A Manager's Guide to **Coral Reef Restoration** Planning and Design

NOAA Technical Memorandum CRCP 36

CITATION:

Shaver E C, Courtney C A, West J M, Maynard J, Hein M, Wagner C, Philibotte J, MacGowan P, McLeod I, Boström-Einarsson L, Bucchianeri K, Johnston L, Koss J. 2020. A Manager's Guide to Coral Reef Restoration Planning and Design. NOAA Coral Reef Conservation Program. NOAA Technical Memorandum CRCP 36, 128 pp.

FOR MORE INFORMATION:

For more information about this report or to request a copy, please contact NOAA's Coral Reef Conservation Program at 301-713-3155 or write to:
NOAA Coral Reef Conservation Program, NOAA/NOS/OCM, 1305 East West Highway, Silver Spring, MD 20910 or visit www.coralreef.noaa.gov.

A Manager's Guide to **Coral Reef Restoration** Planning and Design

Elizabeth C. Shaver[1], Catherine A. Courtney[2], Jordan M. West[3], Jeffrey Maynard[4], Margaux Hein[5], Cherie Wagner[1], Jason Philibotte[6], Petra MacGowan[1], Ian McLeod[5], Lisa Boström-Einarsson[5,7], Kristine Bucchianeri[8], Lyza Johnston[9], Jennifer Koss[6]

[1]The Nature Conservancy, [2]Tetra Tech, Inc., [3]United States Environmental Protection Agency, [4]SymbioSeas, [5]TropWATER, James Cook University, [6]United States National Oceanic and Atmospheric Administration, [7]Lancaster Environment Centre, Lancaster University, [8]US All Islands Coral Reef Committee, Lynker Technologies, [9]Johnston Applied Marine Sciences

National Oceanic and Atmospheric Administration
National Ocean Service
Office for Coastal Management
Coral Reef Conservation Program

NOAA Technical Memorandum CRCP 36

U.S. Department Of Commerce
Wilbur L. Ross
Secretary of Commerce

National Oceanic and Atmospheric Administration
Neil A. Jacobs
Acting Under Secretary of Commerce for Oceans and Atmosphere and NOAA Administrator

National Ocean Service
Nicole LeBoeuf
Acting Assistant Administrator

Restored coral in Seraya-besar, Indonesia. Image: Martín Colognoli | Coral Guardian | Coral Reef Image Bank

ACKNOWLEDGEMENTS

Production of this manual has been made possible through financial support from the United States National Oceanic and Atmospheric Administration (NOAA) Coral Reef Conservation Program and Restoration Center, United States Environmental Protection Agency's Office of Research and Development, and The Nature Conservancy's Reef Resilience Network. This work was also supported by the National Environmental Science Program Tropical Water Quality Hub.

We are grateful to the many coral reef managers and restoration practitioners from a diversity of locations around the globe who provided valuable feedback on this Guide. We extend our sincere thanks to our external peer reviewers who gave substantial and invaluable suggestions that elevated many aspects of this manual:

Ilsa Kuffner, United States Geological Survey

Tom Moore, National Oceanic and Atmospheric Administration

Jerker Tamelander, United Nations Environment Programme

David Wachenfeld, Great Barrier Reef Marine Park Authority

A crucial role was played by managers from the US Pacific jurisdictions of American Samoa, Commonwealth of the Northern Mariana Islands (CNMI), Guam, and Hawai'i in helping to develop, refine and realize the Guide. These teams were the pioneers and test drivers of this document, and their experiences developing restoration action plans in their locations provided invaluable insights into the efficacy of the planning process presented in this Guide. We thank all of the members of these planning teams, especially the following team leads:

American Samoa: Georgia Coward, American Samoa Coral Reef Advisory Group

CNMI: Dave Benavente, Division of Coastal Resources Management

Guam: Whitney Hoot, Bureau of Statistics and Plans

Hawai'i: Ryan Okano, Division of Aquatic Resources

We also extend our gratitude to Lani Watson and Shannon Ruseborn from NOAA's Office of Habitat Conservation and Kim Hum from The Nature Conservancy's Hawai'i Program for supporting the use of this Guide and the chance to learn from real-world experiences with coral reef restoration planning.

Many others volunteered their time to review early versions and provide comments that contributed to the Guide, including: Aric Bickel, Karen Bohnsack, Andrew Bruckner, Robert Brumbaugh, Calina Zepeda Centeno, Nathan Cook, David Cuevas, David Delaney, Mandy Elliot, Ximena Escovar-Fadul, Sarah Fangman, Leslie Henderson, Whitney Hoot, Kristi Kerrigan, Jessica Levy, Caitlin Lustic, Neil Mattocks, Phanor Montoya Maya, David Obura, Hudson Slay, Tali Vardi, Joanna Walczak, Thea Water, and Dana Wusinich-Mendez.

