The Nature Conservancy

EARLY WARNING AND RAPID RESPONSE PROTOCOL

Actions to mitigate the impact of Tropical Cyclones on Coral Reefs

CALINA ZEPEDA CENTENO, AURORA CLAUDIA PADILLA SOUZA, JUAN CARLOS HUITRÓN BACA, MARÍA MACÍAS CONSTANTINO, ELIZABETH SHAVER, GABRIELA G. NAVA MARTÍNEZ AND MIGUEL ÁNGEL GARCÍA SALGADO.

CONANP Comisión Nacional de Áreas Naturales Protegidas · Instituto Nacional de Pesca y Acuacultura · OCEANUS, A.C. · MAR FUND · CCAD Comisión Centroamericana de Ambiente y Desarrollo · cooperación alemana DEUTSCHE ZUSAMMENARBEIT · KFW

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ACRONYMS

CRIAP	Aquaculture and Fishery Research Regional Center - Puerto Morelos, INAPESCA
CPHC	Central Pacific Hurricane Center
NGO	Non-governmental organization
DAN	Divers Alert Network
GIS	Geographic Information System
GPS	Global Positioning System
IMD	India Meteorological Department
INAPESCA	National Fishery and Aquaculture Institute – Mexico
IPCC	Intergovernmental Panel on Climate Change
JTWC	Joint Typhoon Warning Center
PADI	Professional Association of Diving Instructors
PCV	Polychloride Vinyl
PNAPM	Puerto Morelos Reef National Park
TNC	The Nature Conservancy
WMO	World Meteorological Organization

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PREFACE

Coral reefs play an important role in protecting coastlines from the impact of tropical storms and hurricanes, by reducing exposure to strong waves, flooding and erosion. However, in turn, hurricanes inflict considerable damage to the reef in terms of reduced coral cover and loss of structural complexity. Dislodgement and displacement of massive boulder colonies, broken tips and edges to total fragmentation of branched corals and sometimes structural fractures, are some of the effects of cyclone impact to the reef. Without intervention, affected organisms can be moved continuously by the current, become overturned or buried by sediment, leading to severe tissue loss and abrasion and preventing their reattachment and recovery. Addressing impacts quickly and effectively is critical to reduce the risk of subsequent damage to affected corals and for increasing the likelihood that reefs will continue to provide valuable services to local communities in the future. To respond in this manner, the *Early Warning and Rapid Response Protocol* presents a step wise approach to guide *First Responders* and reef managers in terms of what needs to be done before, during and after a tropical cyclone to mitigate the impacts to coral reefs in an orderly and timely manner. The Protocol is a voluntary adoption instrument. We truly hope this instrument provides a useful basis to compliment the valuable effort made by reef managers, tour operators, and local communities in promoting conservation and sustainable use of reefs around the world.


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HOW TO USE THIS PROTOCOL

CONTENT OF THE PROTOCOL

The Protocol is divided into four sections:

01 INTRODUCTION

Presents a brief description of the impact of *tropical cyclones* on reefs and analyzes the role of reefs in coastal protection.

02 STEPS FOR THE IMPLEMENTATION OF THE PROTOCOL.

STEP 1: PLANNING AND PREPARATION
Describes actions to be done outside the *tropical cyclone season*, to prepare and plan for what is needed to implement the Protocol.

STEP 2: EARLY WARNING
Describes actions to be done during the early warning once a tropical cyclone is present in the area, both for the approaching and retreating phases.

STEP 3: RAPID DAMAGE ASSESSMENT
Describes techniques used for the rapid assessment that will be implemented to determine the level of reef damage and the amount of *disaster debris* dragged by the cyclone. It also proposes methods to prioritize and identify sites requiring immediate response.

STEP 4: PRIMARY RESPONSE
Describes Primary Response actions that need to be done immediately, as soon as the cyclone has retreated from the area. These include cleanup and Reef First Aid actions. This is the core section of the Protocol.

STEP 5: SECONDARY RESPONSE
Describes Secondary Response actions that need to be done after Primary Response efforts are completed. These include stabilization of structural fractures, *nursery* management, and maintenance and monitoring of sites assisted during the Primary Response.

STEP 6: POST-RESPONSE ACTIONS
Describes actions that will be carried out once the response steps are completed. These include the development of a restoration plan and evaluating the effectiveness on the implementation of the Protocol.

03 GLOSSARY & REFERENCES

Includes the bibliography cited in the document and a list of the terms used in the Protocol.

04 ANNEXES

Includes additional resources referred to in the document, such as a budget template , recommended apps and software, and a list of equipment and materials that should be used for implementing the Protocol. These resources are organized according to topic and linked to each step of the process.

SECTION 1

INTRODUCTION

INTRODUCTION

Coral reefs are natural breakwaters acting as a first line of defense for coastal communities, protecting the coastline from wave energy and preventing coastal erosion and flooding. Some authors have found that *Acropora palmata* is a key species in the construction of the *reef crest* and other shallow areas (Lighty et al. 1982; Bos and Liddell 1987; McIntyre 1988) and therefore contributes to maintain coastal protection services (Aronson and Precht 1997; Alcolado et al. 2009). Other studies indicate that a high complexity and rugosity in the *reef crest* may significantly dissipate wave energy that crosses the reef towards the coast (Harmelin-Vivien 1994; Alcolado et al. 2009; Busutil et al. 2011; Gardner et al. 2005). Therefore, a healthy and structurally complex coral community can provide the characteristics needed to increase and maintain coastal protection.

Tropical cyclones can cause different types of damage to coral reefs ranging from mild to partial or total damage. Extreme winds during *tropical cyclones* generate heavy seas that can devastate coral reef communities (Scoffin 1993; Harmelin-Vivien 1994). Their effect on coral reefs depends on the cyclone frequency, intensity, and duration, as well as biological and morphological characteristics of the dominant coral species. Other factors include depth, reef slope, platform width, level of exposure, reef size, shape and structural strength, the degree of attachment of benthic organisms, as well as the ecological and any anthropogenic factors of the area (Alcolado et al. 2009; Rioja-Nieto et al. 2012).

Mechanical damage can include tissue loss and abrasion which can weaken corals, resulting in delayed recovery and increased vulnerability to bleaching (Wilkinson and Souter 2008). Likewise, the strong winds of a tropical cyclone can cause powerful waves and storm surges that can break coral colony tips and branches, dislodge and displace entire massive colonies, and produce columns of sediment, that can smother corals. In some cases, cyclones can cause structural damage where sections of the reef framework are partly or wholly removed (Harmelin-Vivien 1994; Done 1992; Fabricius et al. 2008). Furthermore, heavy rains reduce water salinity levels, causing short-term effects on corals.

The hard corals most affected by hurricanes and tropical storms in the Atlantic are *Acropora palmata* and *Acropora cervicornis*, both because of their shallow distribution in the lagoon and *reef crest* and their branching morphology. These branched corals are fragile, break easily and are prone to fragmenting with increased wave action (Bak and Criens 1982; Highsmith 1982). During severe hurricanes they can break into many *fragments* that reattach to the substrate to form many new smaller colonies (Rogers et al. 1994; Jordán-Dahlgren and Rodríguez-Martínez 1998). This process is considered a type of asexual *propagation* by natural fragmentation and it is important for local dispersion, maintenance and growth of the *Acropora* populations because the species widens its distribution in the area (Bothwell 1981; Lirman 2003).

Tropical cyclones appear to be increasing in frequency and intensity due to climate change, particularly in terms of wind force (Solomon 2007) which, together with coastal development and other impacts, are factors that strongly affect reefs in the Greater Caribbean (Gardner et al. 2005). When the frequency of hurricanes is every two years or less, the coral reef crest steadily degrades, leaving little to no time for posterior recovery (Alcolado et al. 2009). This threatens coastal protection services due to the loss of reef structural complexity and coral cover (Fabricius 2008; Alvarez-Filip et al. 2011), which in turn reduces the wave-dissipating effectiveness of the *reef crest*.

However, if the passage of a hurricane occurs every five years, it can be beneficial to coral reefs since the intermediate disturbance allows for reef recovery and also prevents space from being monopolized by competitive coral species (Rogers 1993). These also help alleviate coral reef thermal stress, especially in terms of the cooling effect associated with tropical storms (Manzello et al. 2007).


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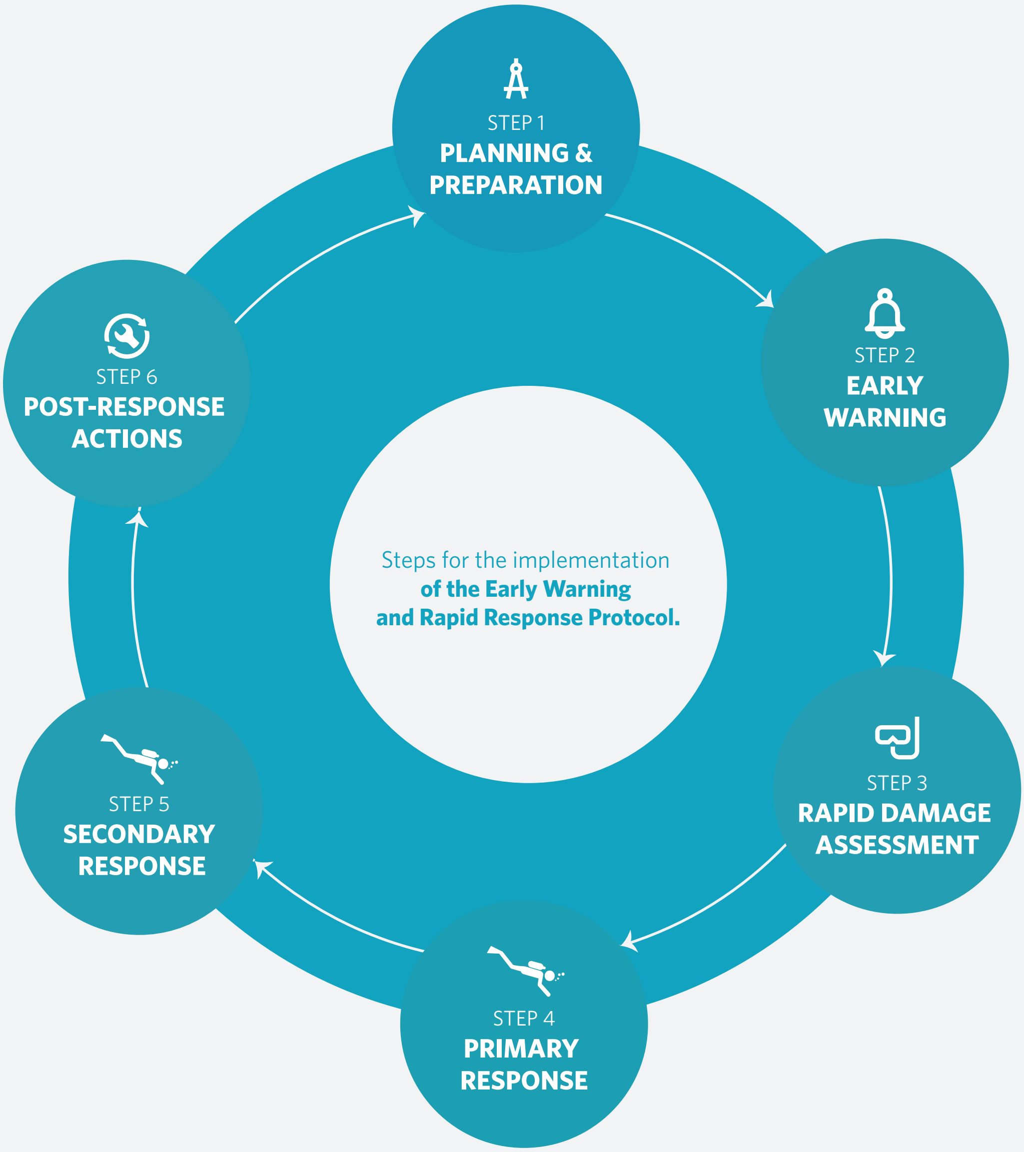
SECTION 2

STEPS FOR THE IMPLEMENTATION OF THE PROTOCOL

This section guides reef resource managers, *First Responders* and key partners through the 6 steps that comprise the *Early Warning and Rapid Response Protocol*. Figure 1 shows the steps that should be implemented throughout the year, including before, during and after the *tropical cyclone season*. Each step is described in the following pages.

FIGURE 1

Steps for the implementation of the Early Warning and Rapid Response Protocol.



STEP 1

PLANNING & PREPARATION

PLANNING & PREPARATION

One of the most critical steps - planning and preparation - is not performed in the field and takes place outside the *tropical cyclone season* (see more information on *tropical cyclone season* on Table 2, in Step 2: *Early Warning*). The following actions will be implemented during the Planning and Preparation Step:

- Define an organizational and operational structure.
- Prepare a *Response Plan.*
- Gather key information.
- Procure funds and other resources.
- Establish inter-institutional partnerships and agreements.
- Prepare materials, tools and equipment for the response.
- Train *First Responders* and form *brigades*.
- Secure insurance policies for *First Responders.*
- Establish a Communication Network.
- Identify threats and reduce risks.

DEFINE AN ORGANIZATIONAL AND OPERATIONAL STRUCTURE

To operate the Protocol, it is suggested to define an organizational and operational structure. The organizational structure determines roles and assigned responsibilities and information flows between the different levels of coordination. Operational procedures are required to maintain a steady workflow to get things done. Having a structure in place can help improve efficiency and provide clarity for partners at every level. However, the structure should be flexible, consider the diversity of actors involved and fit the resources available. For the organization and operation of the Protocol we suggest incorporating the following structure:

- *Committee*
- *First Responder Brigades*
- Operations Team
- Partners Network

THE COMMITTEE

The *Committee* plans, directs and coordinates all the activities from the Protocol, including:

- Preparing and coordinating the implementation of a *Response Plan.*
- Training *First Responders* and forming the response teams or *brigades*.
- Managing funds to implement activities.
- Coordinating with partner institutions throughout the year.
- Reviewing and updating the Protocol annually.

The *Committee* consists of:

- A coordinator, in charge of coordinating the implementation of the Protocol.
- A secretary or record keeper, in charge of facilitating meetings and recording minutes and agreements during meetings.
- A *Brigades Leader*.
- A *Head of Operations.*

BRIGADES

A *First Responder* is a diver or snorkeler with specialized training to assess and provide aid to the reef after a tropical cyclone. *First Responders* work in teams called *brigades.*

First Responders are responsible for the following:

- Implementing a rapid damage assessment immediately after the cyclone retreats.
- Implementing Primary Response activities, including:
    - Carrying out cleanup actions to remove from the reef all debris generated by the cyclone.
    - Providing First Aid to the reefs:
        - Reposition and reattach displaced,

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    dislodged, broken or overturned massive boulders colonies or fragments.
    - Remove colonies buried under the sand.
    - Remove and / or stabilize dead coral fragments and sediment that are loose and causing damage to the reef.
- Implementing Secondary Response activities, including:
  - Stabilize structural fractures.
  - Place rescued coral fragments into nurseries.
  - Provide assistance to reef managers to maintain and monitor nurseries and sites rehabilitated after the cyclone.

The *Brigades Leader* is responsible for forming, coordinating, keeping track of each brigade, and updating with the *Head of Operations* and the *Committee* on the progress of response activities.

OPERATIONS TEAM

The Operations Team coordinates logistics and communications needed for the implementation of the Protocol. This is responsible for:

- Facilitating internal and external communication between *the Committee* and the *brigades*, and other partners.
- Supplying materials, fuel, food, beverages and other supplies required by the *First Responders*.
- Establishing partnerships with key companies and institutions to procure supplies, transportation and a place to operate.
- Monitoring the actions and location of each *brigade*.
- Mobilizing toolboxes, diving gear, boats and other things necessary for the operation.
- Collecting and disposing of debris collected by the *brigades*.
- Preparing, maintaining and safeguarding toolboxes, first aid kits and other equipment used during the response.

