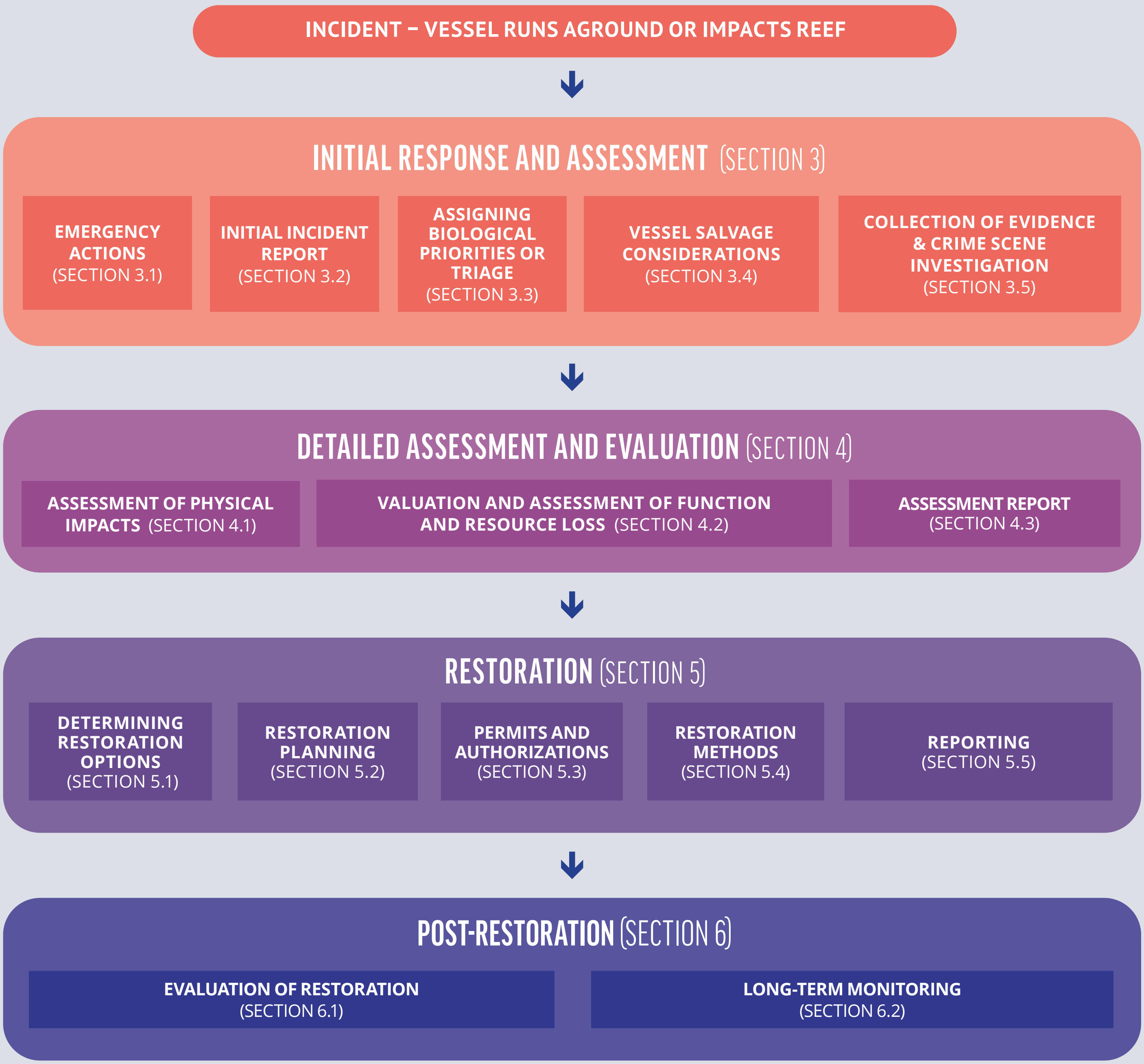

Figure 10. Regional Protocol workflow.

3

INITIAL RESPONSE AND ASSESSMENT

The representatives of the agency or agencies first involved in the protection of reef ecosystems (*Appendix A – Responsible Authorities*) that arrive at a grounding site should secure the scene, if necessary, and begin to gather the information required to develop an initial incident report. In addition to guaranteeing the immediate safety of all the people in the area and minimizing additional damage to natural resources, it is essential to avoid contamination and disturbance of physical evidence as much as possible to preserve the scene. Response authorities may not allow the investigation to run until the safety of the site has been secured. Refloating of the vessel and salvage operations can be dangerous, for which it is important to involve technical experts with the maritime authorities.

3.1 EMERGENCY ACTIONS

STEP 1.	Identify any potentially dangerous situations and contact the appropriate agency.
STEP 2.	Provide medical assistance, if necessary.
STEP 3.	Observe and gather as much information as possible regarding the incident.

The safety and physical well-being of everyone around the impact scene and the surroundings is a priority. This requires the identification of any potentially dangerous situations by examining the area for visible particularities, sounds, or smells, and ensuring there is no immediate threat to others responding to the event (i.e., hazardous or toxic chemicals, flammable material, unsafe structures, etc.). If the situation involves a potentially dangerous situation, immediate superiors should be notified, and appropriate agency personnel should be contacted before entering the scene.

Once any potentially dangerous situations are solved, the next step is to ensure that medical assistance is provided to any injured personnel while minimizing the contamination of the scene. Medical personnel should be informed of any potential physical evidence and instructed to minimize having contact with the evidence.

When the scene is safe and those requiring medical attention have been taken care of, the appropriate authority representatives should approach and enter the grounding scene promptly yet cautiously. At this point, representatives must be diligent observers and gather and document as much information as possible from the beginning:

- Any persons and vessels on-site or leaving the scene.
- Any items removed from or brought to the scene.
- Conversations with witnesses, victims, and/or suspects in the area.
- Any additional incidents in the vicinity that may be related to the potential grounding site.
- Photographs and/or videos with corresponding observations when arriving at the scene and both above and underwater assessments.
- GPS locations of vessels and environmental impacts.

This information can be used afterwards for the initial incident report.

3.2 INITIAL INCIDENT REPORT

STEP 1. Complete the initial incident report based on observations, discussions with others, interviews, and *in-situ* measurements.

STEP 2. Submit the initial incident report to proper authorities.

STEP 3. Submit the initial incident report to regional contacts.

Details are critically important when reporting an incident; however, a lack of detail should not prevent the authorities from reporting. Below is a list of the types of information that can help law enforcement when reporting an incident (see *Appendix B - Example Initial Incident Report Template*):

- What type of incident is reported? The stranding of a vessel, damage caused by an anchor, the presence of damage of unknown, immediate cause, etc.
- An estimate of the extent of physical impacts to the reef should be made, along with an initial indication of potential damage to natural resources. These estimates are not intended to be used as final damage estimates but only as an indication of the damage to areas and resources and to provide guidance and enable preparation for a more detailed assessment (Section 4).
- If possible, the perimeter of the impact site(s) should be delineated using Geographic Positioning System (GPS) points taken at the

outer limits of the impacted area. Data on changes in depth, bottom type, and habitat composition should be included. Referenced photographs of all impacts observed in the background and habitat structure should be obtained. Additionally, locations of potential entry and exit of suspects, witnesses, and elements of the incident should be documented, along with potential sites from which evidence or resources may have been removed.

- If the event involves a vessel, specific data must be reported, such as the vessel's name, IMO (or license) number, type of vessel, brand, model, color, dimensions, and any other characteristics that may contribute to its identification.
- The heading and location of the vessel and whether it is hard aground or continues to move in waves and swells.
- Other environmental impacts related to reef, substrate, and seagrass damage, such as oil spills or other substances.
- If the incident involves a vessel and it is still on the scene, is the operator making efforts to release it, take any other corrective action, or leave the scene? Attempting to release the vessel may cause substantially more damage and should be carefully considered.
- If the person reporting the incident has contacted other agencies or represents other agencies.
- Contact information of the person reporting the incident (useful but not essential).
- Visual documentation of the incident and reef impacts (photographs, videos, sketches).

Be aware of the presence of evidence (see Section 3.5) while evaluating the initial scene of impact. Control of the impact scene must be handed over to the investigator-in-charge along with a detailed report. This will help control the crime scene and establish additional investigative responsibilities.

Once the initial incident report has been provided to the proper authorities, a copy should be shared with regional contacts in the MAR region (if possible and under legal advice). This would enable a consistent tracking of incidents and could provide support and suggestions from counterparts across the region. An entity designated to maintain a database will be helpful to minimize disagreements on how future cases are handled if an effective precedent is established. MAR Fund or COCATRAM is a logical repository for maintaining and organizing these reports and disseminating information to the regional counterparts.

3.3 ASSIGNING BIOLOGICAL PRIORITIES OR TRIAGE

STEP 1.	Turn dislodged corals so their polyps face upwards.
STEP 2.	Place corals in a protected area: baskets, plastic boxes, or sediment-free depressions in the reef.
STEP 3.	Avoid placing corals in sandy areas.
STEP 4.	Record numbers, types and locations of triaged organisms.

The purpose of assigning biological priorities or triage is to prevent the imminent loss of organisms at risk from the incident. This process

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Figure 11. Triaged corals have been turned upright and placed in a secure location for later reattachment.

can be carried out simultaneously with the initial assessment of the scene, or later during more detailed surveys and assessments. It should consist of saving as many relevant biotic resources as possible. Triage should be coordinated so that it does not interfere with evidence collection.

