REEFhabilitation
Rebuilding reefs together

REEFhabilitation Experience

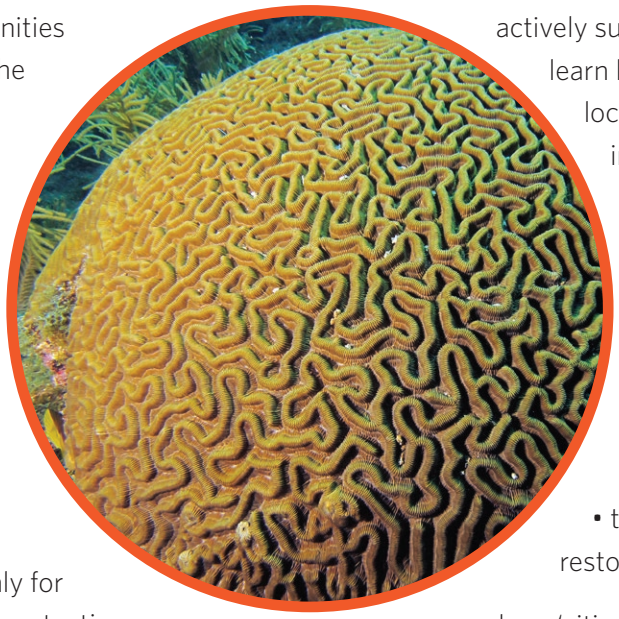
Instructional Guide and Resources

A volunteer coral gardener outplants young corals near Bávaro, Dominican Republic. © Paul A. Selvaggio

Introduction

Essential to both life underwater and on land, coral reefs are complex ecosystems that need and deserve to be protected against a host of current threats.

Rich with marine biodiversity, they support global ocean health and provide extremely valuable ecosystem benefits for people around the world, particularly for communities that are highly vulnerable to the impacts of climate change. Among the most important benefits of coral reefs are coastal protection—which occurs when coral reefs absorb wave energy and thereby reduce coastal erosion and flooding—and revenue from tourism and fisheries. It is vital to maintain healthy reefs and restore degraded ones, not only for preserving our oceans but for protecting community well-being and national economies.



The goal of the REEFhabilitation Experience is to provide tourists and community members who care about the ocean with an opportunity to actively support coral restoration and learn how they can help address local and global threats to reefs, including ocean warming, overfishing and coastal pollution. This guide provides dive instructors and operators with information and recommendations for offering the REEFhabilitation Experience. It covers:

- the basic concepts of coral restoration science and techniques
- how 'citizen science' or 'community science' can help coral reefs
- resources for dive masters/instructors to best provide the REEFhabilitation Experience

COVER A parrotfish takes shelter under healthy elkhorn corals. © Shane Gross
THIS PAGE Grooved brain coral is an important reef-building species in the Caribbean. © iStockphoto

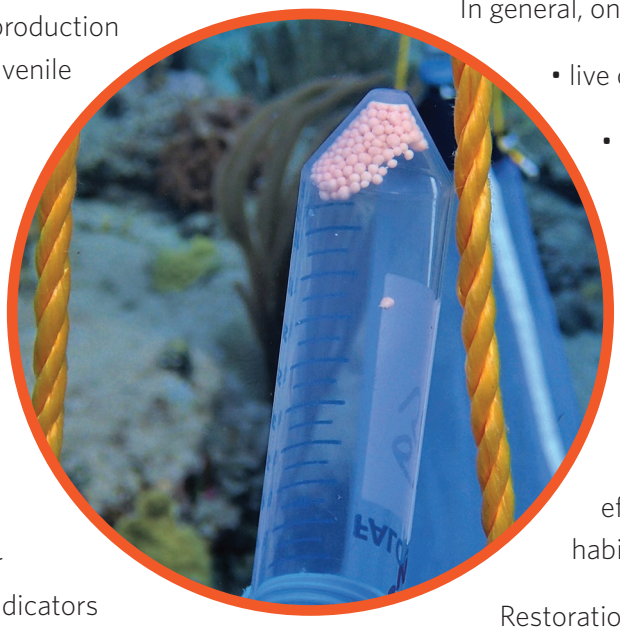
What Is Coral Restoration?