The Operations Team consists of:

- The *Head of Operations*.
- Two logistics teams composed of 2 - 4 people each.

The *Operations Team* will work from the *Operations Center*. The *Operations Center* should be a space to keep the toolboxes, equipment and any other resource required to implement the Protocol. Other alternative safe and accessible sites to keep and safeguard these resources should also be available.

PARTNERS NETWORK

A network of partner organizations is important for obtaining the resources and staff needed for a successful and timely response. Key partners can include government agencies, private sector (tour operators, dive centers and other tourism related companies), NGOs, reef managers, nautical associates, universities, fishermen, and others looking to contribute to response efforts.

Partners should be familiar to the *Response Plan* and the Protocol, so they can identify lines of action and steps where they could collaborate. This includes a full introduction to the Protocol and the Response Plan.

PREPARE A RESPONSE PLAN

Addressing impacts quickly and effectively is critical for increasing the likelihood that coral reefs will continue to provide valuable services to local communities in the future. To respond in this manner, a *Response Plan* should be developed in advance of any event. *The Committee* is in charge of preparing the *Response Plan*.

A *Response Plan* is a course of action that can be acted upon in the case of an event that damages a coral reef in order to quickly mitigate impacts and reduce any further damage. It consists of a pre-made list of relevant contacts and tasks that need to be completed in an orderly manner. This is a general framework for the *Response Plan*:

1. A CLEARLY DEFINED OPERATIONAL STRUCTURE

The operational structure includes all entities and organizations that have agreed to participate in response activities, including a lead organization (or point person) and teams with specific and known responsibilities, logistics information, materials, tools and equipment needed, and a budget (see blank format for the budget in Annex 1).

2. LOGISTICS STRATEGIC PLAN

Set a Logistics Strategy to guarantee the supply and availability of materials and resources during field activities, transportation needs, and a well-defined communication strategy.

3. DIVING SAFETY PLAN

It is crucial that all SCUBA diving activities are implemented under safety diving standards. Having a Dive Safety Plan can ensure diving is conducted in a safe way. This can include: having information on diving equipment, float, sites, dive profiles and emergency contacts. It is recommended to have DAN Oxygen Kit on the boat at all times and to request diving insurance to the *First Responders*.

4. PLANS FOR A RAPID PRELIMINARY ASSESSMENT

A rapid assessment done immediately after an event determines the extent and location of damage to a reef, helping identify emergency activities that need to follow.

5. PLANS FOR EMERGENCY OR PRIMARY RESPONSE

Primary Response includes removing the source of the impact and any remaining hazards and conducting coral reef repair activities such as reattaching broken *fragments* or dislodged colonies, stabilizing lose or broken substrate.

6. PLANS FOR FURTHER OR SECONDARY RESPONSE

Secondary Response includes stabilizing structural fractures from damaged colonies, moving rescued *coral colonies* into the *nursery*, additional outplanting efforts, and any other activities to restore the physical structure of the reef.

Based on feedback from the *brigades*, the *Response Plan* should be updated annually, once the *tropical cyclone season* is over (see Table 2 in Step 2 for *tropical cyclone season* worldwide). Adjustments should be made to improve the *Response Plan* for its implementation the following year.

GATHER KEY INFORMATION

It is important to get familiar with local agencies that monitor meteorological trends and issues official weather bulletins in your region, as well as with the national weather institutions (national meteorological service) at a country level, as these provide information on the local effects of *tropical cyclones* that may arise and threat the area. The official bulletins issued by these entities usually contain the current location and *forecast* the track and intensity of *tropical cyclones*. In Annex 2 you can find a list of tropical cyclone tracking applications for smartphones.

PROCURE FUNDS AND OTHER RESOURCES

Funds are needed to buy materials and tools, buy fuel, rent diving gear, boats and vehicles (if necessary), train *brigades*, and other operational needs (uninterrupted supply of resources).

Here are some options for funding:

- Insurance coverage for tropical cyclone impacts
- Funding/contributions from tourism industry
- Funding/contributions from emergency funds
- Government funding
- International agencies and cooperation

The Committee should prepare funding proposals and/or procure the necessary agreements depending on the funding source. Funding proposals should use the most updated forms to request funds and include all the supporting documents required by each agency.

ESTABLISH INTER-INSTITUTIONAL PARTNERSHIPS AND AGREEMENTS

The Committee should seek to establish partnerships with various partners, such as government agencies, private sector, NGOs, that can help in the implementation of the Protocol. Partnerships and agreements should be formalized prior to the start of the cyclone season. These can include:

- Agreements to obtain space for the *Operations Center* and for keeping/safeguarding response materials and equipment.
- Agreements to obtain supply of food, water, ice, fuel, batteries and other resources required by the *brigades* for the implementation of response activities.
- Agreements with government agencies, NGOs or tour operators for the loan of boats and vehicles during the response.
- Agreements with dive centers and other tourism operators for the loan of diving gear, tanks and other related equipment.
- Agreements with municipal authorities for the assignment of sites for the disposal of debris.

PREPARE MATERIALS, TOOLS AND EQUIPMENT FOR THE RESPONSE

Brigades require special materials, tools and equipment to perform response actions. These should be stored in special toolboxes. The specific content of the toolbox is detailed in Annex 3.

Toolboxes should be resistant, durable, portable (preferably should include wheels for mobility) and with an airtight seal to make it waterproof (see Figure 2a). Pelican Storm Cases (see Figure 2b) are a great option. The number of toolboxes required will depend on the number of brigades operating, as each one needs its own. The content inside the boxes should be properly inventoried, organized and labeled, and must be complete, in good conditions and accessible at all times (Gulko et al. 2008). Likewise, each box should be properly numbered and labeled for each *brigade*.

Brigades Leader is responsible for preparing, keeping and safeguarding the toolboxes during the Primary Response. Outside the *tropical cyclone season*, the organization / institution responsible for their custody must store them in a strategic site and keep an inventory of the content. If the inventory reveals any missing material or tool, then it must be replaced to complete the contents of the box. This ensures that all required materials are always available during the time of a response event.

FIGURE 2
Cases to store materials and tools.

A Waterproof case with handles

B Pelican Storm Case with wheels for easy transportation

IMPORTANT CONSIDERATIONS:

- Diving bags are not recommended for storing materials and tools during response actions because they are soft, which exposes the contents to damage, and makes it difficult to reach for materials and tools during the response efforts.
- Toolboxes should be resistant, durable, portable (preferably should include wheels for mobility) and with an airtight seal to make it waterproof (Gulko et al. 2008).
- Plastic straps or padlocks should be used to secure the content.
- Electronic tools should be stored in a special compartment (a smaller box), apart from the tools or other materials and should be properly labeled.
- After using the toolboxes, they should be replenished so they are complete and ready to use in the next event. Make sure to replace any damaged tool or equipment.

TRAIN FIRST RESPONDERS AND FORM BRIGADES

First Responders should be properly trained to learn all the necessary skills to implement field actions. Training should combine theory and practice, including the following topics:

- Basic concepts on coral biology and the protective services that reefs provide to the coast.
- Rapid damage assessment methods.
- The use of *lift bags* and ropes to remove debris and move heavy corals under water.
- Primary Response activities, incluiding:
  - Reattach broken, displaced, overturned and dislodged corals.
  - Remove corals buried under the sand.
  - Reattach and stabilize broken fragments and boulder colonies using various techniques (cement, epoxy, string, wire).
  - Remove and/or stabilize dead coral rubble and loose sediment that could cause further damage to the reef.
  - Use pneumatic drills to stabilize large coral colonies.
- Secondary Response activities, including:
  - Stabilize structural fractures of coral colonies.
  - Place rescued coral fragments into nurseries.
  - Provide assistance to reef managers to maintain and monitor nurseries and sites rehabilitated after the cyclone.

Practical lessons should be mostly done by SCUBA diving. It is recommended to include a first aid course, aquatic rescue course, and an oxygen provider course (given by a DAN or PADI Instructor), so *brigades* are prepared in case of accidents in the field.

Once *First Responders* are trained, they can be grouped into *brigades*. The number of *First Responders* trained will depend on the number of *brigades* required in the field. Therefore, it is essential to have as many *First Responders* trained as would be needed to respond to a Category 5 storm. Each *brigade* consists of:

- Four to six certified divers implementing response actions underwater.
- Two to four snorkelers on the water's surface available to hand materials (cement, epoxy, etc.) to divers and in turn, collect bags with fragments and/or debris from divers at the bottom.
- One to two boat tenders to pick-up debris or items, prepare the cement, and fill the dosing bags.

The number of *brigades* in action will depend on:

- The magnitude of the event
- The number of *First Responders* available.
- The number of boats available.

First Responders should be members of local communities near the area where the Protocol is being implemented. Tour operators, fishermen, hotel owners, NGO staff, researchers and personnel from government agencies are good candidates to join as *First Responders.* People interested should fill out an application form (see Annex 4) which helps *the Committee* to select the right candidates to be part of the *brigades*, based on the appropriate capabilities and experience.

SIMULATION DRILLS

Once training is completed and *brigades* are formed, it is recommended to conduct *simulation drills* to practice hypothetical scenarios. These trainings are useful for the *First Responders* to identify gaps in training capabilities, strengthen coordination, teamwork and leadership skills, and get familiar with the entire response operation. The drill should include participation from all *First Responders* and all others involved in the implementation of the Protocol.

SECURE INSURANCE POLICIES FOR THE FIRST RESPONDERS

Accidents may occur with the *First Responders* or any other member from the team during field activities. Temporary insurance policies (e.g. Divers Alert Network Diving Insurance) should be secured to cover these potential contingencies.

ESTABLISH A COMMUNICATION NETWORK

The *Head of Operations* should establish a Communication Network to maintain internal communication with all the involved parties. A list of contact information from the *First Responders*, *Brigades Leader*, members of *the Committee* and partners is required. This information will remain confidential among the members of *the Committee*. The list should contain the following information:

- Full name
- Institution/organization/company
- Telephone number (Indicate if it is a cell phone and/or landline, and whether it has access to WhatsApp)
- Email
- Messenger and/or Skype
- Broadband radio channel number (if available)
- Other possible means of communication (optional)

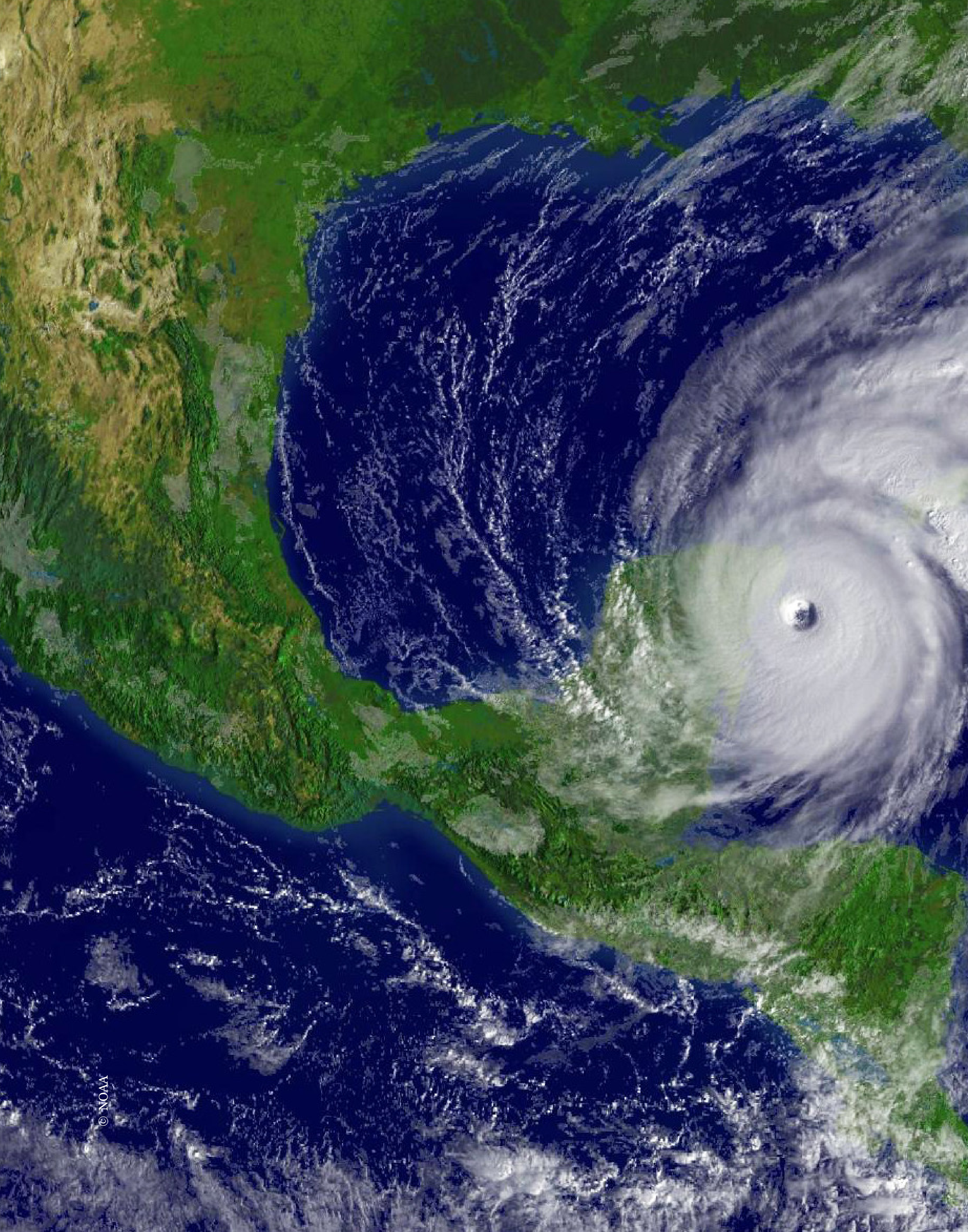
Most communication will take place through cellphone or WhatsApp (or other commonly used messaging service), when Wi-Fi or signal is available. During electrical or cellular signal failure, the *Head of Operations* should identify channels or means of communication (e.g. marine broadband radio). Emergency contact information (hyperbaric chamber, Red Cross, etc.) should be summarized in a diagram, printed, laminated and displayed in the *Operations Center* and meeting areas.

IDENTIFY THREATS AND REDUCE RISKS

Tropical cyclone winds can impact coastal infrastructure, especially when infrastructure is in poor condition leading to the creation of debris that may end up in the *reef lagoon* or on the reef itself. Loose trees or branches near the coastline can also be dragged into the sea. Another threat can include sources of pollutants (drains, sewage drainage areas, garbage dumps near the sea). To reduce risks, the *Committee* should identify and map any potential threats, and notify the corresponding agency, so the threat can be addressed before the *tropical cyclone season* begins.

These are some of the possible mitigation actions:

- Repair and/or remove any infrastructure that are in poor condition and/or no longer usable (piers, roofs, etc.).
- Secure objects that could fly away during a cyclone (television antennas, signs, hanging objects, etc.).
- Clean roofs, drains, vacant lots and garbage dumps near the sea.
- Trim fragile or hazardous trees and shrubs around houses, hotels, green areas.
- Address sources of pollutants that could overflow and drain into the sea and damage the reef.



STEP 2

EARLY WARNING

EARLY WARNING

The Early Warning Step describes the actions to be carried out during the presence of a tropical cyclone in the area, both in its approaching and retreating phases. Members of *the Committee* and *First Responders* should be informed of a potential tropical cyclone to have time to prepare for an immediate and effective response.
The type of actions to be carried out in the early warning step will depend on the level of alert, which depends on the distance and intensity of the cyclone and whether it is approaching or retreating from the area. During both phases (approaching and retreating), data and information is collected and processed, based on forecasts or temporary predictions about the storm and its possible impacts, until wind speed and the estimated time for impact are identified.