Triage must be carried out as soon as possible after an incident. Overturned, detached, or fractured organisms have a limited window of opportunity during which they can be stabilized and reattached successfully. Triage includes placing these organisms in a position or location which allows them to survive until they can be reattached. Corals should be turned over so that their polyps are facing upwards towards the light, without touching other corals or the substrate, and will not move or shift with waves. It is often possible to overturn large coral colonies and place them in their original position so that they remain stable without additional help. However, small colonies and colony fragments can be shifted and moved by currents and wave energy. Small fragments of sponges, octocorals, and hard corals can be placed in baskets, plastic boxes, or other types of containers, or even in shallow holes and/or depressions on the reef for temporary stability and protection (Figure 11).

Care should be taken not to place the baskets, boxes, or corals themselves in sand channels or excessively sandy areas where they can be buried. These should be stored on the existing reef or hard bottom near the impact site. Octocorals and sponges are light and nearly neutrally buoyant and require special care to ensure their safety. Weighted baskets with lids have been used with these types of organisms. These resources are vital during primary restoration and should be collected and sheltered in areas where they are protected as much as possible from additional damage, while assessment and restoration activities are being conducted. Restoration timing must be considered, as it may also play a role in coral triage and temporary storage. If restoration will be performed soon, scientists may choose to leave them close to where the injury occurred to avoid repeatedly handling the coral colonies.

All triage activities should be documented and tracked daily. This includes the numbers and types of organisms collected and stabilized, along with the temporary locations where the organisms are stored.

Debris and rubble should be stabilized or removed from the site as soon as possible to avoid further damage caused by movement due to wave surges or storms. Rapid triage together with rapid primary restoration is critical during a hurricane and seasonal storm events.

3.4 VESSEL SALVAGE CONSIDERATIONS

When a vessel has been involved in an incident that has caused damage to a reef and has been stranded, the Port Authority, Coast Guard, or Navy (Responsible Authorities) may have primary jurisdiction over salvage operations. The RP, however, is generally in charge of retaining the salvage contractor, who will develop plans to be approved by authorities and attempt to remove the vessel (Figure 12). A list of responsible authorities for salvage operations in the region is found in *Appendix A – Responsible Authorities*.

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Figure 12. Tugboats attempting to salvage a stranded liquified petroleum gas carrier.

3.4.1 Environmental considerations for salvage activities

- ☐ Conduct pre-removal survey to identify the preferred extraction route(s).
- ☐ Use floating tow lines.
- ☐ Towing activities should be carried out during high tide.
- ☐ Avoid the use of the stranded propeller and rudder of the vessel.
- ☐ Track the bow and stern of the stranded vessel to identify areas for further assessment.
- ☐ Avoid discharge of bilge and cooling water.

Historically, collateral damage to a reef's resources can occur during vessel removal operations. The movement of the hull is at times inevitable. These damages usually occur in the area surrounding the vessel and can sometimes be avoided using the appropriate salvage techniques. The leading causes of collateral damage include the use of steel cables to tow the stranded vessel, which can come into contact with the reef and break or fracture resources (organisms such as corals, sponges, and structural elements of the reef). Also, the turbulence generated by the propellers of tugs can cause entrained sediments and break or tear organisms.

To avoid or minimize additional damages as a consequence of salvaging the vessel, an underwater survey should be conducted while the vessel is still stranded, if safe and possible. The goal of the survey is to assess the reef and its physical and biological characteristics in the immediate vicinity of the vessel and to help determine the best possible extraction route. If possible, surveys should be conducted jointly with the appropriate authority and with salvage and/or RP environmental representatives for concurrence of observations and agreement of recommendations. If an underwater survey is not possible, bathymetric survey data can help identify potential obstructions.

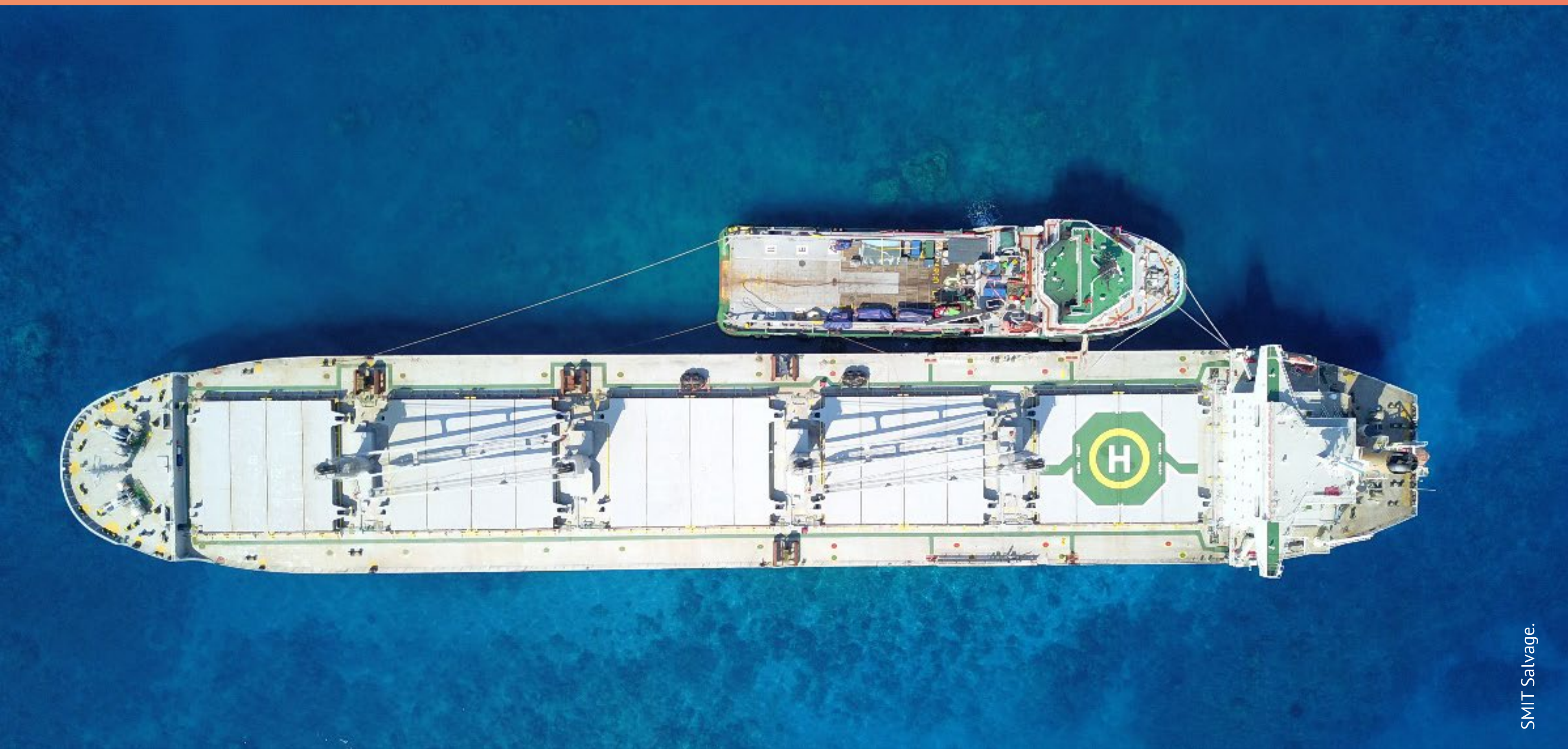

Figure 13. UAV aerial image of a grounded vessel for monitoring vessel location.

Floating lines or towlines provided with floats should be used if available to avoid further damage to the reef. Towing activities should be carried out during high tide. The use of the stranded vessel's propeller and rudder should be avoided while aground and during salvage attempts, as these can cause additional damage to the reef. It is necessary to record the GPS coordinates of the bow and stern of the vessel while aground and during salvage to help identify areas for assessing post-salvage damage. An unmanned aerial vehicle (UAV) can also be used to document vessel location and movement (Figure 13). Avoid or minimize the discharge of bilge and cooling water, if possible. All vessels participating in salvage operations should also be tracked by GPS.

Any response or salvage plans developed should identify and address the meteorological and oceanographic conditions experienced and expected at the incident site.

3.4.2 Net Environmental Benefit Analysis (NEBA) and Alternatives Analysis for vessel removal

While the complete removal of a stranded vessel is usually the preferred outcome for a successful salvage, this may not always be technically feasible, or greater damage to the environment could be caused by the removal than left in place. Many countries are now signatories to the Nairobi Convention or Wreck Removal Convention which calls for the removal of vessels that represent a navigational or environmental hazard. The purpose of a Net Environmental Benefit Analysis (NEBA) is to provide a range and a summary of anticipated effects to decision-makers, including both environmental and socioeconomic components, as they relate to feasible options. The goal is to have a better understanding on which wreck management alternative (complete removal, partial removal, or no-action) will provide the greatest net environmental benefit. A NEBA and Alternatives Analysis should be a collaborative effort between the appropriate governmental agencies, relevant stakeholders, and technical advisors representing the vessel.

3.5 COLLECTION OF EVIDENCE AND CRIME SCENE INVESTIGATION (CSI)

STEP 1.	Document evidence: location, depth, temperature, date, and collector's name.
STEP 2.	Photograph evidence and surrounding habitat before and after collection.
STEP 3.	Transfer information to a chain of custody (CoC) form.
STEP 4.	Place each piece of evidence in a separate bag or container.
STEP 5.	Photograph the evidence bag and CoC form.
STEP 6.	Store evidence and CoC form in a secure location.

Collection of evidence and the subsequent chain of custody (CoC) are critical components for documenting evidence in the event of legal action or disagreement in terms of restoration or settlement. The financial resources spent during the assessment of the grounding incident may not be recoverable, and it will not be possible to hold the RP accountable if the institutions involved do not have the proper evidence. Appropriate documentation relies on evidence that comes only from the use of effective collection techniques.