PHOTOGRAPHY CREDITS:

Cover photo: A local fisherman trained as a coral gardener works with Grupo Puntacana Foundation and The Nature Conservancy to outplant colonies of Caribbean staghorn coral, *Acropora cervicornis,* on reefs near Punta Cana, Dominican Republic. Credit: Paul Selvaggio | The Nature Conservancy.

Other photography credits are appended to individual images.

CONTENTS

ACKNOWLEDGEMENTS III

INTRODUCTION 1

- Types of Restoration and Restoration Principles 2
- Considering Climate Change in Coral Reef Restoration 3

MANAGER'S GUIDE SUMMARY 7

- Steps of the Planning Process 7
- How to Use this Guide 8
- Supporting documents 10

STEP 1: SET GOAL AND GEOGRAPHIC FOCUS 13

- Overview 13
- 1A. Identify and Prioritize Goals 13
- 1B. Identify Geographic Focus for Each Goal 16
- 1C. Select Goal and Geographic Focus for Restoration Planning and Design 19

STEP 2: IDENTIFY, PRIORITIZE, & SELECT SITES 21

- Overview 21
- 2A. Identify Potential Restoration Sites 23
- 2B. Use Framework to Prioritize Sites 24
- Semi-Quantitative Approach 27
- Quantitative Approach 30
- 2C. Finalize Site Selection 34

STEP 3: IDENTIFY, DESIGN & SELECT INTERVENTIONS 37

- Overview 37
- 3A. Identify an Array of Intervention Options 37
- 3B. Apply Climate-Smart Design Considerations 40
- 3C. Evaluate and Select Interventions 50

STEP 4: DEVELOP RESTORATION ACTION PLAN 55

- Overview 55
- 4A. Define SMART Objectives 55
- 4B. Develop Activities and Implementation Timeline 61
- 4C. Build Action Plan 64

MOVING INTO ACTION 67

- Building a Strategic Plan 67
- Considerations for Step 5: Implement Restoration 68
- Considerations for Step 6: Monitor & Evaluate Progress 69

CONCLUSION 71

REFERENCES 73

RESOURCES 75

APPENDIX 1: GUIDE WORKBOOK A1-1

APPENDIX 2: RESTORATION ACTION PLAN TEMPLATE A2-1

Attaching a coral fragment. Image: Martin Colognoli | Coral Guardian | Coral Reef Image Bank

INTRODUCTION

Coral reefs are among the most biologically diverse and economically valuable ecosystems on our planet. Home to a quarter of marine fish and millions of species, coral reefs provide critical services to local communities, including coastal protection, food provisioning, and revenue from fisheries and tourism (Wilkinson 2004, Burke et al. 2008, 2011). Yet despite their importance, coral reefs are rapidly declining across the globe due to extreme temperature events caused by climate change and a host of local-scale threats like pollution and overfishing (Burke et al. 2011, De'ath et al. 2012, Jackson et al. 2014, Hughes et al. 2017). As rising global temperatures result in more frequent and severe bleaching events, many coral reefs across the world will likely struggle to recover and thrive (IPCC 2018).

To combat the global loss of coral reefs, there is a growing interest among resource managers in using active restoration interventions to mitigate reef degradation and promote recovery and resilience (Possingham et al. 2015, Boström-Einarsson et al. 2020). Some of the most common restoration interventions to date have included directly transplanting coral fragments from one reef to another, and coral gardening, where coral fragments are propagated and grown in nurseries before being outplanted to a reef (Boström-Einarsson et al. 2020). More techniques are being trialed and used every day in various regions around the world, such as micro-fragmentation of massive boulder corals, gamete collection and seeding of reefs with coral larvae, and artificial reef structures.

However, coral reef restoration as a field is still in its infancy, only recently growing from small grassroots efforts to becoming a significant component of broader management planning. As reef managers seek to invest in restoration activities, it is therefore essential that thoughtful consideration be made for this endeavor, including how, when, and where restoration will be conducted, as well as how it can complement - rather than take away from - other reef management strategies. Importantly, restoration should not be considered as a replacement for conventional strategies like marine protection and threat reduction. Rather, restoration may only be successful in the long-term when used alongside strong local conservation efforts as well as climate change mitigation.

While coral reefs become increasingly degraded, new techniques are increasingly needed to assist reefs in recovering and adapting to changing environmental conditions (Anthony et al. 2017, Van Oppen et al. 2017, Mcleod et al. 2019). The urgent motivation to sustain coral reefs has fueled a building momentum to restore and rebuild reefs, with increasing numbers of projects, research studies, and investments (Young et al. 2012, Boström-Einarsson et al. 2020). Coral reef restoration is a burgeoning new field with much potential, and the authors of this Guide are excited to contribute to this global effort. As a global community of managers, scientists, restoration practitioners, and stakeholders embarking on the UN Decade on Ecosystem Restoration (2021-2030), we must thoughtfully implement coral reef restoration projects, monitor and evaluate success, and share lessons learned in order to leverage and expand our collective knowledge. *A Manager's Guide to Coral Reef Restoration Planning and Design* supports these needs by providing a six-step, adaptive management planning process to assist managers in setting and meeting their restoration goals.