TROPICAL CYCLONE CLASSIFICATION

A tropical cyclone is an organized system of clouds and thunderstorms rotating counter-clockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. It is considered a natural phenomenon that originates over tropical or subtropical waters and has a closed low-level circulation, forming a warm and humid mass of air. It is characterized by strong winds spiraling around a core, and produces high waves, over-elevation of the sea, and abundant rainfall. Depending on its location and strength, a tropical cyclone is referred to, by different names, including hurricane, typhoon, tropical storm, cyclonic storm, tropical depression, or simply cyclone (WMO 2017; NOAA 2017).

Globally, tropical cyclone formations are divided into seven basins, four in the Northern Hemisphere (NH) and three in the Southern Hemisphere (SH). These include: North Atlantic Ocean, Eastern North Pacific Ocean and Western North Pacific Ocean, the South Pacific Ocean, the Southwest Indian Ocean and Southeast Indian Ocean, and the North Indian Ocean (which includes Arabian Sea and Bay of Bengal). They are classified by the wind speeds located around the circulation center and are ranked from one to five on a tropical cyclone scale by the World Meteorological Organization (WMO 2017).

The weakest *tropical cyclones* are called tropical depressions, and the strongest can be called hurricane, typhoon, or tropical cyclone, depending on the geographic region. Annually, an average of 86 cyclones of tropical storm intensity (with maximum winds 63 km/h) form worldwide, with 47 reaching hurricane/typhoon strength, and 20 becoming intense *tropical cyclones*, super typhoons, or major hurricanes (WMO 2017).

In the North Atlantic, central North Pacific, and eastern North Pacific, the term hurricane is used. The same type of disturbance in the Northwest Pacific is called a typhoon. Meanwhile, in the South Pacific and Indian Ocean, the generic term tropical cyclone is used, regardless of the strength of the wind associated with the weather system (NOAA 2017). The scale used for a particular tropical cyclone depends on what basin the system is located in. All scales rank *tropical cyclones* using their maximum sustained winds over a period between one and ten minutes. Within all basins *tropical cyclones* are named when the sustained winds hit 63 km/h (39 mph). According to Table 1, the National Hurricane Center (NHC), Central Pacific Hurricane Center (CPHC) and Joint Typhoon Warning Center (JTWC) use scales of 1-minute sustained winds, while the India Meteorological Department (IMD) uses 3-minute sustained winds, and all other warning centers use 10-minute sustained winds. This shows the level of classification for the mayor basins of the world, the name of the corresponding agency that monitors the meteorological phenomenon according to each basin, the time they use to measure the average wind speed, and the classification of *tropical cyclones* based on the average wind speed.

TABLE 1

Tropical Cyclone classification in the main basins of the world.

TROPICAL STORM CLASSIFICATION

	Northern hemisphere			Southern hemisphere	
BASIN/AGENCY	**NORTHEAST PACIFIC & NORTH ATLANTIC**	**NORTHWEST PACIFIC**	**NORTH INDIAN OCEAN**	**SOUTH PACIFIC**	**SOUTHWEST INDIAN OCEAN**
	National Hurricane Center/ Central Pacific Hurricane Center	**Joint Typhoon Warning Center**	**Indian Meteorological Department**	**Bureau of Meteorology/ Fiji Meteorological Service**	**Météo-France**
WIND SPEED MEASUREMENT	1-minute sustained winds	1-minute sustained winds	3-minute sustained winds	10-minute sustained winds	10-minute sustained winds
	Tropical Depression <38 mph <33 kn <61 kmh	**Tropical Depression** <38 mph <33 kn <61 kmh	**Depression** 19 - 31 mph 17 - 27 kn 31-51 kmh	**Tropical Depression** <32 - 38 mph <28 - 33 kn <52- 62 kmh	**Tropical Disturbance** <32 mph <28 kn <52 kmh
			Deep Depression 32 - 38 mph 28 - 33 kn 52 - 61 kmh		**Tropical Depression** 32 - 38 mph 28 - 33 kn 51 - 62 kmh
	Tropical Storm 39 - 73 mph 34 - 63 kn 63 - 117 kmh	**Tropical Storm** 39 - 73 mph 34 - 63 kn 63 - 117 kmh	**Cyclonic Storm** 39 - 54 mph 34 - 47 kn 62 - 88 kmh	**Category 1 Tropical Cyclone** 39 - 54 mph 34 - 47 kn 63 - 88 kmh	**Moderate Tropical Storm** 39 - 54 mph 34 - 47 kn 63 - 88 kmh
			Severe Cyclonic Storm 55 - 72 mph 48 - 63 kn 89 - 118 kmh	**Category 2 Tropical Cyclone** 55 - 72 mph 48 - 63 kn 89 - 118 kmh	**Severe Tropical Storm** 55 - 72 mph 48 - 63 kn 89 - 117 kmh
	Category 1 Hurricane 74 - 95 mph 64 - 82 kn 119 - 153 kmh	**Typhoon** 74 - 149 mph 64 - 129 kn 119 - 239 kmh	**Very Severe Cyclonic Storm** 73 - 103 mph 64 - 89 kn 119 -165 kmh	**Category 3 Severe Tropical Cyclone** 73 - 98 mph 64 - 85 kn 119 - 157 kmh	**Tropical Cyclone** 73 - 103 mph 64 - 89 kn 118 - 165 kmh
	Category 2 Hurricane 96 - 110 mph 83 - 95 kn 154 - 177 kmh		**Extremely Severe Cyclonic Storm** 104 - 137 mph 90 - 119 kn 166 - 220 kmh	**Category 4 Severe Tropical Cyclone** 99 - 123 mph 86 - 107 kn 158 - 198 kmh	**Intense Tropical Cyclone** 104 - 131 mph 90 - 114 kn 166 - 213 kmh
	Category 3 Hurricane 111 - 129 mph 96 - 112 kn 178 - 208 kmh				
	Category 4 Hurricane 130 - 156 mph 113 - 136 kn 209 - 251 kmh	**Super Typhoon** >150 mph >130 kn >240 kmh	**Super Cyclonic Storm** >137 mph >120 kn >221 kmh	**Category 5 Tropical Cyclone** >124 mph >108 kn >199 kmh	**Very Intense Tropical Cyclone** >131 mph >115 kn >214 kmh
	Category 5 Hurricane >157 mph >137 kn >252 kmh				

Kmh: Kilometers per hour
Kn: Knots
Mph: Miles per hour

Although each of the above basins has its particular seasonal pattern of tropical cyclone activity (see Table 2), most activity tends to peak worldwide in late summer. The least active month is usually May, and September is the most active (WMO 2017).

TABLE 2

The World's seven *tropical cyclone seasons.*

HEMISPHERE	BASIN	SEASON NAME	START	END
Northern Hemisphere	North Atlantic Ocean	Atlantic Hurricane Season	June 1	November 30
	Eastern North Pacific Ocean	Eastern Pacific Hurricane Season	May 15	November 30
	Western North Pacific Ocean	Northwest Pacific Typhoon Season	April 1	January 31
	North Indian Ocean	North Indian Cyclone Season	April 1	December 31
Southern Hemisphere	Southwest Indian Ocean	Southwest Indian Cyclone Season	October 15	May 31
	Southeast Indian Ocean	Australian/Southeast Indian Cyclone Season	October 15	May 31
	South Pacific Ocean	Australian/Southwest Pacific Cyclone Season	November 1	April 30

EARLY WARNING SYSTEM

An *Early Warning System* (EWS) is an outreach coordinating tool designed to generate relevant and timely information in a systematic way prior to and during the tropical cyclone in order to make informed decisions, take action and alert *First Responders* and other members from the team on the status of the event. The *Early Warning System* must be adapted to be compliant to the official warning system in each country or region where the Protocol is implemented.

The Protocol proposes an *Early Warning System* with various stages during the Approaching and Retreating Phases. It is based on the Saffir-Simpson scale, as it is standard for all regions. The Approaching Phase is considered when a tropical cyclone is detected and predicted to impact a local area. The Retreating Phase is considered when the cyclone is moving away from the local area, regardless of whether it impacted local reefs or not. The actions to be implemented depend on the stage of alert, and this in turn depends on the distance and intensity of the cyclone (see Table 3 and 4), and on whether it is approaching or retreating.

TABLE 3

Stages of the Approaching Phase of a cyclone.

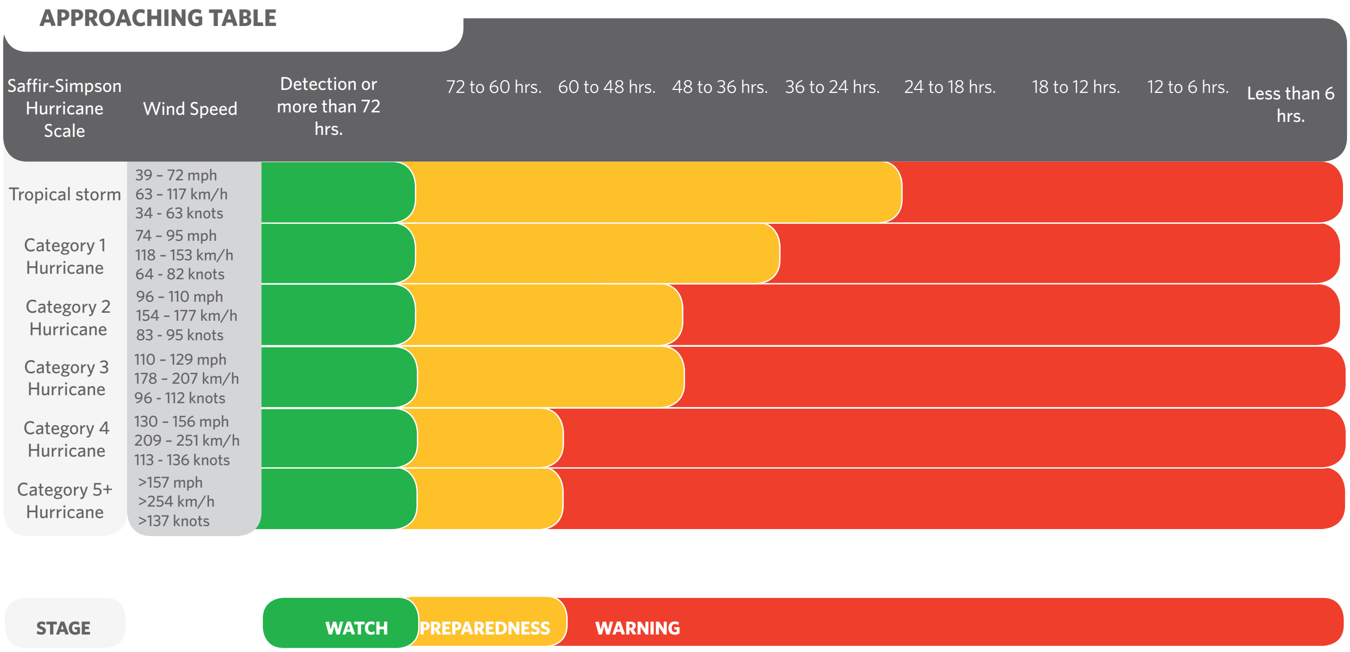
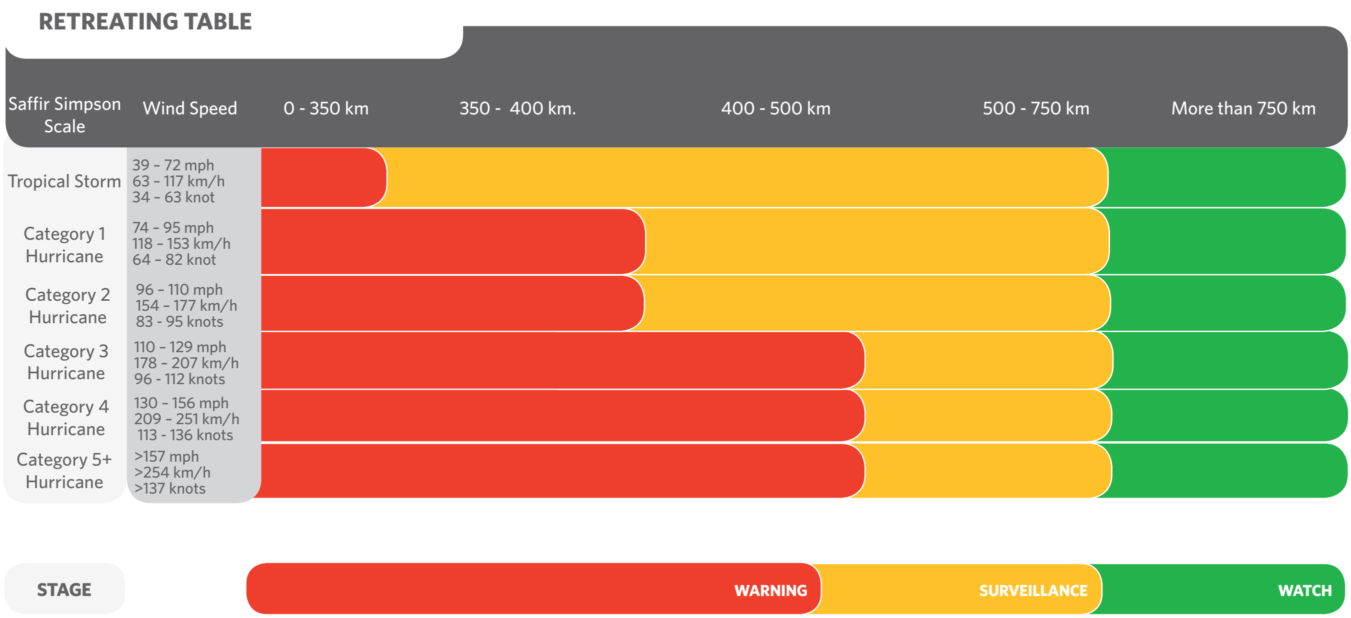


TABLE 4

Stages of the Retreating Phase of a cyclone.



Early warning actions for both the Approaching and Retreating Phases and all alert stages are summarized in Table 5. This table should be distributed among the stakeholders participating in this initiative. The information contained in the table may be updated and improved once the Protocol is put into practice.

TABLE 5

Actions to be carried out during the Early Warning Step.

DURING A TROPICAL CYCLONE

Approaching Phase			Retreating Phase	
MINIMUM DANGER	**LOW DANGER**	**MAXIMUM DANGER**	**LOW DANGER**	**MINIMUM DANGER**
WATCH STAGE	**PREPAREDNESS STAGE**	**WARNING STAGE**	**SURVEILLANCE STAGE**	**WATCH STAGE**
Issued when a meteorological phenomenon is expected to arrive in more than 72 hours.	Issued when the cyclone is expected to arrive between 72 and 36 hours to the coast at different wind speeds.	Issued when the cyclone is between 60 and 24 hours from impacting the coast until the cyclone starts retreating.	Issued when the cyclone has retreated at least 400 km.	Issued when the cyclone has retreated at least 750 km.
Committee activates the *Early Warning System*	Send SECOND Alert message	Send THIRD Alert message	Send FORTH Alert message	Send FIFTH Alert message
Head of Operations activates a Mobile Communications Group to send alerts	Buy supplies (fuel, non-perishable snacks, water and batteries).	Everyone should remain sheltered in a safe place and pay attention to any alerts.	Assess the status from everyone involved	*Committee* activates *Operations Center*
Head of Operations sends FIRST Alert message	*Committee* encourages authorities to remove marine infrastructure (buoys and/or chains that are fixed to deadweight and could be dragged by tide or wind).		Assess the condition of the sea and access routes	*Brigades leader* notifies time and place for the *First Responders* to meet. *First Responders* meet at the *Operations Center*
Brigades Leader check toolboxes to verify materials and tools are complete.	Safeguard toolboxes and equipment (boats, diving equipment, tanks, compressors, etc.) in a safe place.		*Brigades Leader* and *Head of Operations* prepare a map with all the possible access route(s) from land to the sea and within key places (*Operations Center*, piers, gas stations, etc.).	Assess the status of the toolbox and equipment.
			Committee prepares funding proposal to seek emergency funds to implement the response actions.	*Brigades Leader* divide *First Responders* into *brigades* and assigns toolboxes to each *brigade*.