Before collecting any object from the substrate (whether natural or man-made objects), make sure to have the legal authority to collect it. Additional details regarding authority and CSI permit issuance for the MAR region can be found in CSI CURRENT PROCEDURE (Maddox and Pavón, CSI CURRENT PROCEDURES 2018) on the MAR Fund website.

3.5.1 CSI methods

Before collecting evidence underwater, the collection should be documented by logging the location of the evidence (including depth) at the scene, the date of collection, and the collector's name. Photographs of the evidence and surrounding environment should be taken before and after the collection.

Documentation needs to be transferred to a Chain of Custody form (CoC), either on the water or back at the surface. Once the documentation has been completed, each item identified as evidence should be placed in separate containers, bags, etc. All evidence bags must be photographed, as well as the waterproof chain of custody format. CoC forms should remain with the items, and evidence should be stored in a secure location, making sure to preserve the chain of custody of all items.

Evidence that may be collected after an incident and require a chain of custody includes:

- Man-made objects/debris from the vessel.
- Injured natural resources (reference uninjured natural resources may be sampled as discussed below, but should not be collected).
- A sample of hull paint on the reef and from the vessel.
- Samples of spilled pollutants and source samples on the vessel.
- Vessel logs or automatic identification system (AIS) data. These should not be taken from the vessel and should be copied or photographed if possible.

Not all the evidence above may be available. Evidence that does not require CoC forms includes any coral or injury data collected, photographs, observations, diagrams, GPS data collected, and other information discussed below.

4

DETAILED VALUATION AND ASSESSMENT

STEP 1. Essessment of physical impacts:

- detailed assessment of the extent and severity of physical impacts to the reef.

STEP 2. Valuation and assessment of resource and function loss:

- coral cover, coral density, classes of coral size, species diversity,
- rugosity,
- and restoration potential.

STEP 3. Final report detailing the valuation and assessment.

Once the incident site is safe and secured and the initial assessment has been completed by the proper authorities, detailed physical and biological damage valuation and assessment are required to determine the extent and severity of reef impacts and the loss of resources and their functions. Representatives of the environmental agencies responsible for conservation and management, along with the RP technical advisors, should review the preliminary information collected during the initial scene assessment to determine the limits of the inspection and the most appropriate, expeditious, and accurate methods to assess the damage. The goal of the detailed assessment should be a collaborative effort that can be used to help determine any potential restoration options. The data collected should focus on scaling the injury to appropriate restoration methods.

Planning the detailed assessment relies on the vessel information collected during the emergency response. Proper GPS tracking of the bow and stern, or recordings of GPS position transducer and vessel heading, allows the positions of the hull to be plotted while aground. Salvage or refloat actions can also be plotted to create a proposed survey area to inspect, so no potential damage is missed. Towlines can be quite long, and areas where towing was used should be inspected, including depths greater than the hull draft. Tow cable damage has been observed at depths of 20 meters.

Triage for corals and other organisms at risk can be continued during the detailed assessment. As dislodged corals are observed, they should be quickly righted and stabilized, either in natural reef depressions or baskets/boxes that are already on-site for this purpose.

4.1 ASSESSMENT OF PHYSICAL IMPACTS

Detailed assessment and delineation of the extent of physical impacts to the reef are important to help define the areas for assessment of loss of function and resources (Section 4.2) and identify areas where primary restoration is possible. Measuring scarred areas and adjacent rubble deposits is the key first step in evaluating the restoration effort. While the impact should have been rapidly delineated during the initial incident report, this phase of the assessment entails the detailed mapping of the impact perimeter. It includes defining and documenting the extent, severity, and type of physical injury (e.g., scar, rubble berm, hull paint deposition, etc.) within the impacted area. There are many available methods for the detailed assessment process, and the choice of one or more methods may depend on the site conditions.

4.1.1 Aerial photographs

Aerial photographs taken during low altitude flyovers, either with a manned aircraft (e.g., helicopter, fixed-wing) or UAV, can be an excellent tool for mapping damaged areas (Figure 14). Recent damage at shallow depths (<20 meters depending on water clarity) is easier to observe and map. Imagery is also improved when the sea is calm. Photographs should be taken as low as possible at practical height to achieve sufficient coverage and resolution and must be taken perpendicular to the sea surface. To facilitate accurate damage measurements using GIS, photographs must be orthorectified or scaled. This can be done automatically with some UAV software or by deploying a scale of known distance at the site being photographed (e.g., a vessel, anchored floats set at a distance, etc.). It is necessary to collect information on site with a ground truth approach of the damage seen in aerial photographs.

ARDENT

Figure 14. UAV aerial image taken to help delineate physical impacts.

4.1.2 Bathymetric, acoustic, and remote sensing inspections

Bathymetric inspection can be useful when reef impacts are extensive. When appropriate, bathymetric inspections may be conducted after an impact and completion of restoration work to quantify the structural habitat restoration. Single-beam, multi-beam, LiDAR, LADS bathymetric systems, lateral scanning sonar, and multispectral imaging systems can be used to map larger-scale impacts. Inspection of survey transects should be planned with sufficient overlap to ensure adequate inspection coverage. Smaller, less severely impacted areas may not be accurately captured using these methods. Bathymetric data must be georeferenced with GIS for analysis.

4.1.3 Photogrammetry

Photogrammetry consists of using many overlapping photographs to create a scaled photomosaic, which can then provide accurate measurements of features within the mosaic when analyzed with a GIS (Figure 15). Overlapping underwater photographs facing perpendicular to the seafloor are collected by divers while swimming over transects across the impacted area. There are also remotely operated vehicles that can be programmed to collect images, but diver-collected images are simple and easy at smaller sites. Tape measures or scale bars of known size are placed within the photographed area to allow the photomosaic to be orthorectified or scaled during image processing. Photogrammetry software, such as Agisoft Metashape™, is then used to accurately stitch the photograph together to create the scaled image mosaic. The height of the photographs off the seafloor affects the resolution and the required number of transects and usually needs to be determined on a case-by-case basis for the most efficient data collection. Photographs also require significant overlap (>50%) to be successfully processed.

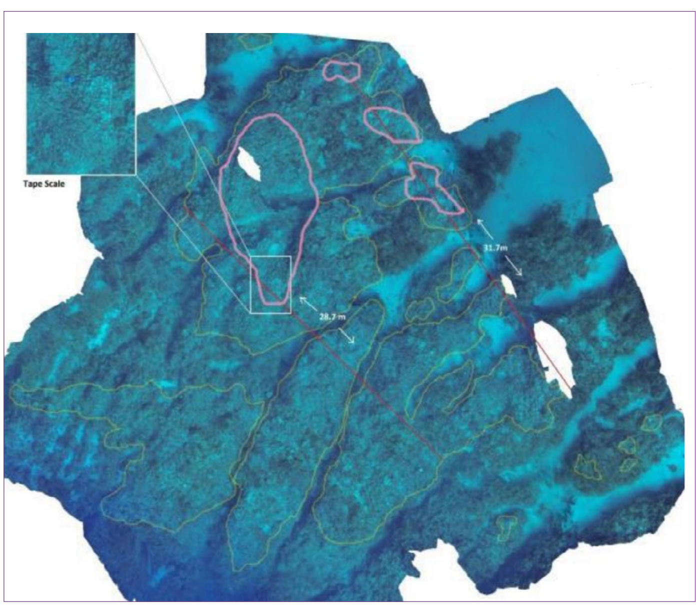

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Figure 15. Orthorectified photomosaic of a reef incident generated to accurately map and delineate impacts.

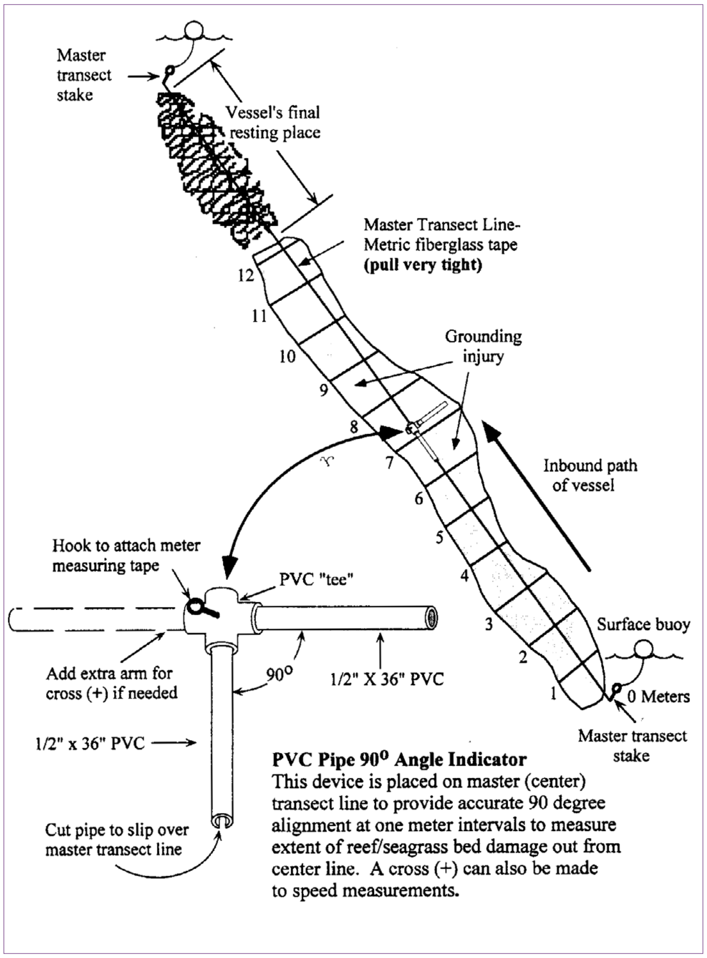
4.1.4 Diver *in-situ* data collection

Aerial photography, bathymetric inspections, and photogrammetry help determine the total area of damage. However, even these methods usually require *in-situ* data collection by divers. Cameras should be used in all cases to document the damage and complement other information collected for evaluation.