Restoration refers to a process in which humans intervene to help ecosystems recover when they are unable to recover on their own.

Restoration aims to improve an ecosystem that is threatened or damaged by positively impacting certain metrics which have suffered due to a myriad of threats—such as the number of native species present, the rate of species reproduction or the presence of abundant juvenile plant and animal life. There are many ways that humans can intervene to promote ecosystem recovery—for example, by assisting the reproduction of threatened species, supporting natural habitats or protecting against invasive species.

The science of coral reef restoration aims to promote or recover various attributes or indicators of marine ecosystem health. The health of coral reefs is typically evaluated in terms of:

- live coral cover, or the percentage of reef area covered by live corals
- algae cover, or the percentage of reef area covered by algae
- rugosity, or a measure of structural complexity of the reef, which indicates its ability to provide habitat and refuge to reef fish and invertebrates



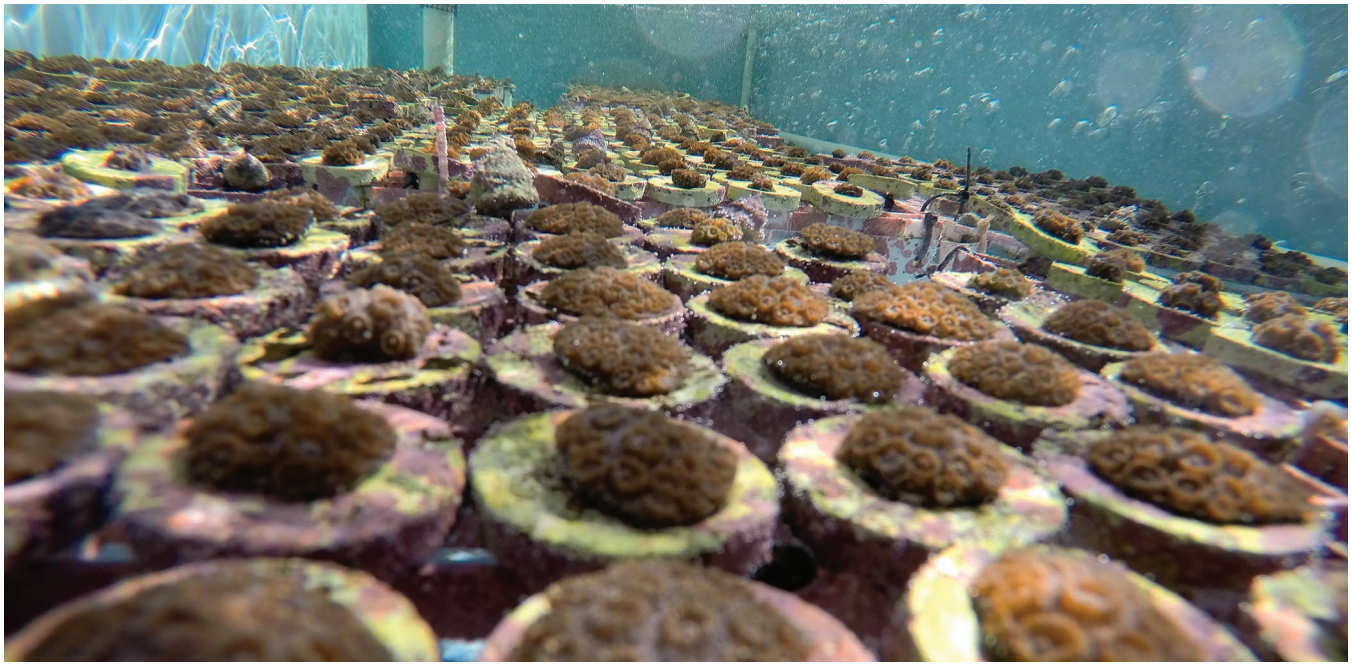
In general, on degraded reefs:

- live coral cover is low
- algae cover is high, to the point where it can become dominant and a threat to corals
- reef rugosity is low and has eroded structure due to the loss of living corals, which means the reef is less effective at providing important habitat for marine life

Restoration efforts aim to reverse these trends using specific methods.