During the Approaching Phase, the members of *the Committee* and the *brigades* should be warned of the potential threat. *The Head of Operations* should create a temporary WhatsApp or mobile communications group to send alert messages to keep everyone informed while the cyclone is in the area and to send updates about further actions.

The Committee should continuously monitor local forecasting reports to track the current location and intensity of the tropical cyclone, based on official bulletins issued by the entities that monitors local weather phenomena. Having a tropical cyclone tracker is handy to get constant alerts of the cyclone's location and strength as it approaches. There are several Tracker Apps for Smartphones available (see Annex 2 for more information on these).

During the Watch Stage of the Approaching Phase, the *Brigades Leader* checks toolboxes to verify the content is complete according to the content list (Annex 3) and all equipment works properly. If necessary, s/he should buy any missing materials or supplies to restock the toolboxes. During the Warning Stage of both the Approaching and Retreating Phase everyone involved in the Protocol should remain in a safe place with their families. During the Surveillance Stage of the Retreating Phase *the Committee* should monitor the storm's movement and work with local authorities to verify sea conditions and safe access routes to the sea. They should also determine when *brigades* can be deployed, and the status of the *First Responders* should be assessed. This stage starts once the storm is at least 400 km from the affected area.

Once the area is safe to operate, *the Committee* identifies a safe place to use as the *Operations Center*. Local emergency agency centers may be an option, but this requires previous coordination. During the Watch Stage of the Retreating Phase *the Committee* should verify the status of vehicles, boats, dive equipment, and toolboxes.

The Committee is also responsible for external communication, to provide the necessary reports outside the group, making the information more fluid and keeping the general public aware of the actions being implemented. In the absence of *the Committee Coordinator*, the *Brigades Leader* takes this responsibility.

STEP 3

RAPID DAMAGE ASSESSMENT

RAPID DAMAGE ASSESSMENT

Once the tropical cyclone has moved away and weather conditions are safe for work, *brigades* are dispatched to sea. Their first task is to conduct a rapid assessment to determine the level of damage to the reef and the amount of debris generated by the cyclone. This assessment should be the first action implemented in the field once the area is safe to operate.

The assessment should seek to identify the most affected reef areas and types of damage to be addressed during the Primary Response. Debris generated by the cyclone should also be assessed to determine the level of intervention required to remove it. The *brigades* will be in charge of carrying out the damage assessment, using the following techniques:

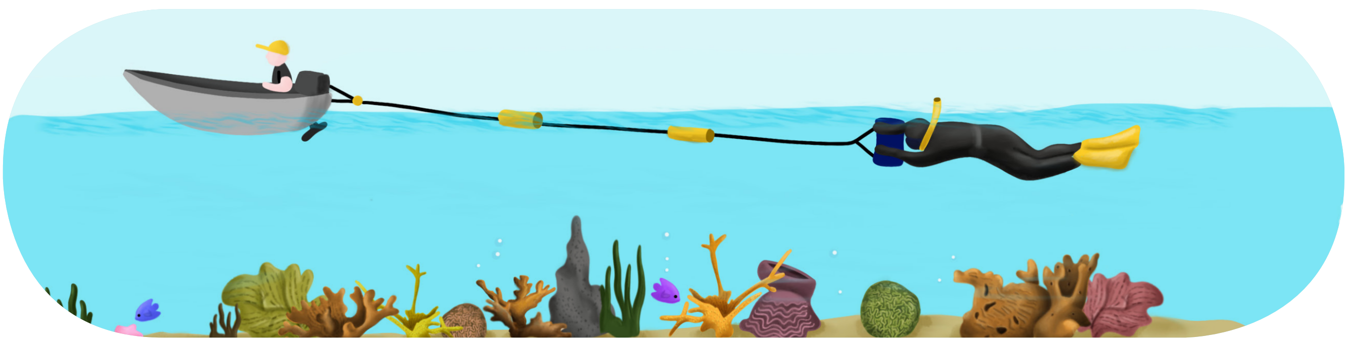
- Trawl surveys.
- Drone surveys.

TRAWL SURVEY

Brigades should conduct underwater surveys, using the trawl or "Manta Tow" techniques (see Figure 3) to document the injury/damage to corals and their location.

FIGURE 3

Manta tow technique suggested for rapid assessments (English et al. 1994).



This method involves a snorkeler that is dragged slowly by a boat while holding onto a floating device or a rope, allowing the snorkeler to record information on an acrylic slate and hold a GPS and camera for photos or videos. Information can also be recorded from the boat by other members of the *brigade*. In this case, team members should agree on a signal code that allows the snorkeler to transmit information on what it is observed on the bottom.

Information recorded includes, the category of damage and the geographical position for each recording. The level of damage is classified in six categories (Table 6).

TABLE 6

This table identifies the damage levels and categories. Damage levels represent groups of ecological impact and encapsulate both, damage to the colonies and the reef. Levels 1, 2 and 3 refer to coral damage whereas levels 4 and 5 refer to reef structural damage (Table taken from Beeden et al. 2015).

DAMAGE LEVELS

Damage Level	Category	Observed Characteristics
0	No damage	Undamaged reef
1	Minor damage	Branched corals with broken edges and tips (1 - 30%) and/or branches (1 - 10%).
2	Moderate damage	Branched and massive corals with damaged tissue and broken *fragments* (31 - 75%).
3	Major damage	Detached *coral colonies* (11 - 30%), *fragments* of various sizes of massive and branched coral loose in the bottom and among the *rubble* (31 - 50%).
4	Severe damage	Detached large *coral colonies* (31 - 50%), *fragments* buried among the *rubble* (51 - 100%). Portions of the substrate totally eroded.
5	Extreme damage	Surface of the seabed without sessile organisms, large colonies of massive and branched corals detached (51 - 100%). Seabed totally removed and with evidence of structural damage.

DRONE SURVEYS

Aerial data can estimate the amount of *disaster debris* dragged into the sea by the cyclone in shallow water areas, reefs, and along the coastline, especially in areas where boats cannot sail. Drones can be used to capture aerial data for damage assessment and obtain high resolution and georeferenced videos and images. This technique can provide a greater detail than satellite imagery and can be of lower cost, but the detail of the images will depend on the conditions of the water. Turbidity and movement can affect the interpretation of the images.

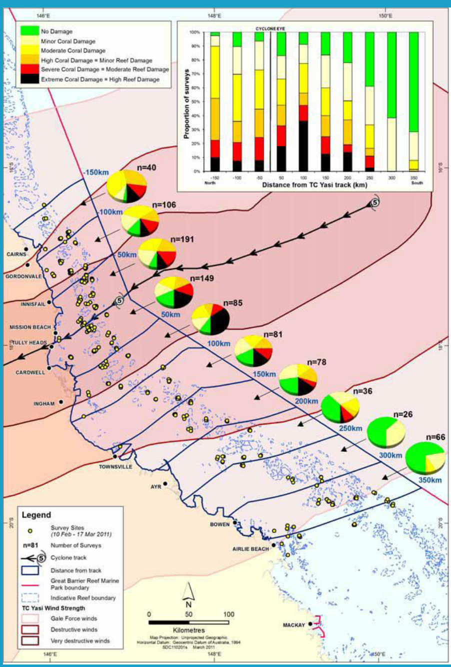
To take underwater photographs or video of the affected areas, it is recommended to do so when the boat is still, because cameras can be flooded by the variable pressure of the water in the trawls.

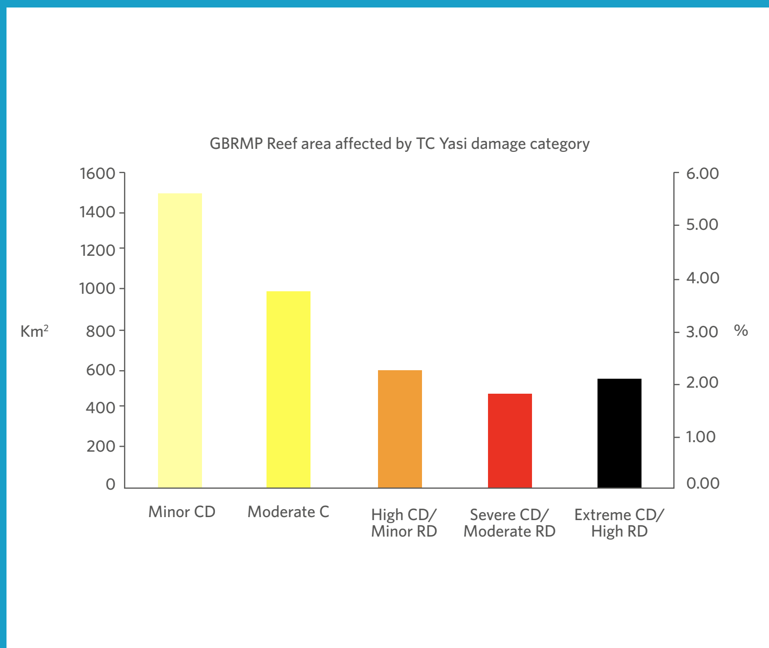
PRIORITIZE SITES FOR IMMEDIATE RESPONSE

Data generated in the surveys should be analyzed immediately, and the results should be used to generate maps (Figure 4), based in GPS coordinates, that shows general impact and the most affected sites. This will serve to prioritize the areas that require immediate response to prevent further damage.

FIGURE 4

Sample Map showing affected areas (Taken from GBPA, 2013).





In order to give assistance to the sites that require immediate attention, the following criteria should be taken in consideration:

- Sites with large whole detached and/or overturned colonies, since these are more likely to recover, giving priority to reef building corals.
- Sites that have type 3 damage where small and medium-sized colonies can be stabilized.
- Sites with considerable amount of debris that could cause further damage to the reef if not removed.
- Sites with large fragments and boulders buried among sediment and / or rubble.

STEP 4

PRIMARY RESPONSE

PRIMARY RESPONSE

This step describes the Primary Response actions that will be carried out based on the Rapid Damage Assessment prioritization. The purpose of the Primary Response is to reduce damage caused by the storm and prevent further damage from occurring. These actions include a series of rehabilitation and repair efforts that should take place ideally within the first 45 days after the cyclone.

The Primary Response consists of:

- Cleanup activities to remove debris and other objects foreign to the sea.
- Reef First Aid.

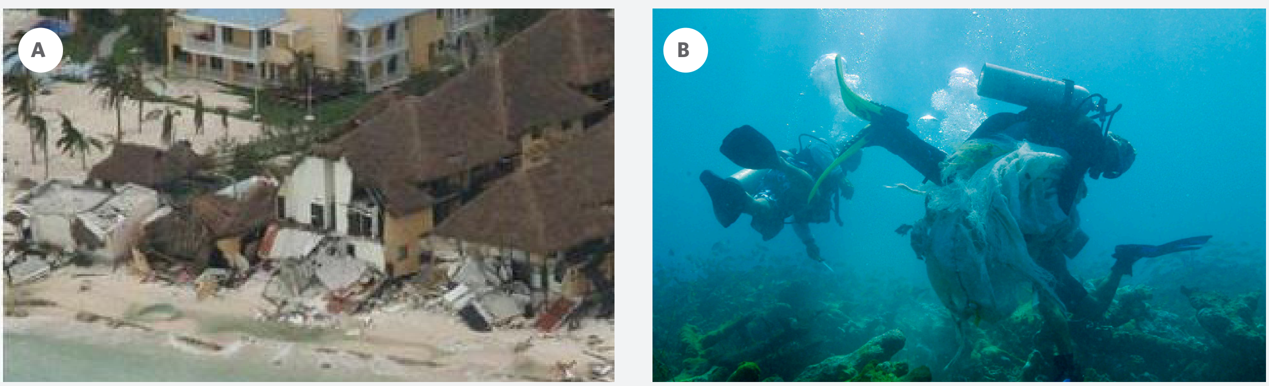
Whenever possible, cleanup activities should be done parallel with the Reef First Aid, to minimize the stress on the affected colonies.

CLEANUP ACTIVITIES

Tropical cyclones have the potential to generate a tremendous amount of debris due to the drag of wind and flooding associated. *Disaster debris* (Figure 5) can be anthropogenic (construction material, appliances, garbage, plastic bags, foreign objects, and harmful pollutants) or natural (tree trunks, branches, organic material), and both types can damage the reef. Activities include cleaning the reef lagoon, and *reef crest*, and removing objects floating in the sea or deposited on the bottom.

FIGURE 5

Debris generated by Hurricane Wilma in hotels in Quintana Roo. Photo: E. Craig. B. Cleanup actions in the reef after hurricane Wilma, 2005. Photo: J.C. Huitrón.



Debris left on reefs can continue to move around and harm corals and other benthic organisms, due to friction and dragging caused by tides, currents and wave action.

Cleanup efforts should be carried out either by diving or *snorkeling*, depending on the accessibility, depth and profile of the reef. *First Responders* should work in pairs and must always install a dive buoy on the bottom for the boat to know their location. Multiple *brigades* can be working at the same time in an area.

Having a boat available during cleanup is useful for collecting debris. When divers find large and heavy objects they should use lift bags and ropes to pick them up and either relocate them or send them to the surface (Figure 6). The use of woven, jute or bulk sacks is recommended to group smaller objects together. Once the sack is full, divers can send it to the surface using the *lift bag*. Snorkelers will receive the sacks or objects at the surface and transport them to the boat. Boat tenders will pile them on the boat for later disposal.

Underwater cleanup efforts should be repeated as many times as necessary until the area is free of debris. Debris collected during cleanup actions should be transported to the coast and discarded in the site designated by municipal authorities.

If debris is found on the beach, it is necessary that *the Committee* coordinates debris removal with local authorities to prevent debris from ending up on the reef. This is not part of the *brigade*'s tasks.

FIGURE 6
Divers sending debris to the surface with a *lift bag*.

REEF FIRST AID

Cyclones can generate a series of impacts to the reef. These can include: torn soft corals, broken tips and edges of branching corals, whole detached and overturned colonies, and structural fractures to the reef (Figure 7). Without intervention, affected organisms can be moved continuously by the current, or buried by sediment, preventing their reattachment and recovery.
As time passes, *coral colonies* impacted by the cyclone lose their chance of survival if not restabilized (due to abrasion and lack of light), or they can cause further damage to the reef.

FIGURE 7

Some of the damage caused by a cyclone. **A.** Colony of *Dendrogyra cylindrus* (pillar cora) overturned by a hurricane. Photo NOAA; **B.** Fragment of *Acropora palmata.* Photo: Kemit-Amon Lewis; **C.** Fragments of *Acropora palmata* produced by hurricane Wilma in Quintana Roo in 2005. Photo. J.C. Huitrón; **D.** Colony with abrasion damage produced during hurricane Emily in Quintana Roo in 2004. Photo: J.C. Huitrón.

During Reef First Aid, *First Responders* are responsible for the following actions, detailed in Figure 8 and described in the next pages:

- Reposition and reattach displaced, dislodged, broken or overturned massive boulders colonies or *fragments*.
- Remove colonies buried under the sand.
- Remove and/or stabilize loose *dead coral rubble* and sediment that could cause further damage to the reef.

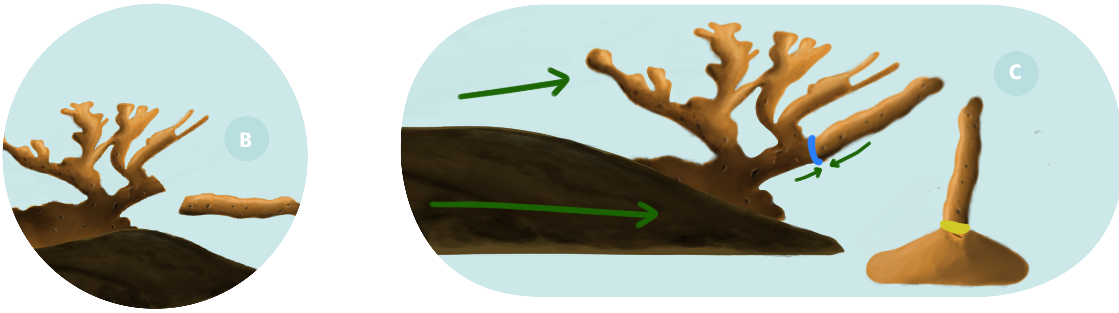
During Reef First Aid, each diver should carry plastic straps, tarred yarn and use gloves to tie and handle colonies or *fragments*. Divers can use lift bags and ropes to lift and relocate heavy corals underwater.