Damaged areas can be mapped by divers swimming across the perimeter and dragging a shallow buoy behind them. The buoy should be kept as close as possible to a position above the diver (depth and currents are limiting to achieve this). When the diver requires a position to be recorded, they must submerge the buoy repeatedly at quick intervals to communicate with the diving vessel.

The diving vessel records the GPS location of the buoy. The team of divers and the vessel crew must record the time at which each location of the buoy was marked. This allows the notes recorded by the diver team to be coordinated with the recorded GPS points. A modification of this system may be attaching a GPS to a buoy dragged by the divers' team. The GPS unit with remote control is connected with a cable to the diver. The diver shoots the GPS unit to record the locations. The GPS can also be set on tracking mode to record the entire course. It is also essential that the diving team synchronize the GPS clock with the divers' watch and camera and record the time when each point was set. As long as the time is known precisely on all devices, they can be synchronized. Photograph locations will be aligned with the GPS data by the time stamp.

It is important not only to collect the perimeter of the scarring but the presence of uninjured areas within the scars. Separate scars should be measured individually and not grouped together. Other important notes and positions relative to physical injury include the location of sediment, rubble, or large, fractured reef pieces, and the approximate measurements of rubble deposits. The presence and location of hull paint or debris from the vessel left behind on the reef are also important for planning restoration.



Hudson y Goodwin 2001

Figure 16. Fishbone mapping system.

Another method used to delineate physical impacts is known as the "fishbone mapping system" (Figure 16), first published by J. Hudson and W. Goodwin of the Florida Keys National Marine Sanctuary (Hudson and Goodwin 2001). This method consists of laying out a metric tape (baseline) along the longest axis of the damaged area and laying sampling transect lines running at 2-m intervals, perpendicular to the baseline within the limits of the damaged area. The data is gathered to produce a map and description of the damage. These methods are generally limited to small and medium sites (for example, <150 m^2).

Several commercially available underwater mapping systems can also be used to accurately delineate impact areas. Typically, these systems often use some combination of GPS, sonar, and/or acoustic Doppler for navigation and tracking.

Regardless of which method or methods are used to carry out the assessment, the data will be compiled along with maps and images and must be included in the assessment report.

4.2 ASSESSMENT AND EVALUATION OF FUNCTION AND RESOURCE LOSS

Once the impacted area has been delineated and defined, and the general physical information is collected, the next step is to conduct an ecological evaluation. This assessment is carried out to determine impacts to the biological community and define the extent and severity of the loss of important resources and their services.

This assessment commonly includes coral cover and density, size class distribution, species diversity, and rugosity, or structural diversity. These metrics should be measured at representative sites within the impacted areas and in adjacent non-impacted or reference areas, representative of the surrounding reef. The reference area should be undisturbed by physical impacts, including sedimentation, and be as close to the impact area as possible. The difference between coral metrics in the impacted and reference areas is a surrogate for the lost functions and resource services as a result of the impact, including habitat for other species, productivity, and nutrient cycling, among others.

4.2.1 Coral cover, coral density, classes of coral size, and species diversity

Coral colonies should be counted, and identified by species, and diameters must be measured within a defined sampling location of a known area. There are several commonly used techniques in the Caribbean that are appropriate. Two possible tools that can be used to collect these data within a known area are quadrats or belt transects.

Quadrat. Quadrats are square measuring devices often made from PVC pipes with 0.5 or 1-meter long frames. The quadrat is placed at the sample site, and then corals that fall within the quadrat are identified, counted, and measured. The quadrat can then be moved to the next sample location.

Belt transect. Belt transects are performed by placing a tape measure or weighted line along the reef to a set distance (Figure 17). Divers then swim up on one side and down the other, counting, identifying, and measuring corals within 1 meter of the tape or line. A single piece of 1-meter PVC pipe is often carried by the diver to help to identify which corals fall within the 1-meter band. A point-intercept transect method may also be used if the tape is difficult to maintain in currents or swells. This method requires documenting just what is present at each scaled interval directly in contact with the transect line or measuring tape.

Quadrats and belt transects should be placed randomly within the assessment areas and with enough frequency to provide representative data of the areas. A stratified random approach is also acceptable to ensure complete coverage of different habitat types potentially affected.

An alternative to counting, identifying, and measuring corals *in-situ* is to take photographs or videos of the sampling locations (e.g., quadrats and belt transects) and then process the images on land to collect the required metrics. This allows for rapid collection and more time underwater to collect data. Images should be taken looking directly downward at the quadrat or line (not oblique), and a scale or item of known length should be visible in each image. The collected images can then be processed on land using software such as Coral Point Count with Excel extensions (https://cnso.nova.edu/cpce/index.html). A disadvantage to this method is that very small corals have a higher chance of being missed or not identifiable.

For each sampling location, the following metrics can be calculated based on the data collected:

Coral cover (%). The area of coral cover can be calculated using the diameters of each measured coral and assuming a circular shape. The coral area is then divided by the area of the sampling location. [coral area]/[area]

Coral density (#/**area**). The number of corals in each sampling location is divided by the area of the sampling location. [# of corals]/[area]

Classes of coral size (#/**area**). The size of corals by species in each sampling location. Information on coral size can be collected from either transects or quadrats. The size class distribution contributes to the assessment of recolonization and recovery projection.

Species diversity (#/**area**). The number of distinct species in each sampling location is divided by the area of the sampling location. [# of species]/[area]

The metrics for each sample location can then be averaged for each area (e.g., impact vs. reference) or even sub-areas, as necessary.

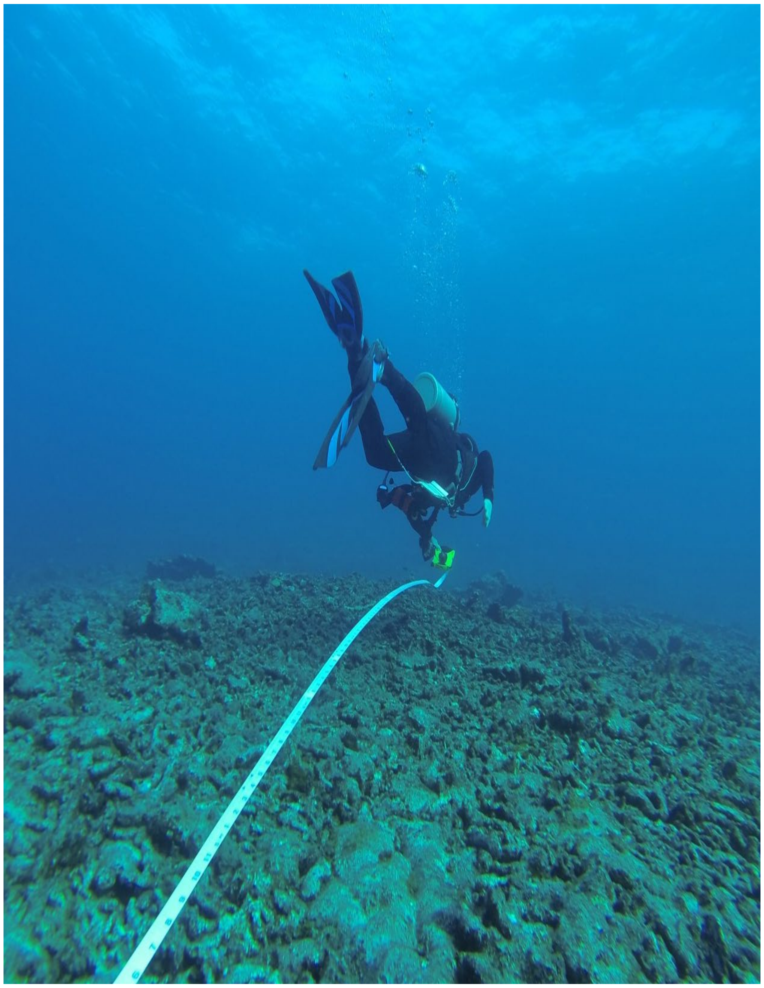

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Figure 17. Laying out a tape measure for a belt transect.

4.2.2 Rugosity

Rugosity is a measure of the topographic and structural complexity of a reef. A rapid method for measuring rugosity is the tape and chain method (Figure 18). This involves a light, but negatively buoyant 5-m chain laid across the reef, in contact with the reef for as close as 100% of the length as possible. The linear distance from the ends of the chain (0-5 m) is then divided by the total length (5 m) and subtracted from 1 to gauge the rugosity from flat (0%) to vertical (100%) surfaces.

Rugosity measurement locations should be selected randomly within the assessment areas and with enough frequency to provide representative data from the assessment areas.

4.2.3 Other assessment methods

There are various detailed coral reef rapid assessment methods that use some of the features described above. These methods are mostly developed for long-term, systematic assessments at defined sites. However, principles of these methods can be used during a vessel grounding, especially if they have been used consistently in surrounding areas prior to the grounding.

AGRRA: The protocol for rapid reef assessments in the Atlantic and Gulf (Atlantic and Gulf Reef Rapid Assessment). https://www.agrra.org/training-tools/agrra-method/

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Figure 18. Laying out weighted chain (gold-colored links in image) to measure rugosity.

Reef Check: The protocol for rapid reef assessments in the Atlantic and Gulf (Atlantic and Gulf Reef Rapid Assessment). https://www.agrra.org/training-tools/agrra-method/

MAR SMP: The Mesoamerican Reef System Project developed a special Synoptic Monitoring Program for the region. The MAR SMP, for its acronym in English, was designed for long-term monitoring, and includes physical and biological parameters of three components: reef ecology, marine pollution, and physical oceanography. https://marfund.org/en/wp-content/uploads/2020/03/Manual-of-Methods-Monitoring-Program.pdf

The Coral Reef Monitoring Manual for the Caribbean and Western Atlantic. A manual that describes some of the techniques above. It was developed by the U.S. National Park Service, Virgin Islands National Park, in 1994 (Rogers, et al. 1994).