Most restoration techniques focus on repopulating reefs with healthy coral fragments or entire colonies to increase live coral cover and improve reef rugosity, or structure. There are two methods of doing this: asexual propagation and sexual propagation.

Coral gametes, or bundles of eggs and sperm, are collected to help restore reefs through facilitated coral sexual reproduction. © Emily Nixon



Boulder star coral fragments grow in a land-based nursery until they are ready to be outplanted to a degraded reef. © Joe Pollock/TNC

Asexual propagation

Asexual propagation is also known as coral fragmentation. In this process, small coral fragments are collected from donor colonies, which are grown in underwater or land-based nurseries, and then transplanted onto reefs. Asexual propagation can take place as micro-fragmentation or fragmentation. Micro-fragmentation is primarily used with slower-growing massive, or boulder-shaped, corals and involves specialized equipment for cutting corals into polyp-sized fragments, causing them to grow exponentially faster than normal. Micro-fragments are generally grown in land-based nurseries and then planted together on a dead coral skeleton, as they are able to grow, fuse with each other and 're-skin' the reef. Fragmentation is used only on branching corals—or those that grow in branch-shaped or pilar-shaped formations—that can be easily fragmented with hand-held tools. Typically, the corals used for fragmentation are grown in underwater nurseries. These structures require regular maintenance, or gardening, which includes cleaning algae, repairing ropes and eliminating predators like fireworms or snails, which can often be removed manually using gloves.

Sexual propagation

This method involves collecting coral gametes, or bundles of eggs and sperm, that are released into the ocean during natural spawning events and then assisting the sexual fertilization process in a lab. This ensures higher rates of larval development and survivorship, as larvae are often reared in land-based nurseries where they are kept safe from predators. In addition, because millions of coral larvae can be created from just one spawning event, this method is effective for large-scale restoration and promoting the natural genetic diversity of corals that makes reefs more resilient. Once the coral larvae have grown into colonies that are large and strong enough to survive in the wild, they are 'settled' onto special substrates, or surfaces they can attach on to and grow. They are then transplanted, or outplanted, to degraded reefs.

The REEFhabilitation Experience focuses on the asexual propagation method of coral fragmentation, typically using corals grown in underwater nurseries that require regular gardening.

For more on restoration techniques, see Table 1.

How Can Citizen Science Help Coral Reefs?

Citizen science, or community science, has become a common practice in various fields.

The term refers to non-scientist volunteers participating in scientific research, often helping to gather data out in nature. In the case of coral restoration, volunteers can support data collection and coral nursery maintenance—but they must be trained in the proper methods and accompanied by an expert in the field at the beginning. The REEFhabilitation Experience is an opportunity for citizen scientists to participate in restoration efforts in three ways:

Collecting data

Participants may be able to collect data that contributes to the long-term monitoring of a coral reef and helps guide restoration efforts. After collection, the data needs to be reviewed and curated by experts or under their supervision.

Maintaining underwater coral nurseries

To reduce mortality rates and improve coral growth, it is important to keep nurseries clean and to mitigate the presence of coral competitors such as sponges, algae and other sessile organisms. Participants may be able to take part in nursery maintenance, or gardening, which includes cleaning the corals with soft brushes or eliminating predators like snails and fireworms. Proper nursery maintenance is key to improving the corals' chances of survival after being outplanted.

Raising awareness

Participants can learn how coral restoration works, why coral reefs are important, the role people can play in preserving these precious ecosystems, and how to share this information with others.