REEF FIRST AID

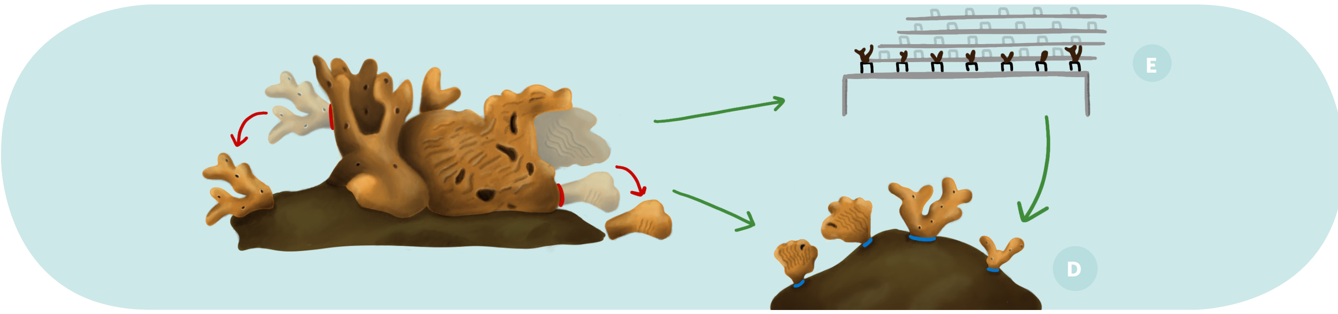
FIGURE 8

Example of Reef First Aid actions. Diagram from OCEANUS A.C.

A Large **live** and complete colonies may be reattached/cemented

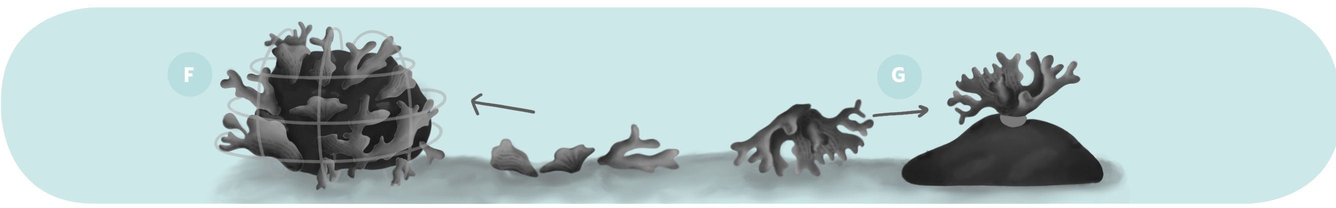


B Large **live** *fragments* may be reattached to original colony or C Cemented in new location



D Small **live** *fragments* may be cemented directly into holes or special bases

E Attached in *nurseries* for recovery and posterior relocation.



F Small **dead** *fragments* may be collected to form a conglomerate glued together with cement, isolated with special netting and attached to the bottom.

G Large **dead** colonies may be cemented to the substrate to avoid dragging and abrasion.

Impact Action Cement Plastic strap Net

REPOSITION AND REATTACH DISPLACED, DISLODGED, BROKEN OR OVERTURNED MASSIVE BOULDERS COLONIES OR FRAGMENTS

When finding large, living *coral colonies* that have been completely detached (without fragmentation), or loose *fragments* (Figure 9 and 10), *First Responders* should locate the place from where it was detached. However, after a hurricane, it is very likely that the original site of the colony cannot be located, and it will be necessary to find another suitable point for its fixation. A firm surface, free from loose material such as sand or pebbles should be chosen to ensure the fixation of colonies to the substrate. It is recommended to clean the surface with a wire brush to ensure the attachment (Figure 11). Different fixation techniques are used depending on the size of the coral and the level of impact sustained by it.

FIGURE 9

A. Colony completely detached from an Elkhorn Coral (*Acropora palmata*), Photos: Rescue/restoration efforts done by CRIAP, INAPESCA in the PNAPM. **B.** *Fragments* of *Acropora palmata* produced by hurricane Ivan in Quintana Roo in 2004. Photo: J.C. Huitrón.

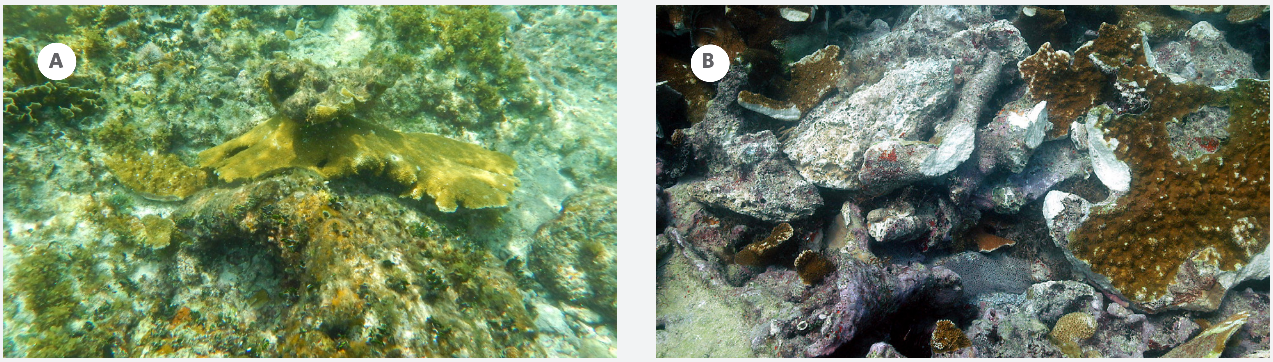


FIGURE 10

A. Whole brain coral (*Pseudodiploria strigosa),*colony overturned, and **B**. Brain coral colony *(Pseudodiploria strigosa) fragments*. Photos: Rescue/restoration efforts done by CRIAP, INAPESCA in the PNAPM.

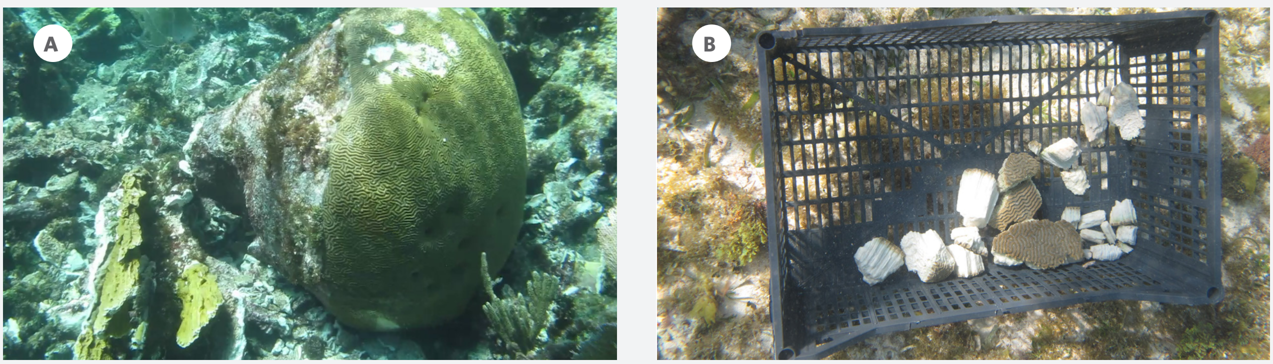


FIGURE 11
Diver brushing the surface where the cement will be placed to fix a coral *fragment*. Photo: J.C. Huitrón.

Scattered *fragments* can be wedged in holes or cracks, secured with plastic straps or tarred yarn (Figure 12), or glued with epoxy or cement (Johnson et al. 2011) (Figure 13).

FIGURE 12
A. A. Colony of *Acropora palmata* fixed with tarred yarn, and **B.** Diver fixating an *Acropora palmata* fragment using plastic straps. Photos: J.C. Huitrón from the primary assistance after hurricane Wilma in Quintana Roo in 2005.

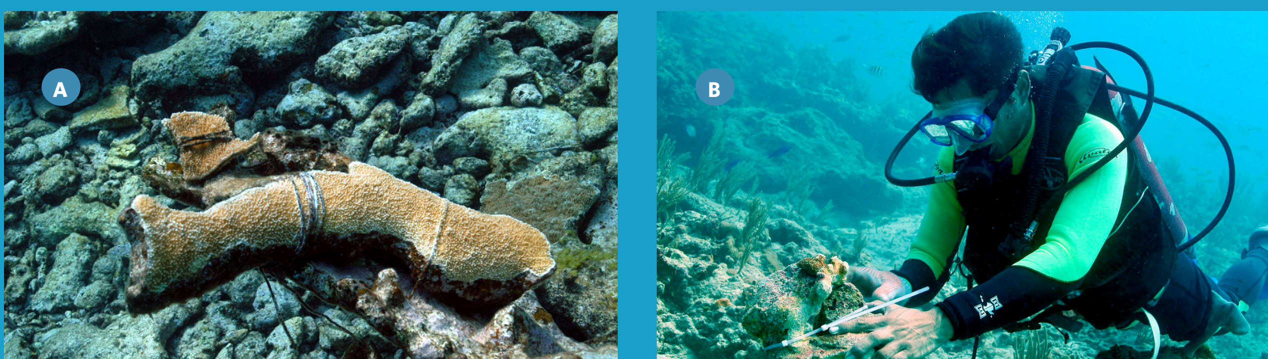


FIGURE 13

Colony of *Acropora palmata* fixed with cement.
Photo: J.C. Huitrón from the primary assistance after hurricane Emily in Quintana Roo in 2004.

Detached whole *coral colonies* and large *fragments* can be anchored to the substrate using cement, attaching the corals directly to the reef or substrate (Figure 14 and Figure 15). This ensures the stability of the colony and avoids the loss of colonies in areas with high intensity and exposure to waves.

Coral fragments and colonies should be quantified to determine the percentage of living tissue still present. Preferably, corals that have 50% or more of living tissue should be rescued and reattached.

Collect coral *fragments* with a living tissue **greater than 50% and restabilize back onto the reef.**

Reposition the *fragments* orienting the greater proportion of living tissue towards the surface so that it has access to sunlight

When there are too many small fragments, sea conditions limit time in the water, there is no suitable place to attach the fragments directly on the reef structure, or corals have little living tissue, then corals should be collected to be attached later to structures in coral *nurseries* as part of the Secondary Response actions.

There is the possibility of finding large colonies, with very little living tissue, that are very damaged, and it may not be worth trying to rescue these corals. In these cases, corals should be discarded for reattachement, or collected as fragments of oportunity to conserve the live portion, to move to the nursery.

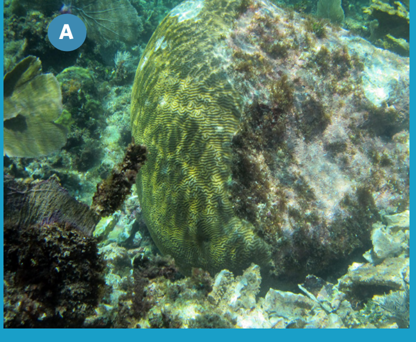
Collect small coral *fragments* or with **less than 50% of live tissue to be moved** to coral *nurseries*

FIGURE 14

Reattaching a colony of Elkhorn Coral *(Acropora palmata)* using cement and tarred yarn to place the colony in its original location. Photos: Rescue/restoration efforts done by CRIAP, INAPESCA in the PNAPM.

FIGURE 15

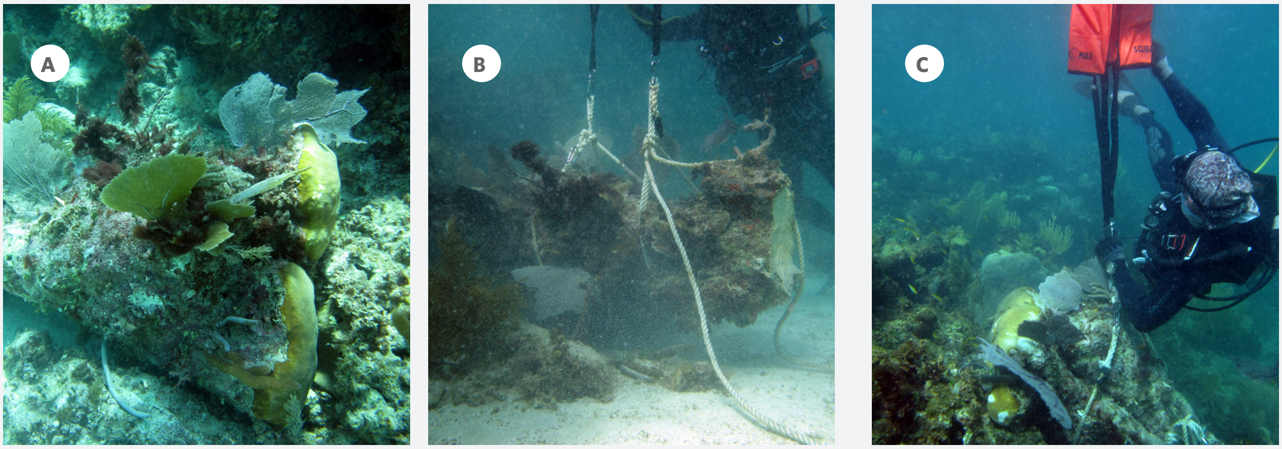
Reattaching of a brain coral colony *(Pseudodiploria strigosa).* Cement and *dead coral rubble* were used to build the base for stabilizing the boulder. Photos: Rescue/restoration efforts done by CRIAP, INAPESCA in the PNAPM.



In some cases, it is necessary to use *lift bags* to rearrange large structures that have been detached and move them to the place where they must be accommodated (Figure 16).

FIGURE 16

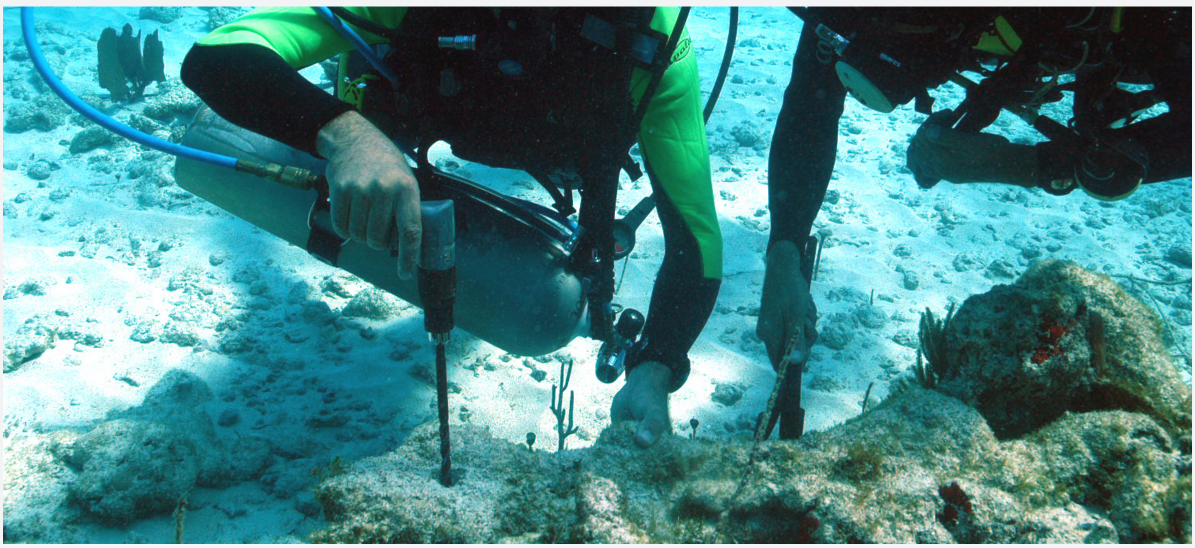
A. Detached massive coral that remained on the sand, **B.** Lifting the massive coral with the use of a *lift bag*; and **C.** Using the *lift bag* to accommodate the massive coral in a final position. Photos: Rescue/restoration efforts done by CRIAP, INAPESCA in the PNAPM.