4.2.4 Documenting restoration potential

Detailed assessments should also document the restoration potential of the site. Counting and identifying dislodged corals that are large enough to potentially reattach not only helps to assess lost organisms but also provides an indication of the effectiveness and level of effort of the restoration. Cracks and fissures in the reef structure that may need to be repaired or could be used to stabilize rubble should be noted. Potential locations for coral reattachment that do not interfere with unaffected organisms should be mapped. Areas with organisms that have been naturally dislodged due to storms, heavy surges, or tourist or fishermen anchoring damage should be documented since they could potentially be used to supplement the available coral fragments for reattachment (pending the appropriate agency approval). The oceanographic conditions at the site should also be investigated for restoration feasibility. Shallow water with large waves may not be conducive to traditional restoration techniques.

4.3 ASSESSMENT REPORT

Once the valuation and assessment in the field are completed, a report summarizing the methods and observations needs to be prepared. This report should include:

1. **A summary of the incident.**
2. **A description of the setting** (**e.g., reef description, impact types, depths of impact, etc.**).
3. **Methods used to evaluate the incident.**
4. **A detailed account of the collected evidence.**
5. **A map or outline of the incident location detailing the types and severity of impacts and locations of assessment and reference sites.**
6. **Documentation of any triage activities that were performed.**
7. **An assessment of the loss of function and resources in the impact area relative to the reference area.**
8. **Representative photos of the impacts and reference locations.**
9. **Pending activities and analysis.**
10. **Restoration potential and recovery predictions.**

The report should be a collaborative effort with all parties involved in the valuation and assessment, including the RP.

5

RESTORATION

STEP 1.	Determine restoration options.
STEP 2.	Develop a step-by-step restoration plan.
STEP 3.	Obtain proper authorizations and permits for restoration.
STEP 4.	Conduct restoration and follow up on activities.
STEP 5.	Provide periodic updates to key stakeholders.
STEP 6.	Compile a final report summarizing all complete restoration activities.

Once the detailed valuation and assessment have been carried out and thoroughly documented, there should be a clear understanding of the extent and severity of the impact. This will allow viable restoration options to be determined.

5.1 DETERMINING RESTORATION OPTIONS

5.1.1 No Action

There may be times when no action is taken to restore a reef after an incident. The following are reasons for this option:

- Insufficient funding and/or insufficient resources to undertake restoration.

- Dangerous or difficult conditions which pose a risk to life.
- It may be better for the environment to recover through natural processes rather than other restoration activities.

The No-Action option assumes that the natural processes of recruitment, colonization, and growth of biotic resources will overcome obstacles that would otherwise have been removed through a primary restoration action. Implementing the No-Action option may increase the risk of damage to nearby coral communities if the fractured structure and loose rubble at the damaged site generate unstable conditions.

5.1.2 Primary restoration

Primary restoration involves carrying out activities designed to restore the resources of the area where the damage occurred. The designated RP technical advisor formulates a primary restoration plan, which then is reviewed and approved by the proper authorities responsible for the conservation and management of the area, or they can also request modifications. If restoration is determined as the best option, the RP is responsible for hiring contractors to complete the restoration activities and financing the restoration (Figure 19). The regulatory authorities are responsible for approving the completed restoration and monitoring the success.

Additional information on the proper authorities responsible for restoration in the countries of the MAR region can be found in *Appendix A – Responsible Authorities* and *Necessary measures in each country to build and implement regional protocols for the restoration of reefs* (Maddox and Pavón, *Necessary measures in each country to build and implement regional protocols for the restoration of reefs* 2018), on the MAR Fund website.

Figure 19. Divers preparing to begin primary restoration at a grounding site in Cancun, Mexico.

5.2 RESTORATION PLANNING

A good primary restoration plan allows all parties involved to clearly understand the damage caused to the environment and the methods that will be applied to reduce and restore that damage. Typical primary restoration plans cover the following topics:

1. **Basic information about the incident.** Name and type of the vessel, date and location of the incident, heading of the vessel, depth, and an overview of the damaged habitat(s).
2. **Damage assessment.** Describes the methods applied to assess and map the extent and type of damage.
3. **Biological prioritization or triage.** Describes the methods applied to stabilize displaced organisms.

4. **Restoration method**. Describes the restoration required and step-by-step methods applied to complete these activities, including, if necessary, removal of debris, reef structure repair and stabilization, rubble stabilization and/or removal, and reattachment of organisms.

5. **Mapping of restoration and reattached organismss.** Outlines the plan to map the restoration site and the distribution of reattached organisms.

6. **Timeline.** Provides a detailed timeline of each step of the restoration work to be undertaken.

7. **Reports.** Reports the progress in detail for each task, the issues encountered that may delay the restoration and a final restoration report that summarizes all activities.

8. **Monitoring**. Outlines how to verify the restoration once accomplished.

When planning for a restoration, there are several factors that affect the total cost. These factors include not only the extent and complexity of the restoration site but also the personnel and equipment used. Some key factors affecting restoration costs are summarized in the table below.

FACTORS AFFECTING RESTORATION COSTS	
Restoration area	In general, larger areas may take longer and are more expensive to restore.
Complexity of restoration area	Areas with more coral and structural complexity may require more time and effort, thus higher costs.
Types and scale of injuries	The volume and size of rubble per unit area and the number of viable coral fragments per unit area will affect the effort and cost required for restoration.
Number of personnel	If more people are involved in the restoration, restoration costs become higher. This includes divers, surface support personnel (e.g., cement mixers), and shoreside logistics personnel (e.g., equipment or material suppliers.
Number and types of diving vessels	A large diving vessel and/or multiple diving vessels used in restoration will increase costs. Vessel types and sizes need to be chosen to account for: • The distance of the restoration area from shore. • The sea state and weather conditions experienced in the area. • The number of personnel required on the vessel (e.g., divers, support personnel, safety, etc.). • Activities conducted on the vessel, such as mixing cement or collecting debris.
Weather delays	The weather (and sea state) can be planned for, but it is often unpredictable, and adverse conditions can delay or restrain restoration activities. Restorations that are expected to last multiple days may require to include some lost days due to the weather, which will increase the expected costs.
Personnel and equipment logistics	Travel costs and potential lodging (or moorage) are factors to consider if personnel, dive vessels, equipment, or supplies need to move to a different location at the staging area for restoration activities. This can represent a significant cost if the restoration is expected to last multiple days. Restoration in areas staged out of remote or less populated locations can also be more expensive because logistics costs for personnel, equipment, and supplies can increase.

5.3 PERMITS AND AUTHORIZATIONS

Permits and authorizations required to conduct restoration activities depend on the jurisdiction of the different authorities involved, the identification of the cause of the damage, the identification of the RP, and the nature of the intended restoration. The RP is responsible for working with the proper authorities to obtain all the necessary permits and authorizations required to successfully complete the restoration.

Additional specific country details of the permits required for authorities to conduct coral restoration activities in the MAR region can be found in *CSI CURRENT PROCEDURE* (Maddox and Pavón, CSI CURRENT PROCEDURES 2018), on the MAR Fund website.

5.4 RESTORATION METHODS

Depending on the nature of the grounding and the restoration required, several methods can be applied to complete the restoration. Daily documentation and tracking of all activities will be used to provide a detailed post-restoration report. It is helpful to have the general work area defined and mapped so activities can be monitored and documented by sub-area (Figure 20).

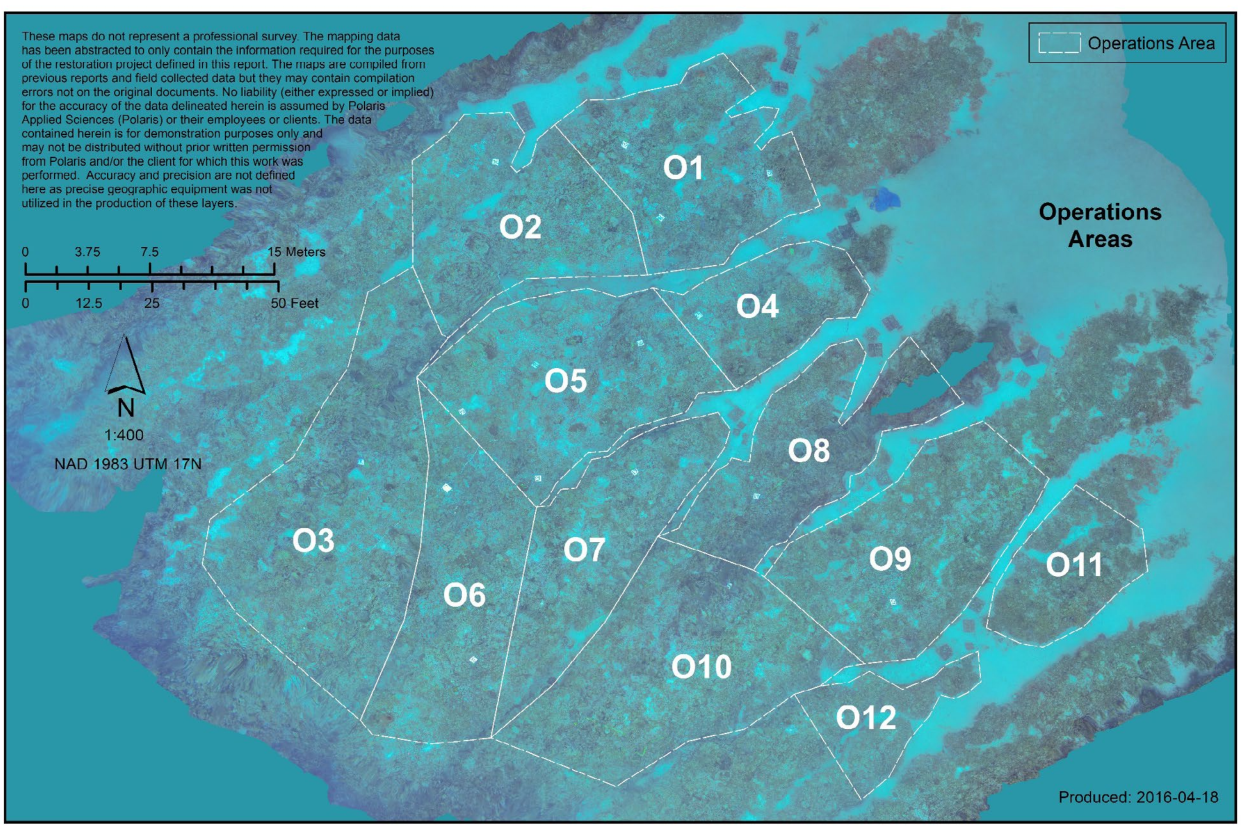

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Figure 20. Delineated work areas for tracking restoration activities.