Deciding Whether to Conduct Restoration

Coral reef restoration is not always a viable management strategy for every context. Before starting a restoration project, managers are advised to complete a thorough assessment of whether restoration should be conducted in their location. For users of this Guide, it is assumed that this evaluation has taken place and restoration has been determined to be necessary and feasible.

The *Reef Rehabilitation Manual* (Edwards 2010) provides guidelines and a decision tree that can be used to assist in this evaluation. Several key questions from this manual have also been summarized in *Coral Reef Restoration as a Strategy to Improve Ecosystem Services: A Guide to Coral Restoration Methods* (Hein et al. 2020) to guide managers and practitioners with this assessment, including:

1. **Why did coral mortality or reef degradation happen in the first place, and have these causes of degradation stopped or are they currently under effective management?**
   If local threats to reefs have not been identified, managed, or mitigated, they may continue to threaten restored coral populations and severely limit the success of the restoration project. Restoration may need to be considered after other management activities are in place.
2. **Are there currently any barriers to natural reef recovery?**
   Restoration is cost and labor intensive, and many techniques and approaches are still being trialed. If a reef ecosystem is likely to recover naturally (e.g., coral recruitment is occurring), other management actions may be a more suitable approach than restoration.
3. **What type of repair or intervention is necessary to recover ecosystem function?**
   The most common restoration interventions involve outplanting corals onto reefs. However, some reefs may require physical repair of the reef structure, or rehabilitation of ecological processes like herbivory. Step 3 of this Guide helps managers decide on a suite of interventions to use for restoration, but a broad understanding of what is needed will help guide whether restoration is appropriate for your location.

For more information, see Edwards 2010 and Hein et al. 2020.

Types of Restoration and Restoration Principles

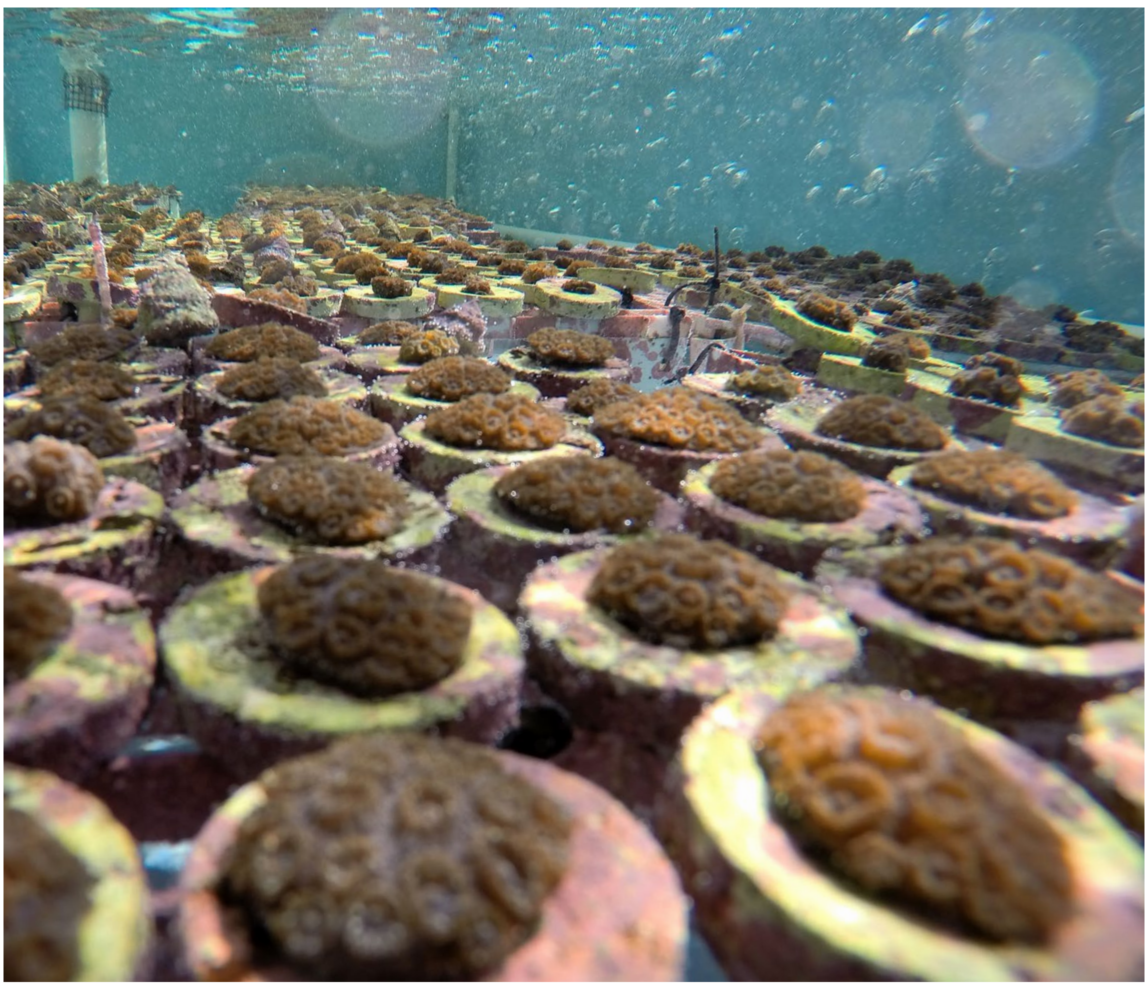
Ecological restoration is defined as the "process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed" (Society for Ecological Restoration, Gann et al. 2019). Restoration helps place an ecosystem on a trajectory towards recovery so it can persist on its own in its natural state. For coral reefs, most restoration projects aim to restore ecosystem functioning in a degraded or damaged reef habitat. Restoration includes any activity that aims to help an ecosystem recover, regardless of the amount of time it takes to achieve a certain level of recovery (Gann et al. 2019).