Occasionally, when *fragments* or colonies are very large *First Responders* should use metal rods that are drilled through the colony into the substrate to ensure proper attachment to the reef substrate. To achieve this, a pneumatic drill should be used to make perforations in the colony and the substrate (Figure 17). The diameter of the drill bit should be ½ to ⅝ inches and the length of the perforation in the substrate should be 4 to 6 inches.

FIGURE 17

Diver with pneumatic drill coupled with an additional dive tank. Photos: J.C. Huitrón.



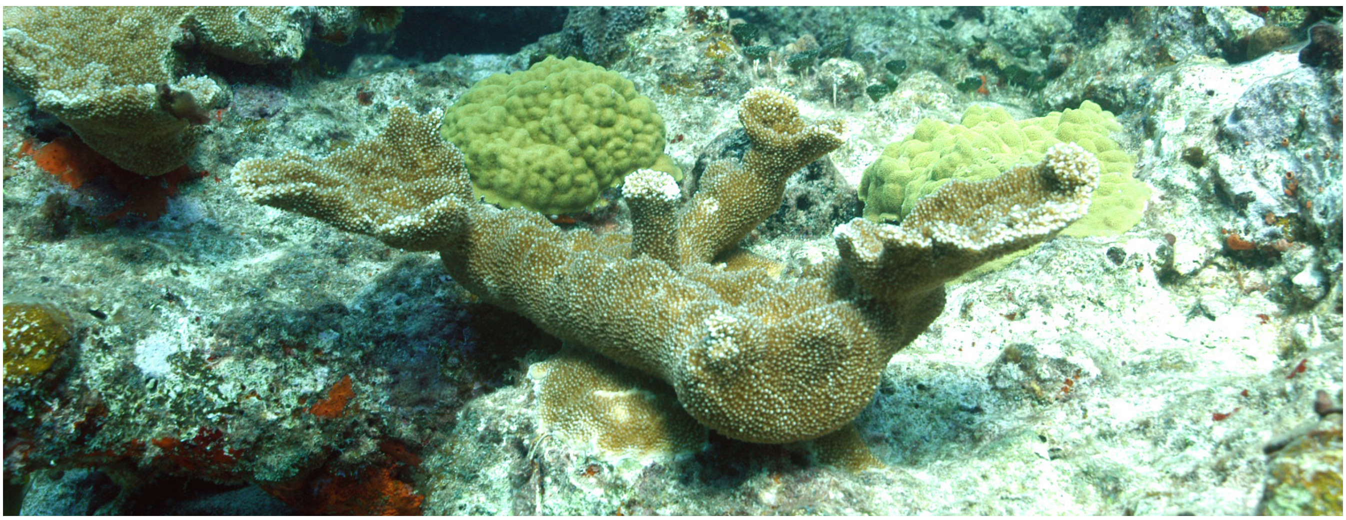
Once the perforation is done, the rod can be inserted. If the rod is not tight in the hole, it is suggested to fill in the extra space with epoxy putty. It is ideal to use a rod slightly bigger than the perforation so that it is fixed under pressure when hit with a hammer. The material of the rod can be galvanized steel or stainless steel (Figure 18). As time goes by, the coral tissue will cover the rod (Figure 19).

FIGURE 18

Acropora palmata colony fixed with a galvanized steel rod.
Photo: J.C. Huitrón, primary assistance after hurricane Wilma in 2005.

FIGURE 19

Colony of *Acropora palmata* fixed with a galvanized steel rod. In the center of the colony the rod is completely covered by the coral tissue. Photo: J.C. Huitrón.



REMOVE COLONIES BURIED UNDER THE SAND

Some *fragments* and colonies may end up buried by the sediment, which alters the capacity of zooxanthellae to fulfil coral energy requirements through photosynthesis due to lack of light (Falkowski et al. 1990; Richmond 1993). Corals can survive high sedimentation rates from 24 hours for sensitive species to a few weeks (more than 4 weeks of high sedimentation or 14 days for complete burial) for very tolerant species. Corals will attempt to clean themselves of the sediment by a combination of ciliary and tentacular action, mucus production and polyp inflation, however this expends a lot of energy and can lead to coral exhaustion (Peters and Pilson 1985; Riegel and Bloomer 1995; Riegel and Branch 1995; Erftemeijer et al. 2012).

It is necessary to dig out and clean buried corals using various techniques, depending on the level of sedimentation, the condition of the coral, and whether the coral is attached to the substrate or loose. Some techniques are the following:

- When there is major sedimentation, it is recommended to use the alternate gauge air source of the regulator to blow away sediment. This should be done from a distance of about 6 - 10 inches between the coral and air source, with low intensity air releases.

- When there is minor sedimentation, the use of the hand in a swing-wave motion can be enough to remove the sediment.

It is important not to touch the coral tissue when using these techniques, as corals are under sedimentation stress and very sensitive.

The use of an **extra tank with its own regulator** is necessary when using the pneumatic drill and when blowing away sediment from buried corals.

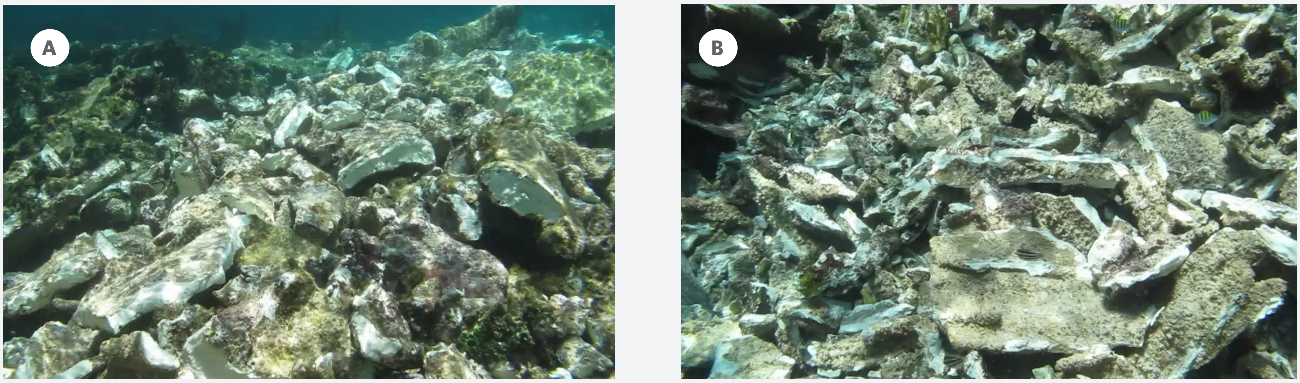
REMOVE AND/OR STABILIZE LOOSE CORAL FRAGMENTS THAT ARE CAUSING FURTHER DAMAGE TO THE REEF

After the cyclone, there is often loose material, such as dead coral rubble of various sizes (Figure 20). Loose material should be either removed or stabilized to prevent it from becoming projectiles and injuring surrounding corals.

If the option is to stabilize it, loose coral rubble can be grouped in mounds. Cement, string, wire, biodegradable nets and / or metal framework can be used to retain and consolidate the coral rubble. The shape and height of the mound must be according to the relief, roughness and height of the local reef. During the Secondary Response, consolidated rubble mounds can serve as substrate to attach rescued live coral fragments.

FIGURE 20

Loose *dead coral rubble* in the reef. Photos: Rescue/restoration efforts done by CRIAP, INAPESCA in the PNAPM.

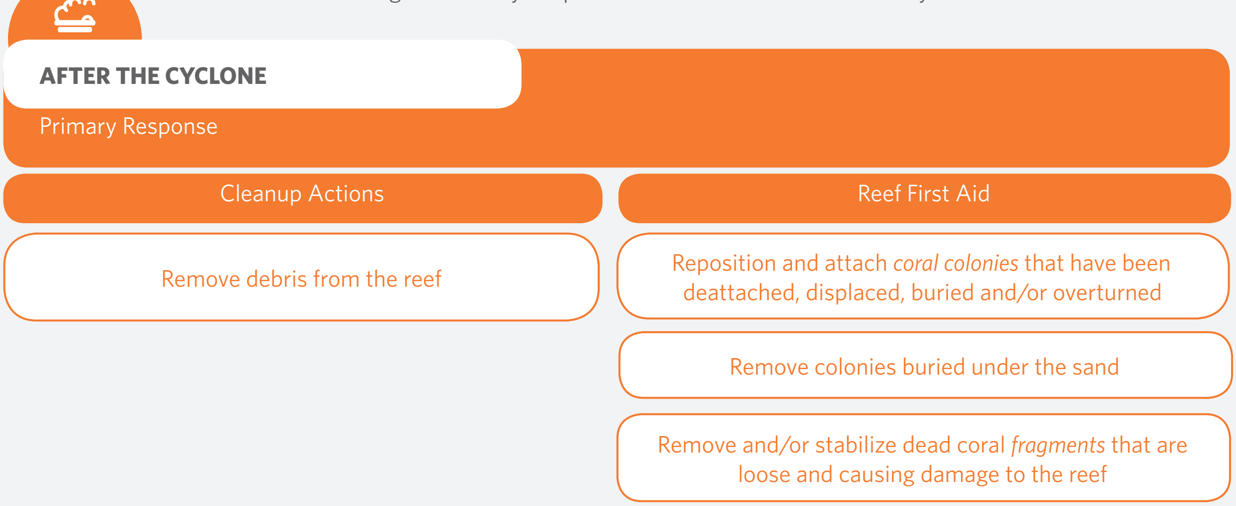


Attaching fragments over loose (unconsolidated) rubble is not recommended, because rubble continues to shift around with wave energy, tissue suffers abrasion, and fragments could end up buried. Also, it is not recommended to attach live fragments over standing dead *Acropora* branches, as these may collapse when the new colony reaches certain weight, especially if dead branches are in a porous condition.

The Primary Response actions are summarized in a flow diagram (Figure 21), which should be shared with agencies participating in this initiative. The information contained in the diagrams can be updated or improved once the Protocol is put into practice.

FIGURE 21

Flow chart showing the Primary Response actions to be done after the cyclone.



STEP 5

SECONDARY RESPONSE

SECONDARY RESPONSE

Once the Primary Response actions have been completed, *brigades* should proceed with the Secondary Response. During the Secondary Response, corals that could not be assisted during the Primary Response should be addressed. Activities include moving rescued coral *fragments* into *nurseries*, additional outplanting efforts, stabilizing structural fractures from damaged colonies and any other activities needed to restore the physical structure of the reef. It also includes providing maintenance to sites assisted during the Primary Response.

STABILIZE STRUCTURAL FRACTURES

Corals can be damaged and overturned by the current, resulting in fractures, partially cracked colonies, or broken into pieces. Smaller structural fractures can be stabilized by accommodating the dislodged pieces of coral and attaching them like a puzzle, either with epoxy clay, cement mortar or other reinforcing materials (Figure 22).

FIGURE 22

Restoration of an injury in a brain coral colony (*Pseudodiploria strigosa*).

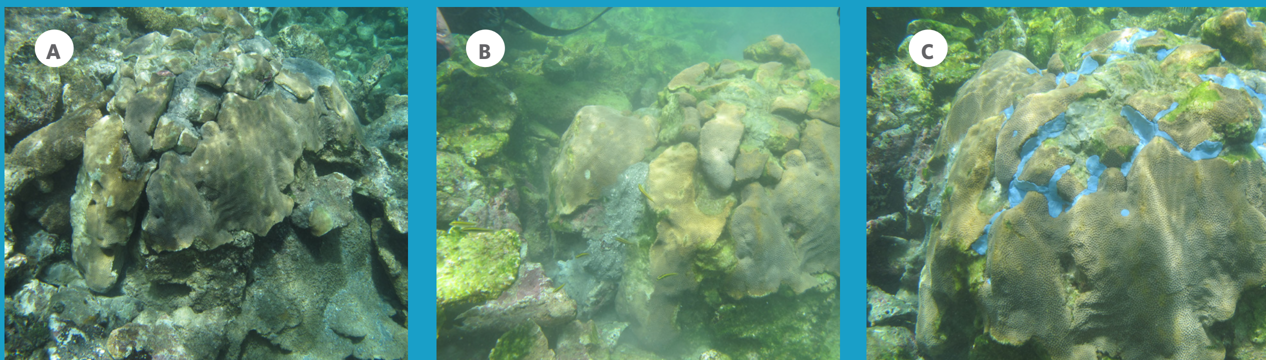
Photos: Rescue/restoration efforts done by CRIAP, INAPESCA in the PNAPM.

When fractures are very large and affect most of the colony, fractures should be stabilized to prevent them from becoming larger using mechanical reinforcements such as stainless steel rods. Larger structural fractures can be filled using *dead coral rubble* combined with cement mix. This reduces the amount of cement needed to repair the structure. First, large pieces are joined together, and then smaller ones are accommodated between the gaps. Finally, any remaining exposed areas are sealed with epoxy clay (Figure 23).

First Responders must make sure that collected coral *fragments* belong to the same colony to avoid further growth problems related to genetics.

FIGURE 23

Restoration of a massive coral colony *(Orbicella faveolata)* fragmented into several different sized pieces. Photos: Rescue/restoration efforts done by CRIAP, INAPESCA in the PNAPM.



MOVE RESCUED CORAL FRAGMENTS INTO NURSERIES

During the Primary Response, it might not be possible to reattach many loose or broken small coral *fragments*. These *fragments* should be collected, rescued, and moved for later stabilization in coral *nurseries* that can be built for this purpose.

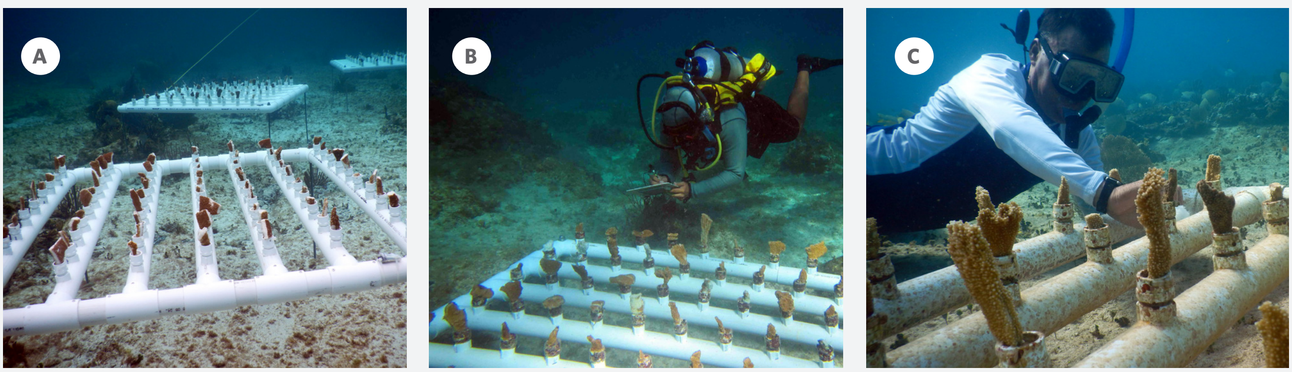
A coral *nursery* is a structure used to fix *fragments* of coral that have been rescued from the reef. These structures shelter the coral *fragments* for a certain time to allow coral colonies to stabilize and recover before they are transferred back to a permanent area on the reef. There is no ideal coral *nursery* design that applies to all the conditions or every place. Therefore, *nursery* designs should consider various factors such as water conditions (e.g. depth, wave energy, turbidity), habitat suitability, competition and likelihood of human impacts.