THIS PAGE A volunteer helps to outplant young staghorn coral colonies. © Jennifer Idol

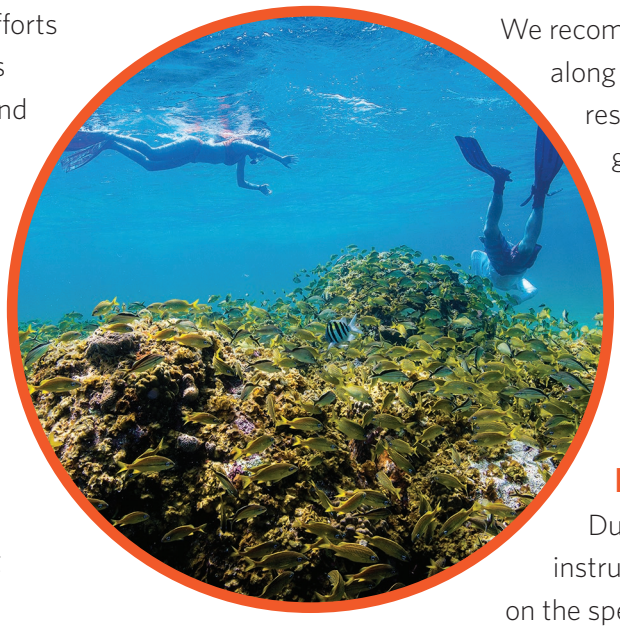
Young staghorn corals grow in an underwater nursery in the Dominican Republic. © Paul A. Selvaggio

The REEFhabilitation Experience

Coral reef restoration through isolated conservation projects can typically only accomplish small-scale results.

By engaging people who are passionate about the ocean and applying the principles of citizen science to restoration initiatives, the REEFhabilitation Experience strives to expand, or scale up, existing efforts to save coral reefs. It combines responsible tourism, science and conservation to benefit local coral restoration programs.

The purpose of this guide is to help dive operators engage tourists in such programs. It is intended to accompany dive instructors as they deliver the REEFhabilitation Experience, which includes a learning component, a briefing and a diving field trip.



Learning component

Learning about coral reef conservation is the first step in the REEFhabilitation Experience. The topics listed below are presented in a REEFhabilitation video, available at The Nature Conservancy's REEFhabilitation.org.

- What are corals and coral reefs?
- Why are coral reefs so important for people and nature?
- Why are coral reefs in trouble, and how we can help?
- What is coral restoration, and how does the REEFhabilitation Experience support it?

We recommend using this video, along with the information and resources offered in this guide, to give participants a foundational understanding of the above topics before getting into the water. Additional information and resources can be found at reefresilience.org/restoration.

Briefing

During the briefing, diving instructors provide more detail on the specific restoration activities occurring at their center, go over best practices or protocol for the diving field trip, and answer questions from participants. Recommended topics include:

- How your business/organization contributes to or collaborates with coral restoration projects
- The nursery structures the participants should expect to see

Snorkelers enjoy swimming among vibrant schools of fish supported by healthy coral reefs. © Paul A. Selvaggio

- Protocol during the dive, including:
  - do not touch corals or marine life
  - make sure diving gear and/or body does not come in contact with corals
  - make sure to stay the proper distance away from nursery structures
  - if there are currents, make sure to orient your body properly to avoid coming in contact with the nursery structures or corals
  - pay attention while kicking to avoid your fins hitting the nursery structures or corals
  - use eco-friendly sunscreen lotion
- If participants will collect data, go over the tables they will need (see Appendices)
- If participants will engage in nursery gardening, clearly explain and demonstrate the activity
- Perform a snorkeling or diving skills checkout before the dive
- Review guidelines for all activities to be carried out and introduce any materials that will be used (see Table 5)

Diving field trip

The dive operator will choose the activities to be conducted in the water, which will depend on the participants' level of diving experience, the dive center's policies and weather conditions. A brief description of each potential activity is described below.

Coral nursery observation visit (recommended for snorkelers or less experienced divers)

Participants will be able to observe the coral nurseries while snorkeling or diving, accompanied and guided by the diving instructor. It is important to review reef safety and care considerations with participants before they enter the water.

Data collection visit (recommended for experienced divers)

Participants will be able to observe coral nurseries and/or restoration sites and collect data at one or both of these locations. The data they collect will be used to help monitor the nurseries and outplanted corals. It is important that this data collection is only done by experienced divers, as they will need to maintain adequate buoyancy in the water while working. The data should be recorded in the tables provided (Tables 3 and 4) and uploaded at REEFhabilitation.org. Please refer to Table 5 for recommended materials.