5.4.1 Debris removal

The grounding of a vessel or the salvage process will often result in the accidental or unavoidable loss of man-made debris on or near the reef (Figure 21). This debris may include anchors, cables, or similar equipment placed specifically to facilitate the removal of the vessel, or it can be equipment or items from the vessel itself. Either way, the debris poses a threat to the reef, may represent a violation of ocean dumping regulations and should be removed, if feasible. Debris that is non-toxic and stable (not at risk of continuous movement) may be considered for a NEBA to ensure that no further harm than good is done by the removal project, much like a NEBA for removing a vessel hull. Depending on the size and number of the items, options for removal include manual collection by divers, divers using lift bags, or ship-mounted cranes.

Hull paint deposited on the reef substrate can be scraped off using paint scrappers and placed in plastic bags *in-situ* before being brought to the surface for disposal. Paint disposal may require special authorization or permit, and the proper authorities should be contacted. Small or fine particles of hull paint on reef substrate are often difficult to remove and can result in increased mobilization of the paint into the environment. One solution can be to “cap” these areas with cement during reef structure stabilization and repair (Section 5.4.3) instead of trying to remove the paint. These methods need to be agreed upon and approved by the proper authorities.

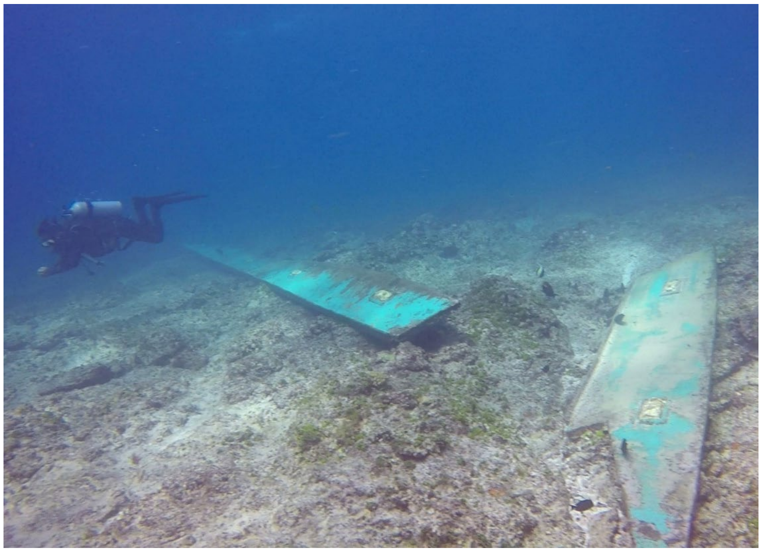

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Figure 21. Debris left behind by a stranded vessel.

Older vessels may have an organotin-based hull paint in underlying layers. This paint is extremely toxic. In 2001, the International Maritime Organization (IMO) adopted the International Convention on the Control of Harmful Antifouling Systems on Ships (AFS Convention). The AFS Convention requires signatory nations to ban or restrict the use of organotin-based marine paints on ships flying their flags, as well as ships using any of their ports, shipyards, or offshore facilities. Ships greater than 400 gross tonnage, sailing internationally, must be screened before receiving a required International Antifouling System Certificate. It is important to acquire these data to evaluate whether the simple mechanical paint removal described above is sufficient. Several regions have dredged ship grounding site sediments due to the contamination with organotin paints. A chemical analytical sampling assessment may be necessary if a hull painted with organotin has left paint residue on the reef.

5.4.2 Rubble

Rubble may be removed from the reef where its movement may cause injury or bury live corals. It can sometimes be safely disposed of in deeper water on sand bottoms in a location designated by authorities. However, if the reef structure has been lost, it is practical and beneficial to incorporate as much rubble as possible into the repair of the reef

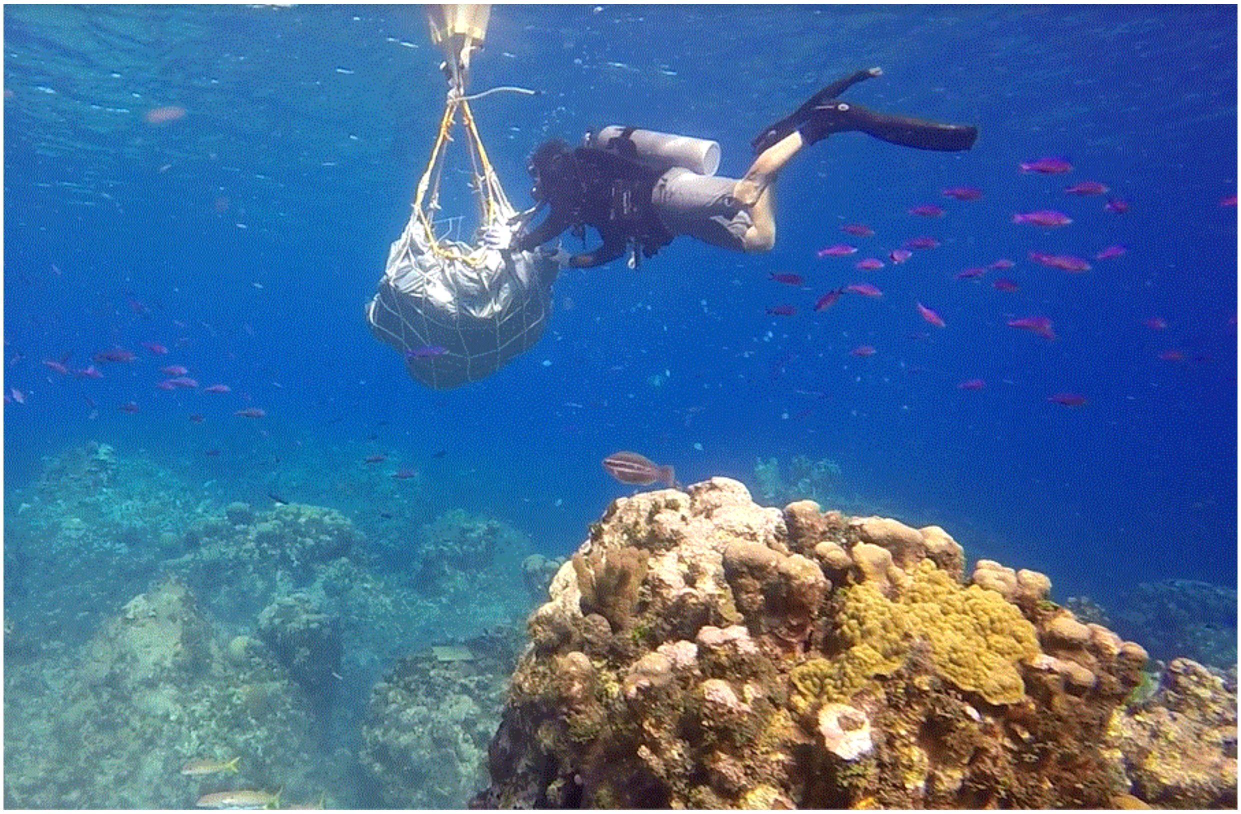

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Figure 22. Manual rubble removal using lined cargo net and lift bag.

structure (Section 5.4.3) using cement. Fissures, grooves, and cracks in the substrate can be filled with rubble and then "capped" with cement. Rubble can be used to re-create relief on the reef prior to coral attachment. Any remaining or unused rubble can be stabilized by moving to areas that will not pose a risk to organisms (e.g., sand channels and natural rubble areas) or removed from the site for disposal, as discussed above. Divers using baskets or lined cargo nets and lift bags can safely move limited amounts of rubble (Figure 22). Large quantities of smaller rubble and sediment may be removed by suction dredge equipment if required. Disposal of any remaining rubble, either in deepwater offshore or in another location, will require approval and/or permits from proper authorities. Final disposal methods should be described in the restoration plan.

At the end of each day, the estimated amount of rubble disposed of or removed from the site should be documented for reporting purposes (Section 5.5).

5.4.3 Reef structure stabilization or repair

One of the most successful methods for stabilizing and repairing reefs is the use of Portland cement with sand as an additive. Cement is mixed on the surface, either by hand or by mechanical mixer, and then quickly delivered in buckets to divers underwater (Figure 23).

Small cracks and fissures in the reef substrate can be stabilized using cement or filled with rubble material and then "capped" with cement.