Coral *nurseries* should be placed in strategic areas, sheltered from strong currents, and should at least meet all the criteria described in Annex 5.

Many types of coral *nurseries* have been tested and established in the Caribbean. Figure 24 shows a *nursery* that consists of PCV structures in the shape of a grill with capacity for 70 *coral colonies* each.

FIGURE 24

Coral *nursery* built with a rectangular structure of PCV. This model is used by OCEANUS A.C. Photos: OCEANUS A.C.



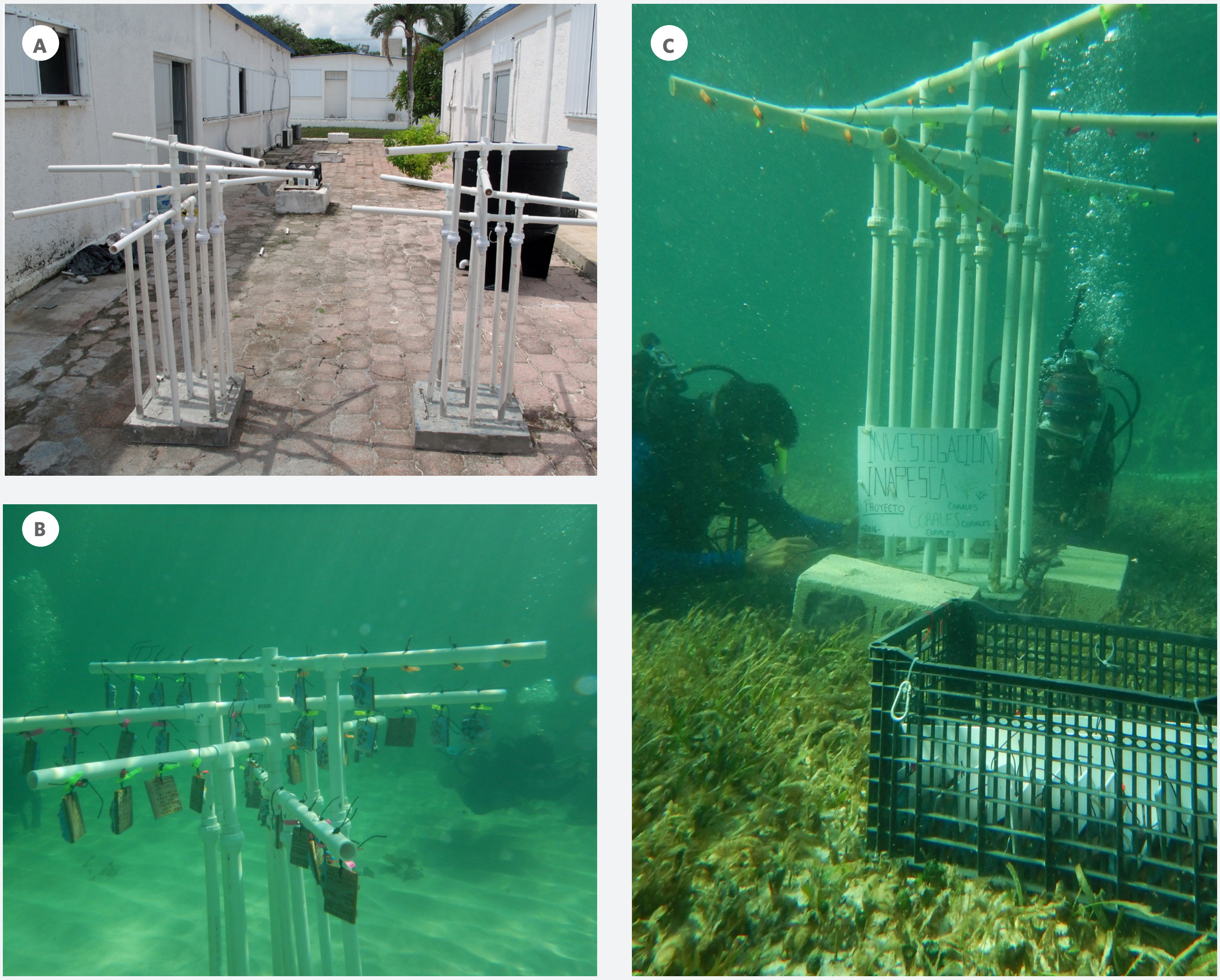
Other types of *nurseries* depend on specific requirements. During an emergency vessel grounding in Quintana Roo, Mexico, the Aquaculture and Fishery Research Regional Center (CRIAP in Spanish) built a dome shaped *nursery*, made of electro-welded mesh, anchored to the bottom with construction blocks (Figure 25).

This design is simple, with low-cost materials that can be easily purchased, and does not require a prior preparation. The advantage of this design is that it can be installed quickly and has a large capacity for *coral colonies*, but it has the disadvantage that only small pieces of coral can be secured to the structure. Colonies can be attached with yarn or cable ties.

FIGURE 25
Dome shaped coral *nursery*, built with electro-welded mesh and anchored with construction blocks. This model was used by the staff of the CRIAP / INAPESCA to rescue broken *coral colonies* during vessel grounding.

Nurseries can also be installed on sandy areas to keep *coral colonies* hanging on previously manufactured PCV structures. Figure 26 shows a coral *nursery* that was used in a project of CRIAP-INAPESCA to hang plates with coral colonies produced through micro-fragmentation techniques. The system has union knots to facilitate its assembly and disassembly. Each unit has a capacity for 40 plates of coral tissue.

FIGURE 26
Hanging coral *nursery* built with a PCV structure used by the staff of CRIAP, INAPESCA.
Photos: CRIAP Puerto Morelos, INAPESCA.



Other types of *nurseries* include a pyramid shape with capacity for 50 colonies that serves to keep the structure away from the sand (Figure 27); and a modular *nursery* that supports 9 grills with a capacity for 100 colonies each, for a total of 900 colonies (Figure 28). Coral *nurseries* built with PCV are versatile and can be constructed into various shapes to adapt to the conditions of thesite and the nursery functionality required.

FIGURE 27
Pyramid shaped coral *nursery* built with PCV used by CRIAP, INAPESCA.

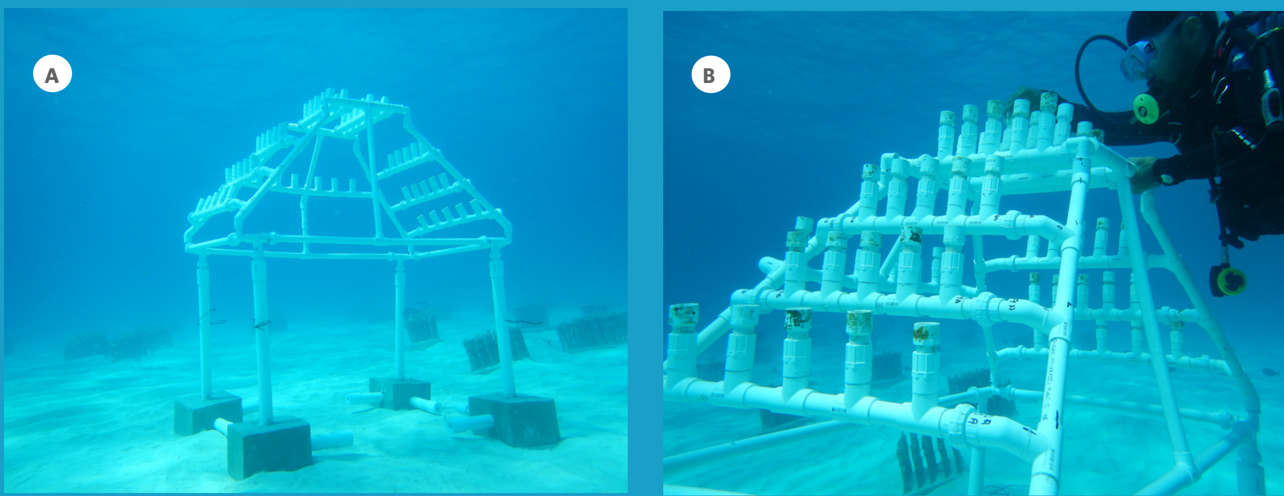
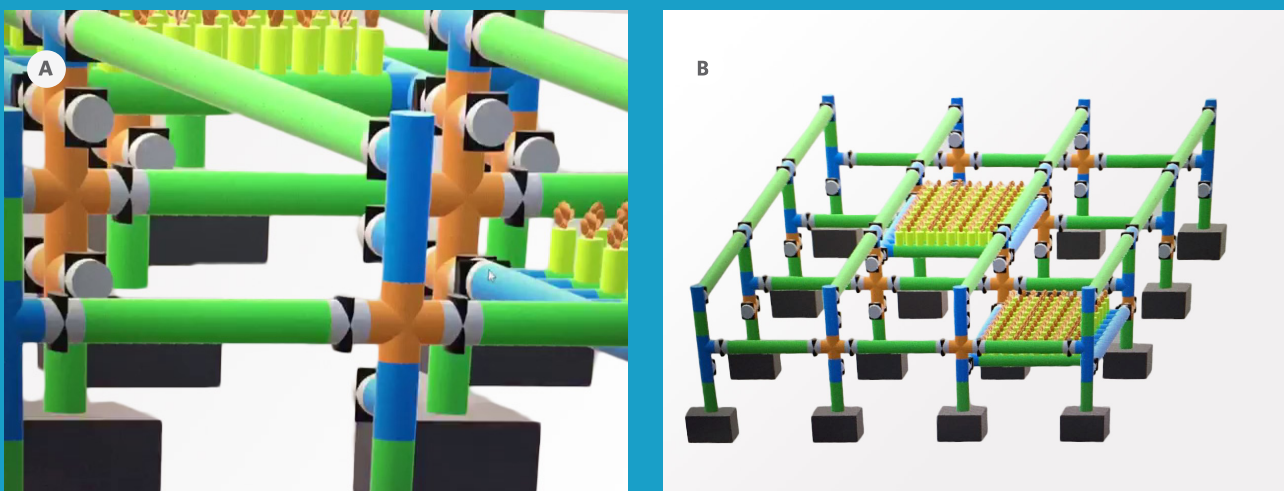


FIGURE 28
Modular grills coral nursery built with PCV used by CRIAP, INAPESCA.



MAINTAIN AND MONITOR NURSERIES AND SITES ASSISTED DURING THE PRIMARY RESPONSE

Maintenance

Coral *nurseries* and sites assisted during the Primary Response require routine maintenance to keep macroalgal growth and other benthic organisms under control. Maintenance should be implemented whenever required.

Maintenance actions do not require expertise or extensive knowledge of coral biology; therefore, divers from local diving centers could provide this support.

Maintenance activities may include the following:

- Remove algae and other organisms potentially harmful to corals (tunicates, sponges, hydroids, etc.) growing on the *nursery* structure. They can be removed using small wire brushes, paint brushes or scrubbers (Figure 29). When removing these organisms, divers must be careful not to damage the coral *fragments* during the process.
- Remove macroalgae and other organisms growing on the corals. If these have reached the coral tissue, a curved blade should be used to remove the damage.
- Remove predatory species from corals, such as snails and fire worms.
- Stabilize broken, damaged or diseased *fragments* using epoxy or other mechanisms.
- Check and repair the structure of the *nursery* and change damaged parts, especially materials used for attaching corals and anchoring nursery structures.
- Remove or isolate diseased corals.
- Carry out coral fragmentation and propagation when necessary.

FIGURE 29
A. Diver cleaning macroalgae from a coral *nursery* in Bajo Pepito, Isla Mujeres Bay. Photo: J.C. Huitrón.
B. Wire brush used for cleanup in the *nursery*.

A

B

Monitoring of nurseries and assisted sites

Routine monitoring is also helpful to assess the general condition of corals, both, in the *nursery* before outplanting and in the sites assisted during Primary Response. Monitoring should be done as frequently as possible through a quick visual/minimum effort assessment, with data collected on:

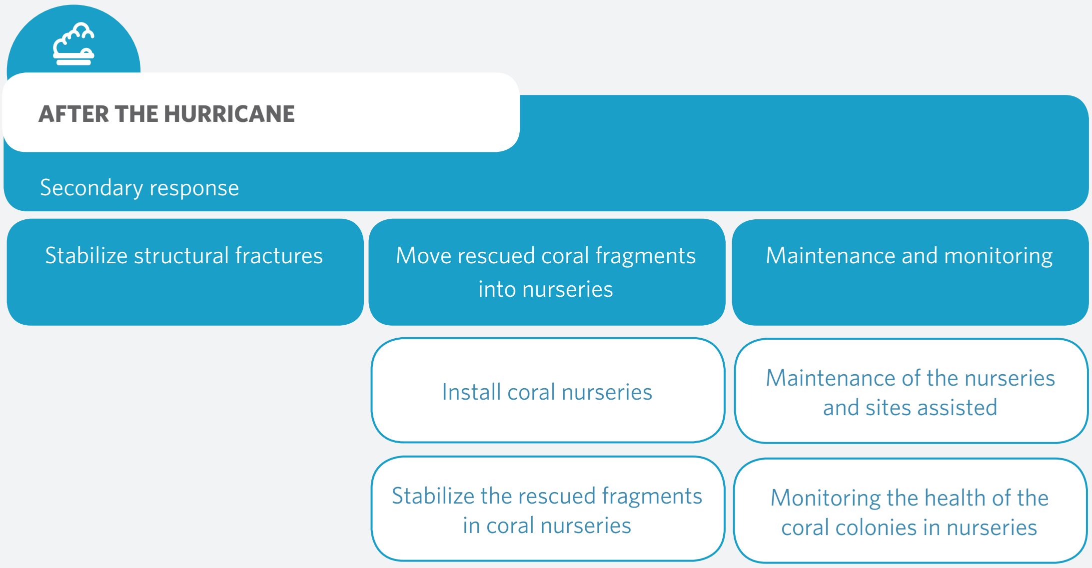
- Presence or absence of predators, opportunistic

- species, bleaching and diseases.
- Percent survival.
- Condition of the *fragments*.

Secondary Response actions are summarized in a flow diagram (Figure 30), which should be shared with the agencies participating in this initiative. The information contained in the diagrams can be updated or improved once the Protocol is put into practice.

FIGURE 30

Diagram showing Secondary Response actions to be done after the cyclone.



STEP 6

POST-RESPONSE ACTIONS

POST-RESPONSE ACTIONS

EVALUATE AND UPDATE THE PROTOCOL

Each year, once the Primary and Secondary Response actions have been completed, an evaluation must be carried out to improve coordination, communication, and promote accountability, transparency and build constituency. This evaluation should assess the effectiveness of implementing the Protocol, including failures and achievements. The annual evaluation should be conducted by the Brigades Leader (see Annex 6). The evaluation can be done through a meeting with involved participants in the response efforts. The Brigades Leader should analyze the evaluation and submit a report to the Committee with the results from the annual evaluation. This report should then be used to identify areas of improvement for the following year. The Committee should integrate recommendations from the evaluation and make the appropriate adjustments to improve the response the following year, procure any additional equipment needed, make any additional necessary alliances, and obtain required funds.

PREPARE A RESTORATION PLAN

The Committee in conjunction with other relevant stakeholders, should define a restoration goal for the affected area. The proposal should include the outline from the restoration project and the financial mechanism to support it. Restoration efforts should follow the *Guidance Document for Reef Management and Restoration to Improve Coastal Protection*: *Recommendations for Global Applications based on lessons learned in Mexico*, published by The Nature Conservancy in 2018. http://reefresilience.org/wp-content/uploads/Guidance-for-Reef-Management-and-Restoration_digita.pdf

SECTION 3

GLOSSARY & REFERENCES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GLOSSARY

The glossary provides the definition of terms and keywords used in the Protocol, which are bold in their first appearance and italicized in the rest of the text.