Coral nursery maintenance visit (recommended for experienced divers)

Participants will be able to conduct gardening activities at the nursery. Specifically, they can help clean the structures using the materials listed in Table 5. It is important that only participants with strong diving experience and good buoyancy engage in this type of visit.

Diving centers should work with local partners and experts to train their staff in the correct restoration techniques. The videos listed at the end of this guide provide some instruction on how to maintain nursery structures and other activities within the REEFhabilitation Experience.

IMPORTANT NOTE:

Diving operators or centers are solely responsible for making decisions about the experience level of snorkelers and divers who engage in the activities described in this guide. They must ensure that participants follow dive safety protocols and comply with local laws. All the activities described in this guide should only be performed with the appropriate permits and approvals from local resource management agencies.

APPENDICES

Table 1. Summary of coral reef restoration techniques[1]

Method	Definition	Other Common Names
Asexual propagation methods (fragmentation or micro-fragmentation)		
Fragmentation	Segmenting a coral colony into small pieces or individual polyps to transplant onto the reef	
Direct outplant	Transplanting coral colonies and 'fragments of opportunity' (pieces of coral broken naturally by storms or disturbances) directly to the reef without using nurseries	Coral triage or repair after a disturbance
Transplant of fragments with nursery phase	Transplanting fragments with an intermediate adaptation period in nurseries at sea or on land; restoration is only complete when the fragments or micro-fragments are transplanted from nurseries to the reef	
Coral gardening with nurseries as a source of tissue for transplants	Transplanting fragments grown in nurseries; the nursery serves as a source of tissue and is never completely harvested, so donor colonies are always growing in the nursery; restoration is only complete when the fragments or micro-fragments are transplanted from nurseries to the reef	Coral transplantation, asexual propagation
Sexual propagation methods		
Assisted fertilization and larval propagation	Collecting gametes and using them in assisted fertilization on a boat-adapted or land-based laboratory; embryonic development and production of larvae occur in situ (in the laboratory) or ex situ (in pools moored in the ocean) until they settle (form the primary polyp) on previously treated substrates; the substrates are transplanted to the reef after a period of acclimatization.	Larval propagation, sexual propagation, assisted reproduction, larval seeding
Substrate improvement methods		
Adding substrates to artificial reefs	Using human-made structures for restoration purposes	Artificial structures or engineered solutions (e.g., BioRock, EcoReef, ReefBall, marsSpiders)
Substrate stabilization	Stabilizing the substrate to promote coral recovery or incorporation of new corals into the population (recruitment); often combined with artificial reefs and transplants	
Substrate improvement via electricity	Improving the substrate using direct current or electricity	Mineral accumulation, BioRock
Substrate improvement via algae removal	Improving the substrate by removing macroalgae	

[1] Modified from Boström-Einarsson et al. (2020).

Method	Definition	Other Common Names
Glossary of terms		
In situ nursery	In the laboratory, structures of various shapes consisting of ropes and frames that serve as support and substrate for fragments or micro-fragments of corals; the corals remain in the water until they reach an optimal size to be transplanted to the reef	Water nursery
Ex situ nursery	Same as the in situ nursery but takes place in pools moored in the ocean	Land nursery
Fragmentation	Dividing a donor colony into smaller fragments or branches; used for branching corals that can be cut by hand or with pliers	Breaking off
Micro-fragmentation	Dividing the donor colony into fragments that are less than 1 cm in diameter; used for massive corals that are cut using band saws	
Outplant	The fragment or micro-fragment from a parent or donor colony that will be transplanted to the reef	Fragment, micro-fragment, colony
Disturbance	A natural or human-made force that can alter the composition, appearance, structure and/or function of a natural or artificial reef; if a disturbance is intense and/or frequent, it can impact the ecosystem's ability to recover	Stressor

For Tables 2, 3, and 4, the data are divided into two groups:

Metadata is the information such as the person responsible for data entry, the data collection location, the date of the visit, the number of structures in the location, the diving time, and the type of nursery.