Larger rubble pieces can be used together and cemented to provide additional relief to scarred or flattened areas (Figure 24). Fiberglass or stainless-steel rods (re-bar) can be pounded into the underlying reef substrate in these areas and covered with cement to provide reinforcement and shear strength to filled fissures or rubble piles. No re-bar should be visible or protruding from the cement, and very little cement should be visible after the completion of rubble and coral reattachment. Large dislodged reef pieces can be moved and positioned into areas for stabilization with cement and re-bar, using lift bags and lined cargo nets, securely tied rope, or moving straps. If there are problems caused by the currents and the energy of the waves, a tarp or mesh can be placed over the cement, and temporarily secure it using diving weights or sandbags.

5.4.4 Reattachment of organisms

Corals salvaged during triage or found in the impacted area should be reattached in areas that have previously been stabilized or are already structurally intact and are away from sand and rubble. Organisms should be reattached at similar depths from where they were dislodged or fractured. Also, an attempt should be made to keep organism densities and species diversity as similar as possible to nearby reference areas. Options for reattaching organisms on the reef structure include cement, epoxy, cable ties, nails, screws, or some combination of the above.

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Figure 23. Cement delivered in a bucket to a diver for reef restoration.

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Figure 24. Rubble cemented together to provide additional relief to a flattened surface.

Cement can be used successfully to reattach organisms to the reef, especially hard corals. Cement should not be poured over areas with biota, such as crustose and calcareous algae, sponges, and/or pre-existing epibenthic organisms.

With the approval from the proper authorities, organisms that have been naturally dislodged as the result of storms or heavy surge, and are at risk of mortality, can potentially be harvested from unimpacted areas and used to supplement the available pieces for reattachment. Similar coral types and densities should be salvaged and reattached.

At the end of each day, the number, species, and size class of each reattached coral, along with an estimate of the amount of cement used, should be documented for reporting purposes (Section 5.5).

Reattached organisms should be marked and mapped to be revisited during post-restoration monitoring (Section 6.2). If the restoration area is relatively small, each reattached organism can be marked and documented. However, if the area is large or there are many reattached organisms, a representative sub-set (e.g., species, locations, sizes) of the organisms should be marked and mapped (Figure 25).

HARD CORALS (SCLERACTINIA)

Hard corals can be attached using epoxy, cable ties, nails, or screws, but the most common and successful way is with a mixture of Portland cement and sand (Figure 26). A mixture of 1:1 cement and sand with a thick consistency works in most situations. Up to 10% plaster of paris may be added to decrease setting time in high wave environments. In general, all hard corals and hard coral fragments, 15 cm in their longest diameter or greater, should be reattached. Smaller corals recruit and recover faster, and their survival in cement is low. The normal sequence of hard coral reattachment using cement usually involves:

1. Positioning one or more coral pieces near the site of adhesion.
2. Clearing sediments, seaweed, and algae from the adhesion site with a wire or stiff bristle brush.
3. Cleaning the basal portion of the detached coral with a wire brush or stiff bristle.
4. To the extent feasible, placing a cement mass larger than the cleaned portion of the coral piece(s) at the adhesion site and avoiding surfaces with reduced adhesion.
5. Placing the coral on the cement mass by carefully pressing down and turning slightly to maximize the contact area of the cement with the cleaned portion of the coral piece.

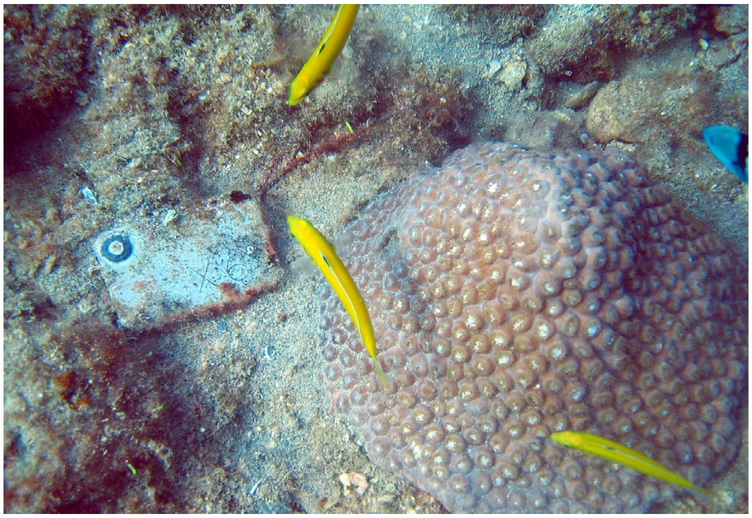

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Figure 25. Reattached hard coral marked with a metal tag for later monitoring.

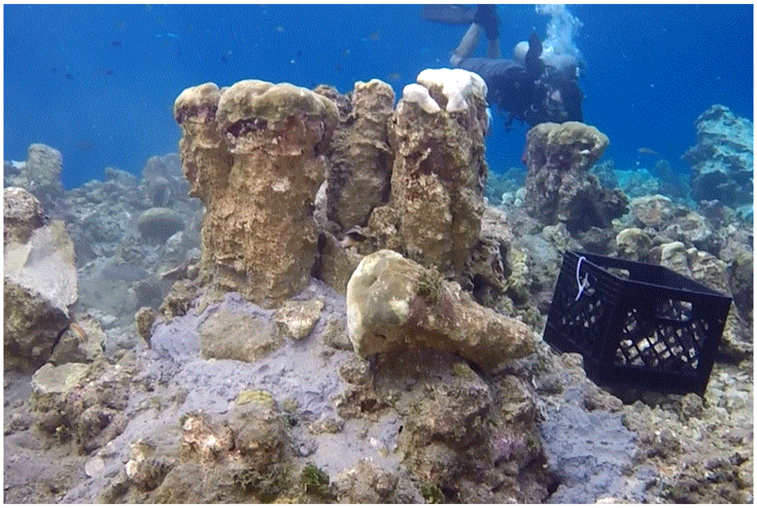

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Figure 26. Hard corals reattached using cement.

6. Additional cement is applied around the edges of the colony, as needed.

If the current or waves are causing the cement to disperse, soft weights or sandbags can be used to protect it until it sets. Large coral colonies and fragments that cannot be moved by hand should be moved and positioned using lined cargo nets, ropes, or moving straps and lift bags to manipulate the colony into the desired place, after which the lift bag can be deflated. Once the colony or large fragment has been placed in the cement mass, additional cement can be applied around the edges for reinforcement. Stainless steel or fiberglass re-bar can be pounded into the reef substrate and covered with the cement mass before placing the coral to reinforce the installation. This is especially important on larger corals and fragments, or several corals attached with interconnected cement masses. No re-bar should be visible or protruding from the cement. An engineering analysis of the general wave environment, depth, size, and weight of structures to maintain stability is sometimes required if the reef restoration structures cannot be cemented to existing reef or bedrock.

Small pieces of rubble, sediment, calcareous algae, and shells can be gently and carefully pressed into any areas of exposed cement. This will help hide any visible cement and provide limestone surfaces for epibenthic and boring and etching organisms that bare cement may inhibit.

Polaris Applied Sciences, Inc.

Figure 27. Octocoral reattachment in small fissure using cement.

OCTOCORALS (GORGONIANS)

The reattachment of octocorals (sea fans, feathers, and sea whips) represents challenges as the movement of waves and currents tends to reduce the stability of the colonies while the material used to reattach them hardens. If the detached colony retains a solid foundation, cement or epoxy can be used for reattachment. Nails that pass through the solid base and reach the substrate have also been used as reinforcement until the reattachment material is hardened (cement or epoxy is applied between the head of the nail and the base of the colony). Soft weights or sandbags can be used temporarily to stop the colony from shifting while the reattachment material hardens. If the colony lacks a foot or base, reattachment methods include the use of structural support for the colony stem. A small-diameter hole can be drilled into the reef structure, the stalk inserted into the hole, and secured with epoxy or cement. Another method uses thin stainless-steel rods secured to the substrate and the octocoral secured to the rod by line, cable ties, cement, or epoxy. The octocorals can also be reattached by securing the colony in small cracks or fissures on the reef along with cement or epoxy (Figure 27). Small pieces of rock can be used to fill the gaps and increase the support of the colony.

SPONGES (PORIFERA)

Many attempts to date to reattach colonies or fragments of sponge colonies have failed. Some smaller tube or finger-shaped sponges may be attached to a rock base, which can then be reattached to the substrate using cement, epoxy, or nails. Smaller fragments without solid bases can be secured in cracks and holes without adhesives. Sponges such as the "barrel" or "mallet" (e.g., *Xestospongia* and *Spheciospongia*) are much larger, but their survival and incorporation into restoration have been successful in many cases. The experiments that have been conducted to

Continental Shelf Associates, Inc.

Figure 28. Fragment of sponge wedged into a crevice for reattachment.

Sea Ventures

Figure 29. Harvesting developed coral fragments from an *in-situ* nursery.

reattach them with cement have produced mixed results. Securing them to the bottom so that they are well embedded in the cement is not essential. It is common to observe that the severed base of a colony of Xestospongia begins to regenerate a few weeks after an incident, while the upper portion of the sponge recovers very slowly or not at all because it is detached and mobile. The upper portion of the sponge may be cut into pieces and wedged into crevices, or attached with tie wraps or lines, with greater success than the attempts at reattaching it with cement (Figure 28).

CORAL TRANSPLANTS/NURSERIES

Broken coral fragments at the site may benefit from triage and placement in a coral nursery if the restoration effort is expected to take a long time to complete before their attachment (6 months or more). This will allow the fragments to survive and grow to provide more viable organisms for reattachment (Figure 29).