Brigade: Organized team of *First Responders* who work on the reef under a work scheme, to implement the response actions of the protocol.
Brigades Leader: Person in charge of coordinating the response brigades.
Committee: Interdisciplinary working group in charge of coordinating and supervising the activities in the Protocol before, during and after a tropical cyclone.
Coral colony: Numerous genetically identical polyps that are connected to each other by tissue and displaced in a simple body over a calcium carbonate skeleton.
Dead coral rubble: Coral *fragments* and reef structure that have been broken or dislodged and died, with no living tissue left.
Disaster debris: Natural vegetation, (branches, trunks, etc.) or anthropogenic material (artificial structures, appliances, construction material, garbage, etc.) left by the cyclone in the coast and sea.
Early Warning System: System to issue warnings about the approach, presence, imminence or retreating of a weather phenomenon, allowing the post-hurricane *committee* and *Brigades* to act appropriately and with sufficient time.
First responder: Diver or snorkeler with specialized training to assess and provide assistance to the reef after a tropical cyclone.
Forecast: A temporary prediction or estimate of actions and possible effects of future weather events.
Fragment: A section of coral colony that has been separated and fragmented, naturally or induced; *fragments* are taken to coral *nurseries* and used in propagation/transplant areas.
Head of Operations: Leader of the Operations Team, responsible for facilitating communication, supplying materials, and other logistic tasks for the implementation of the Protocol.
Lift bag: Diving equipment consisting of a robust and air-tight bag with straps, which is used to lift heavy objects underwater by means of the bag's buoyancy.
Nursery: Place in the sea (or less commonly, on land) that provides structures for corals to be stabilized and grown before being transplanted onto reef to help recover degraded reef areas.
Operations center: Site from where the Primary Response actions operate.
Per Diem: Refers to a set daily rate that an employer provides to cover expenses related to the services provided from an employee or a consultant. The term "per diem" is Latin for "each day."
Propagation: Process of increasing the number of coral colonies. It can be done by cutting or pruning fragments from an adult colony (coral larger than 30 cm) into smaller segments called "fragments".
Reef crest: The shallowest part of the reef, commonly marked by waves breaking.
Reef lagoon: Shallow and elongated body of water parallel to the coastline and separated from the open sea by a natural barrier (reef)..
Response plan: A course of action that can be acted upon in the case of an event that damages the reef in order to quickly mitigate impacts and reduce any further damage. It consists of a pre-made list of relevant contacts and tasks that need to be completed in an orderly manner.
Simulation Drill: Test and application of previously planned actions in a simulation of a phenomenon, to observe, prove and correct effective responses to possible real emergency/disaster situations. It involves a scenario in a specific place based on risk identification/analysis and the vulnerability of the affected systems.
Snorkeling: Swimming at the surface of the water using a mask, snorkel and fins.
Tropical cyclone: A tropical cyclone is a generic term used by meteorologists to describe a rotating, organized system of clouds and thunderstorms that originates over tropical or subtropical waters and has closed, low-level circulation.
Tropical Cyclone Season: Period of the year when most tropical cyclones form within a specific basin. Table 2 in Step 2 (Early Warning) shows the world's seven tropical cyclone seasons.
Zooxanthellae: Symbiotic, unicellular algae that live as symbionts inside the coral tissue and produce most of the coral's energy requirements through photosynthesis (Erftemeijer et al. 2012).

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ANNEXES

ANNEX 1

BUDGET

A blank budget is provided as an example for expenses commonly required to implement the Protocol during the Rapid Assessment and the Primary Response. This budget is based on the level of intervention by brigades, where the cost of each activity is determined by unit effort (boat, people, equipment, materials, linear meter, etc.).

	EXPENSES					
	STEP/ACTION	AMOUNT	UNIT	# DAYS	UNIT COST USD$	TOTAL COST USD$
DAMAGE ASSESSMENT	**Underwater Damage Assessment**			2		
	Per Diem					
	Snorkelers (3), boat tenders (2), sailor (1) & captain (1)					
	Materials, Tools and Equipment (See list in Annex 3)					
	Rental					
	Boat rental					
	Supplies					
	Fuel for the boat and snacks for Brigades					
	Aerial Assessment (Drone-based)			2		
	Per Diem					
	Surveyor (2)					
	Materials, Tools and Equipment					
	Drone					
	Prioritize Sites for Immediate Response			2		
	Rental					
	Meals and venue for the meeting					
	Consultant fees					
	Assessment report					

	EXPENSES					
	STEP/ACTION	AMOUNT	UNIT	# DAYS	UNIT COST USD$	TOTAL COST USD$
PRIMARY RESPONSE	**Marine Cleanup**					
	Per Diem					
	Divers, snorkelers, boar tenders, sailor, captain					
	Materials, Tools and Equipment (See list in Annex 3)			4		
	Rental					
	Boat, vehicle, diving tanks rental.					
	Supplies					
	Fuel for boat & vehicle, and snacks					
	Reef First Aid					
	Per Diem					
	Divers, snorkelers, boat tenders, sailor, captain					
	Materials, Tools and Equipment (See list in Annex 3)			20 - 45		
	Rental					
	Boat, vehicle, diving tanks rental.					
	Supplies					
	Fuel for boat & vehicle, and snacks					
MISCELLANEOUS	**Operating Expenses**					
	Per Diem					
	Head of Operations & Assistants					
	Materials, Tools and Equipment (See list in Annex 3)					
	Communication expenses					
	Communication (phone plans, etc.)					
	Supplies					
	Fuel for vehicle					
	Other expenses					

ANNEX 2

TROPICAL CYCLONE TRACKER APPS

- **Hurricane by American Red Cross:**

This award-winning, free iOS and Android app not only tracks and forecasts the hurricanes, it also explains how to make and execute an emergency plan and how to use social media, text, or email to tell others you're safe during and after a storm.

Find the App in this link: https://www.redcross.org/get-help/how-to-prepare-for-emergencies/mobile-apps.html

- **The Weather Channel**

Many people with smartphones have this free app already to check their weather on a daily basis, so using it to track hurricanes will be easy and not require any new downloads. Detailed radar maps, forecasting, and severe weather alerts are combined with video reports on specific storms including hurricanes for comprehensive coverage.

Find the App in this link: https://weather.com/apps

- **Storm by Weather Underground**

However, if you want to a deeper dive into current hurricane conditions, The Weather Channel's partner claims its app's "hyperlocal" forecasts use the "most advanced severe weather algorithms to provide a detailed analysis of an impending storm," making it potentially one of the most accurate hurricane trackers at your fingertips.

Find the App in this link: https://www.wunderground.com/download

- **Hurricane HD by Kitty Code**

This iOS-only, award-winning app is especially good for iPad users due to its level of detail and comprehensive features. There are free and paid versions of this app, The app offers detailed storm tracking and forecasting, satellite and radio imaging and maps, text bulletins, global models, and news feeds.

Find the App in this link: http://kittycode.com/2011/05/hurricane-hd-2-0/

- **Hurricane Tracker by EZ Apps**

Using four simple categories at launch, this iOS app lets you see detailed threat level and radar maps, National Hurricane Center updates, video forecast updates, and real-time alerts for hurricanes, tropical storms, tropical depressions, and invests. There are free and paid (ad-free) versions of this app, which has more than 65 maps including animated maps and images.

Find the App in this link: https://itunes.apple.com/us/app/hurricane-tracker/id327193945?mt=8

- **NOAA SuperRes Radar US by Shuksan Software**

This iOS app is aimed at weather enthusiasts and boasts high resolution graphics four times more detailed than other apps as well as full text warnings from the National Weather Service. Multiple map styles and different view options make this app a good one for serious trackers. This third-party app is not an official platform of the National Oceanic and Atmospheric Administration or the National Weather Service. As with any app that relies on mapping software, these hurricane trackers should be used sparingly as maps can drain battery power quickly, which could be catastrophic in an emergency situation. Turn off when not in use.

Find the App in this link: https://itunes.apple.com/us/app/hurricane-tracker/id327193945?mt=8

ANNEX 3

MATERIALS, TOOLS AND EQUIPMENT FOR THE IMPLEMENTATION OF THE PROTOCOL.

	STEP/ACTION	AMOUNT	UNIT
OPERATIONS TEAM	First Aid Kit	1	Unit
	Extra, new or recharged batteries	6	Dozens
	Extra SD memory	6	Units
	Marine VHF radio	1	Unit
	Portable power plant	1	Unit
	Cellphone	1	Unit
	5-gallon containers (fuel and lubricant containers).	4	Units
RAPID ASSESSMENT	GPS	1	Unit
	Trawling device (Manta tow)	1	Unit
	Underwater camera	1	Unit
	3/4 – inch silk cord	25 / 82	Meters / feet
	Acrylic writing table	1	Unit
PRIMARY RESPONSE: CLEANUP EFFORTS	Woven Sacks	12	Units
	Diving gloves	12	Pairs
	Lifting bags	1-3	Units
	Marine rope (1-meter / 3 feet length)	12	Units
	Dive buoys	3	Units
RIMARY RESPONSE: REEF FIRST AID	Rubber bands-different sises	15	Dozens
	Plastic straps (35-40 cm)	20	Dozens
	Diving slates (30x25cm)	1	Unit
	Ziploc bags	100	Units
	Cement	100	Kilograms
	Thick plastic bags to dosify cement	6	Units
	Extra batteries	2	Dozen
	SD memory	1	Unit

MATERIALS, TOOLS AND EQUIPMENT FOR THE IMPLEMENTATION OF THE PROTOCOL.

	STEP/ACTION	AMOUNT	UNIT
RIMARY RESPONSE: REEF FIRST AID	Submersible camera	1	Unit
	GPS in waterproof bag	1	Unit
	Tarred yarn	1	Roll
	Bronze hooks	6	Units
	Large and small carabiners	6	Units
	Diving buoys	3	Units
	¾ inch silk rope	25 / 82	Meters / feet
	Lifting bags	1	Unit
	Submersible drill with broach	1	Unit
	Diving gloves	12	Pairs
	Low pressure hose with adapter for pneumatic drills	3	Units
	Wire brushes	6	Units
	Lump hammer	1	Unit
SECONDARY RESPONSE: MAINTENANCE OF ASSISTED SITES	Wire and nylon brushes		
	Small paint brushes		
	Scrubbers		
	Plastic straps		
	Pliers or cutters		
	Epoxy		
	Flexible plastic rulers or calibrators		
	Clipboard		
	Pencils		
	Thin diving gloves		
	Coral ID badges		
	Underwater camera		

MATERIALS, TOOLS AND EQUIPMENT FOR THE IMPLEMENTATION OF THE PROTOCOL.

Bronze hooks

Marine rope

Clipboards

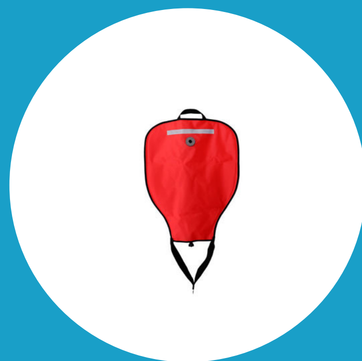
Ziploc bags

Diving buoys

Mechanical pencils with extra lead

Plastic straps

Carabiners-different sizes



140 pounds lifting bags

Mesh bags

Rubber bands

Diving gloves

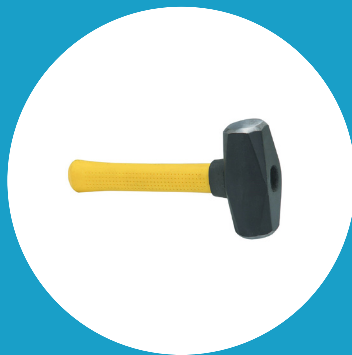
Pneumatic drill with hose

Low pressure hose

Additional weights

Cement

Tarred yarn



Lump hammer

Cement dosing device

Jute sack

Woven sack

Bulk sack

ANNEX 4

BRIGADES FORM

The following application describes required information from support staff interested in participating as *First Responders* in the *brigades*:

BRIGADE MEMBER INFORMATION

Full name

Affiliation

Home address

Landline | Mobile phone

Driving certificate: Yes ○ No ○ | Mechanical: ○ Automatic: ○

Boat handling and driving capabilities: Yes ○ No ○

Snorkeling technique and swimming capabilities: Yes ○ No ○

Diving certificate: Yes ○ No ○ Certifying diving agency:

Accident insurance: Yes ○ No ○

Company | Policy No.

Life insurance: Yes ○ No ○ Social Security type/number:

Diving insurance: Yes ○ No ○ Diving insurance number:

Company | Date of expiration:

Blood type: | Tetanus vaccine: Yes ○ No ○

ANNEX 5

CORAL NURSERY SITE SELECTION CRITERIA

Coral Nursery Site Selection Criteria (Johnson et al. 2011):

- **Presence of wild populations:**

Coral reef habitats/areas with healthy Acropora populations provide adequate environmental conditions for coral growth in nearby nurseries.

- **Adequate depth:**

Successful *Acropora* nurseries have been set-up at depths of 2-10 meters (6.5 – 32 feet) , which is where this species traditionally lives. Deeper places can protect from storms and navigation impacts but can result in reduced growth.

- **Water movement:**

Ideal nursery locations provide moderate to low water movement without causing excessive physical damage to structures or corals. Consider changes in seasonal weather patterns that could dramatically affect site conditions at different times of the year.

- **Substrate type:**

The appropriate type of substrate depends on the type of nursery you are installing. Fixed nurseries can be set-up in most types of substrates (i.e., sand, coral debris, or hard substrate) but could require different anchoring methods (i.e., bars, cement). Floating nurseries are typically set-up on sandy substrates but can also be anchored in other types of substrates. Try to avoid places with gravel and sand in constant movement as they could potential damage the corals.

- **Area size:**

The area selected for the nursery should have adequate space for expansion to accommodate additional colonies over time.

- **Adjacent habitat:**

Consider the local conditions when assessing proper proximity to the reef. Areas adjacent to healthy reefs with adequate trophic structures can provide a source of herbivores but also coral predators.

- **Presence of competitors:**

Coral competitors such as algae and sponges can quickly colonize nursery platforms and overburden the coral nurseries, even at significant distances from the natural reef habitat. Periodic cleanup is necessary to minimize damage when these organisms are present. Predators need to be removed in areas where worm and snail populations are a source of mortality in the coral nursery.

- **Presence of human impacts:**

Nurseries should be setup in areas with minimal human activities to reduce coral and platform damage. Areas where human activities are limited, such as park core zones, are ideal places for nurseries.

- **Accessibility:**

Nursery accessibility is a key consideration, especially when frequent or intense maintenance is required. Nurseries setup in shallow areas near the home base minimize fuel, boat and diving costs.

- **Number of nurseries:**

There is a logistic balance between the number of nurseries that can be setup and the care and maintenance provided to each site. Having several nurseries in different environments minimizes the likelihood that a given disturbance, such as a disease outbreak or storm, could destroy all the nurseries.

- **Permit:**

It is important to obtain the necessary permits before starting a coral nursery. Partnerships should be established with the marine park managers to select appropriate sites to setup the nurseries.

ANNEX 6

ANNUAL EVALUATION REPORT

THIS IS A LIST OF CONSIDERATIONS TO BE INCLUDED IN THE ANNUAL EVALUATION REPORT THAT WILL BE ELABORATED BY THE BRIGADES LEADER.

a. Brigade leader name.

b. Number *brigades* deployed.

c. Number of First Responders.

d. Tropical cyclone name and category.

e. Number of hours / days worked.

f. Diving effort (number of dives per operation).

g. Number and name of participating boats.

h. Number of participating vehicles.

i. Amount of fuel spent on vehicles and boats.

j. Indicate any items lost or damaged form the Toolbox.

k. List of partners that helped with the activity
(specify type of help: equipment, material, staff).

l. Expenses to be reimbursed, if any.

m. Results in quantitative units (number of colonies relocated or repositioned, number of bags or kilograms of debris collected, number of fragments rescued and established in nurseries, etc.).

n. Incidents or unforeseen events during the response, if applicable.

o. Protocol feedback and suggestions.

p. Additional comments.

The Nature Conservancy

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