Indicators are metrics that allow the condition of the coral nursery to be established quantitatively or semi-quantitatively. The indicators presented here are those suggested by the Coral Restoration Consortium, modified so they can be utilized by the non-scientific public.

Table 2. Data collection sheet for a new outplanting event

OUTPLANT EVENT DATA COLLECTION
METADATA
Observer
Name
Last Name
E-mail
Diving Center
Name
Country
Town/site

Outplant Site		
		Notes
Outplant Site Name		
Local organization associated (if any)		
Country		
Town/site		
Latitude (decimal degrees)		
Longitude (decimal degrees)		
Donor Site Name (if known)		
Local organization associated (if any)		
Country		
Town/site		
Latitude (decimal degrees)		
Longitude (decimal degrees)		
Diving/Event Information		
	From	To
Outplanting event dates (dd/mm/yyyy)		
Dive date (dd/mm/yyyy)		
Depth (meters or feet)		
Bottom Time (minutes)		
Environmental Data		
Temperature (C or F)		
Visibility (meters or feet)		

OUTPLANT EVENT DATA COLLECTION			
INDICATORS			
	From	To	**Instructions**
Outplant #			
Coral Species/Common Name			
Estimated size (inch/cm)			
Outplant #			
Coral Species/Common Name			
Estimated size (inch/cm)			
Outplant #			
Coral Species/Common Name			
Estimated size (inch/cm)			
Outplant #			
Coral Species/Common Name			
Estimated size (inch/cm)			
Outplant #			Add the fragment/outplant number if any. If unknown refer to it with 1 to 10. Indicate the coral species name or common name, and estimates size. If it is a branching coral measure its longitud, if it is a massive coral measure its diameter
Coral Species/Common Name			
Estimated size (inch/cm)			
Outplant #			
Coral Species/Common Name			
Estimated size (inch/cm)			
Outplant #			
Coral Species/Common Name			
Estimated size (inch/cm)			
Outplant #			
Coral Species/Common Name			
Estimated size (inch/cm)			
Outplant #			
Coral Species/Common Name			
Estimated size (inch/cm)			

Table 3. Data collection sheet for a nursery visit

NURSERY DATA COLLECTION	
METADATA	
Observer	
Name	
Last Name	
E-mail	
Diving Center	
Name	
Country	
Town/site	
Coral Nursery	
	Notes
Name	
Type (if more than one type, add in notes)	
Local organization associated (if any)	
Country	
Town/site	
Latitude (decimal degrees)	
Longitude (decimal degrees)	
Local organization associated (if any)	
Diving Information	
	Notes
Date (dd/mm/yyyy)	
Bottom Time (minutes)	
Depth (meters or feet)	
Number of structures visited	
Environmental Data	
	Notes
Temperature (C or F)	
Visibility (meters or feet)	

NURSERY DATA COLLECTION	
INDICATORS	
Live Coral	
Coral species in the nursery	**Instructions**
Structure #	
% live coral	
Structure #	
% live coral	
Structure #	
% live coral	
Structure #	
% live coral	
Structure #	
% live coral	
Structure #	
% live coral	
Structure #	For each of the nursery structured visited, please indicate an estimate of live coral observed. Indicate the Structure # if any/known, if you don't know refer to it with 1 to 10
% live coral	
Structure #	
% live coral	
Structure #	
% live coral	
Structure #	
% live coral	
Structure #	
% live coral	
Structure #	
% live coral	
Structure #	
% live coral	

NURSERY DATA COLLECTION		
Observations of predators, competitors, bleaching or diseases		
	Present/Absent	# of Structures with Presence
Predators		
Fireworms		
Snails		
Competitors		
Fire corals		
Sponges		
MacroAlgae		
Disease		
White Band		
Bleaching		
Other		

Conservation practitioners in the Dominican Republic communicate and share tools underwater as they outplant healthy young corals. © Paul A. Selvaggio