5.5 REPORTING

The RP environmental contractor performing the restoration should submit progress reports to the proper authorities from start to completion of restoration activities. The frequency of these reports will be agreed upon with the authorities and the RP, and may be based on the overall length of the project. These reports should include:

- Activities completed for the time covered in the report.
- Numbers, species, and size classes of corals reattached along with estimated amounts of cement used and cumulative tally, with the day's totals incorporated.
- Estimated amount of rubble removed and disposed of from the site (if any).
- Maps showing marked reattached organisms and restoration progress.
- Any predicted changes to the restoration timeline.
- Any other significant activities or observations.

A final report summarizing all activities should be completed by the contractors and submitted once the restoration is complete. This serves to document restoration compliance and as a reference to compare all future monitoring efforts.

6

POST-RESTORATION

The scope of the post-restoration period is limited to the evaluation of the primary restoration and monitoring but may be the longest period of the incident. Monitoring of the incident site may continue for several years beyond the settlement of the case. The RP will typically rely on local authorities to monitor and consider adaptive management after receiving monitoring results. In general, studies have shown that cement can be stronger than the corals themselves, and the survival of transplanted corals typically mimics natural survival within the first several years.

6.1 EVALUATION OF RESTORATION

Once the restoration activities have been completed, the RP environmental contractors and the technical personnel assigned to the area by the corresponding authority should evaluate their results. This is a "sign-off" process to gain regulatory acceptance that the work has been completed properly. This evaluation must account for two questions:

1. Was the job successfully completed according to the proposed restoration plan?
2. Is the damaged area likely to recover, based on its current condition and historical criteria?

The typical assessment compares the biological and ecological attributes of the restored site with those of the reference sites, including stability or percent detached corals or rubble, coral metrics, and rugosity. The performance of the restoration program is considered satisfactory if the biological attributes are similar to those of the reference sites, or all rubble and benthic reef organisms available have been attached successfully, even if less than reference sites, such that recovery of the area is greatly enhanced.

If the work is found to have deficiencies, these must be identified and corrected.

6.2 LONG-TERM MONITORING

Site monitoring should be on a time scale sufficient to understand the recovery trajectory or when the injured site is similar to the reference site in coral growth and survival. Reattached corals generally track the natural condition within several years. The initial period after transplant is when corals are most at risk of mortality. Monitoring is typically more intensive at the start (e.g., post-construction, 6 months, 1 year) with less effort toward the end, such as a one-time monitoring event at year 5 and year 10. Monitoring is the only way to measure restoration success, document trends and issues, and correct problems. Monitoring of vessel grounding sites has been done extensively, and the information learned from other sites may help to understand monitoring needs.

Although each monitoring program is tailored to address each individual impact, several elements are common to most programs. The maps, reports, and tables produced during restoration activities are used to identify the elements of the monitoring program. Commonly, the experimental design consists of repeated measurements of the restored elements and the reference areas. The general principle states that the reference site (or sites) represents the pre-impact system conditions. As time passes, it is assumed that the quality and quantity of sites in an impacted area will tend to improve and increasingly resemble reference or control sites. There may be unplanned events resulting in changes that will have an almost identical influence on the impacted sites and the reference sites. The environmental conditions at both types of sites are assumed to be equivalent.

A sampling schedule that considers the likely post-construction risks and continues long enough to document stability and survival must be developed and must be consistent with the reference condition. The reference condition must also be monitored during every sampling period as it is also dynamic. Adverse effects in the restoration area that occur after 5 or 10 years are unlikely to be related to the vessel grounding or the restoration effort. In other words, monitoring for more than 10 years is unlikely to produce results that can be attributed to the vessel grounding. The sample collection should be adjusted towards more monitoring visits at the start of the recovery process and less towards the end.

Those responsible for the conservation and management of the area should be the drivers of the monitoring program. RP environmental contractor is commonly responsible for the sampling. However, the manager of conservation and management may choose to carry out additional sampling processes.

The monitoring program should assess:

- The reconstruction and structural stability of the restored site.
- The survival, health, and growth of the transplanted organisms.
- The survival and growth of the plants and animals that are naturally recruited in the damaged sites of the reef.
- The same data collected in reference locations immediately adjacent to the grounding site.

Common analyses of data include a statistically valid comparison between the parameters of the restored site and those of the reference site(s) with a temporal perspective. A report should be prepared after each sampling. This report should include a summary of all the findings, as well as copies of all the data related to the monitoring work, including photographic and video documentation.

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APPENDIX A. RESPONSIBLE AUTHORITIES

	Groundings	Oil/chemical spills	Reef restoration
Belize	**Belize Port Authority (BPA)** 120 North Front Street P.O. Box 633 Belize City, Belize Tel: 501-223-0716 or 501-223-0714 Fax: 501-223-0433 info@portauthority.bz **Fisheries Department** Tel: +501-224-4552 Fisheries_department@fisheries.gov.bz **Department of the Environment** Tel: +501-822-2548 or +501-822-2819 envirodept@environment.gov.bz	**Belize Port Authority (BPA)** 120 North Front Street P.O. Box 633 Belize City, Belize Tel: 501-223-0716 or 501-223-0714 Fax: 501-223-0433 info@portauthority.bz **Fisheries Department** Tel: +501-224-4552 Fisheries_department@fisheries.gov.bz **Department of the Environment** Tel: +501-822-2548 or +501-822-2819 envirodept@environment.gov.bz	Department of the Environment Coastal Zone Management Authority Fisheries Department
Guatemala	**Port Authority and Caribbean Naval Command (CONACAR) of the General Directorate of Port Authorities of the Ministry of National Defense** Infantry Brigade: presidentekenn@hotmail.com **General Directorate of Maritime Affairs of the Ministry of National Defense** Tel: +502 4497-4254 jefatura@dgam.gob.gt ***Prosecution Office for Environmental Crimes***[2]	**Caribbean Naval Command** **Santo Tomás de Castilla Izabal** Tel: +502-7948 3127 **National Contingency Commission for Oil and Potentially Hazardous Substance Spills at Sea (CODEMAR)** codemarguate@gmail.com **General Directorate of Maritime Affairs of the Ministry of National Defense** Tel: +502 4497-4254 jefatura@dgam.gob.gt prevencioncontaminacion@dgam.gob.gt subdireccion@dgam.gob.gt	Ministry of Environment and Natural Resources (MARN) National Council of Protected Areas (CONAP)
Honduras	**Port Authority. Department of Maritime Analysis and Control** jochoa@marinamercante.gob.hn **Ministry of Energy, Natural Resources, Environment and Mines (MiAmbiente+)** despachoministerial@miambiente.gob.hn Luckymedina@miambiente.gob.hn **General Directorate of Biodiversity (DiBio)** biodiversidad@miambiente.gob.hn **National Institute of Forestry Conservation and Development, Protected Areas and Wildlife (ICF)** Wildlife Department vidasilvestre@icf.gob.hn vidasilvestreicf@yahoo.com Protected Areas Department oreyes@icf.gob.hn **General Directorate of the Merchant Marine** Tel: +504 2239-8228 / +504 9650-8261 prevencion@marinamercante.hn segmaritima@yahoo.com psc.cortes@marinamercante.gob.hn ***Special Prosecution for Environmental Protection (FEMA)***[2] Lorena Alfonsina Fernández Meza Chief Prosecutor lorenaalfonsinafernandez@yahoo.com	**General Directorate of the Merchant Marine, Marine Environmental Protection Department** Tel: +504 2239-8228 / 8334 / 8346 or +504 9916-5024 direccion@marinamercante.gob.hn prevencion@marinamercante.gob.hn	Ministry of Energy, Natural Resources, Environment and Mines (MiAmbient.e+) National Institute of Forestry Conservation and Development, Protected Areas and Wildlife (ICF)
Mexico	**Port Authority** **Secretary of the Navy** Tel: +55 56246500 Ext: 1000,2000 cc2_@semar.gob.mx **Secretariat of Environment and Natural Resources (SEMARNAT)** **National Commission of Natural Protected Areas (CONANP)** ***The Federal Attorney of Environmental Protection (PROFEPA)*** [2] ***The Office of the Mexican Attorney-General (PGR)*** [2]	**General Directorate of Oceanography, Hydrography and Meteorology** Tel: +52 555 6246500 Ext. 7277 / 7278 or +52 555 6246543 promamdir@yahoo.com.mx **Secretary of the Navy** +55 56246500 Ext: 1000,2000 cc2_@semar.gob.mx	Secretariat of Environment and Natural Resources (SEMARNAT) Secretariat of Livestock, Agriculture, Fisheries and Food

2 - Agency responsible for prosecution and/or fines.

Note: Additional information can be found in (Maddox and Pavón, *Necessary measures in each country to build and implement regional protocols for the restoration of reefs* 2018) and in *Identification of applicable legislation for the restoration of reefs in the four countries of the Reef System Mesoamerican and recommendations for a viable legislation to local and regional level* (Pavón 2019). Both documents are available on the MAR Fund website.

APPENDIX B. EXAMPLE OF INITIAL INCIDENT REPORT TEMPLATE

Date and time of incident:	
Incident reported by:	Contact information (phone number):
Incident location:	Type of incident (e.g., grounding, collision, anchor damage, etc):
Incident lat/long:	Weather/sea conditions:
Injuries or persons at risk:	
Name of the vessel (if known):	Name of the captain (if known):
Approximate size and type of vessel:	Name of the responsible party (if known):
Cause of incident (if known):	Name of the insurer (if known):
Summary of the damage to the vessel:	
Heading and current location of the vessel, if still aground:	
Description of impact to reef:	
Approximate size of impact(s) to reef:	
Depth(s) of impacts:	
Potential natural resources affected:	
Name of any material spilled:	
Containment actions so far:	Plans for further action:
Agencies currently onsite:	
Agencies notified/contacted:	
Report completed by (name, agency, position):	
Contact information (phone number):	

Include any other documentation collected (e.g., photographs, videos, sketches of the incident site or impacts to the reef, etc.).

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