Table 4. Variables to monitor at restoration sites

RESTORATION SITE DATA COLLECTION	
METADATA	
Observer	
Name	
Last Name	
E-mail	
Diving Center	
Name	
Country	
Town/site	
Restoration Site	
	Notes
Name	
Local organization associated (if any)	
Local organization associated (if any)	
Country	
Town/site	
Latitude (decimal degrees)	
Longitude (decimal degrees)	
Diving Information	
	Notes
Date (dd/mm/yyyy)	
Depth (meters or feet)	
Bottom Time (minutes)	
Environmental Data	
	Notes
Temperature (C or F)	
Visibility (meters or feet)	

OUTPLANT EVENT DATA COLLECTION			
INDICATORS			
	Height	**Width**	**Instructions**
Area and number of outplants			
Ecological Footprint			With fin kicks measure the approximate areal (heightXwidth) extent of reef which encompasses all outplant plots.
Number of Outplants			While swimming through the area, estimate the # of outplants you observe
Health			
Coral Species of Outplants			
Outplants Health			Based on observations indicate the overall health of outplants
Outplant #			Pick randomly 5 outplants. Indicate the Outplant # if any/known, if unknown refer to it with 1 to 5. With drop down option, indicate its health and estimated size in inches or centimeters
Health			
Size			
Outplant #			
Health			
Size			
Outplant #			
Health			
Size			
Outplant #			
Health			
Size			
Outplant #			
Health			
Size			

Table 5. Materials recommended for activities

Activities	Materials	Recommendations
Prior to all in-water activities: REEFhabilitation Experience learning component and briefing	REEFhabilitation video	Provide briefing period after the video to review the information presented and answer questions; explain best practices, protocols and safety measures
Coral nursery observation visit	Camera (optional)	For snorkelers and less experienced divers
Data collection visit	Underwater data slates, pencils, rulers/measuring tape, data sheet (Table 3), camera (optional)	For experienced divers only; buoyancy check is recommended to avoid damage to corals
Coral nursery maintenance visit	Small wire brushes and metal scrubbies to clean areas close to the coral fragments and ropes/frames, gloves, tweezers, t-raps, and buoys (or gallons) in case a structure must be re-floated	For experienced divers only; buoyancy check is recommended to avoid damage to corals, as well as a demonstration by the dive instructor

Additional Resources

International Organizations and Institutions

- Coral Restoration Consortium: crc.reefresilience.org
- SECORE: secore.org
- Coral Restoration Foundation: coralrestoration.org
- Fragments of Hope: fragmentsofhope.org
- Coral Reef Ecosystem Restoration Working Group: floridakeys.noaa.gov/review/coralrestoration
- International Coral Reef Initiative: icriforum.org/restoration
- Citizens of the Great Barrier Reef: citizensgbr.org

Dominican Organizations and Institutions

- Red Arrecifal Dominicana: redarrecifaldominicana.org/que-hacemos/#restauracion
- Consorcio Dominicana de Restauración Costera: restauraciondearrecifes.org/index.php
- FUNDEMAR (Fundación Dominicana de Estudios Marinos): fundemardr.org/

Coral Restoration Guides and Videos

- Coral Reef Restoration Guidelines: icriforum.org/coralrestoration
- Caribbean Acropora Restoration Guide: reefresilience.org/pdf/Johnson_etal_2011_Acropora-Coral-Guide.pdf
- Restoration: reefresilience.org/restoration
- Reef Restoration Concepts and Guidelines: sprep.org/att/IRC/eCOPIES/Pacific_Region/218.pdf

REEFhabilitation Portal

- REEFhabilitation.org

REEFhabilitation

Rebuilding reefs together

Healthy coral reefs in the Dominican Republic are vital for maintaining beaches and supporting fun activities for visitors, like boating and snorkeling. © Paul A. Selvaggio

GRUPO PUNTACANA® FUNDACIÓN

The Nature Conservancy

fundemar Fundación Dominicana de Estudios Marinos, Inc.

Learn more about our work

nature.org/Caribbean

puntacana.org

fundemarDR.org