Following guidance from the Society for Ecological Restoration's (SER) *International Principles and Standards for the Practice of Ecological Restoration* (Gann et al. 2019) and the United Nations (UN) Report *Coral Reef Restoration as a Strategy to Improve Ecosystem Services: A Guide to Coral Restoration Methods* (Hein et al. 2020), restoration is part of a continuum of activities used to support habitats, from reducing local threats to fully recovering ecosystem function. Interventions that protect reefs and encourage natural recovery processes can be thought of as "proactive" (also called passive interventions), and include examples such as marine protected areas and water quality management. These actions also support "reactive" interventions, commonly thought of as "restoration". Reactive interventions involve measures that more directly assist in the recovery of reef functions or populations, should they not be able to recover naturally (McDonald et al. 2016). Examples include coral propagation and outplanting, algal removal, or substrate addition (Hein et al. 2020).

Although restoration in coral reef ecosystems is a relatively new field, restoration has been practiced in other natural habitats for many decades. Lessons learned in other habitats and shared through SER's International Principles and Standards can be adapted for use by coral reef managers and restoration practitioners. For instance, the Standards defines the following eight principles that underpin the best practices of ecological restoration (from Gann et al. 2019):

- Engages stakeholders
- Draws on many types of knowledge
- Is informed by native reference ecosystems, while considering environmental change
- Supports ecosystem recovery processes
- Is assessed against clear goals and objectives using measurable indicators
- Seeks the highest level of recovery possible
- Gains cumulative value when applied at large scales
- Is part of a continuum of restorative activities

This Guide was developed considering the principles and standards set forth in other ecosystems by the Society for Ecological Restoration.



Micro-fragmented corals growing in land-based nursery. St. Croix, US Virgin Islands.

Image: Joe Pollock | The Nature Conservancy

Considering Climate Change in Coral Reef Restoration

Changing climate conditions, including rising temperatures and increasingly intense storms, are the greatest threat to many reefs around the world. While restoration is being conducted, climate change is likely to pose significant direct impacts to the restoration effort, such as causing mass bleaching events on outplanted corals. It will also have indirect effects on local threats that are also of concern to the restoration effort. For instance, changing patterns of precipitation, drought, storms, and currents may influence the intensity, timing, and spatial pattern of local threats in ways that would affect restoration success.

Therefore, this Guide recommends that adaptative management be used in order to account for these changes and adapt restoration projects over time. **Adaptive management** is a process that involves a continuous cycle of experimentation and evaluation, where strategies that are not successful are removed from further work (Tompkins and Adger 2004). Adaptive management is a core component of resilience-based management that can help identify strategies that are robust to climate change (Mcleod et al. 2019).

The need to account for climate change has been integrated into each of the Guide's planning and design steps. Specific sections of the Guide where adaptation is particularly relevant include:

- **Restoration goals and objectives**: restoration planning should result in establishing goals and objectives that account for existing and projected future conditions.
- **Site selection and maintenance**: restoration planning should, as much as possible, target sites where local threats are under effective management and climate change vulnerabilities are minimal relative to other sites.
- **Restoration interventions**: restoration planning should identify and design restoration interventions that will be robust under existing and projected future changes in global and local conditions.

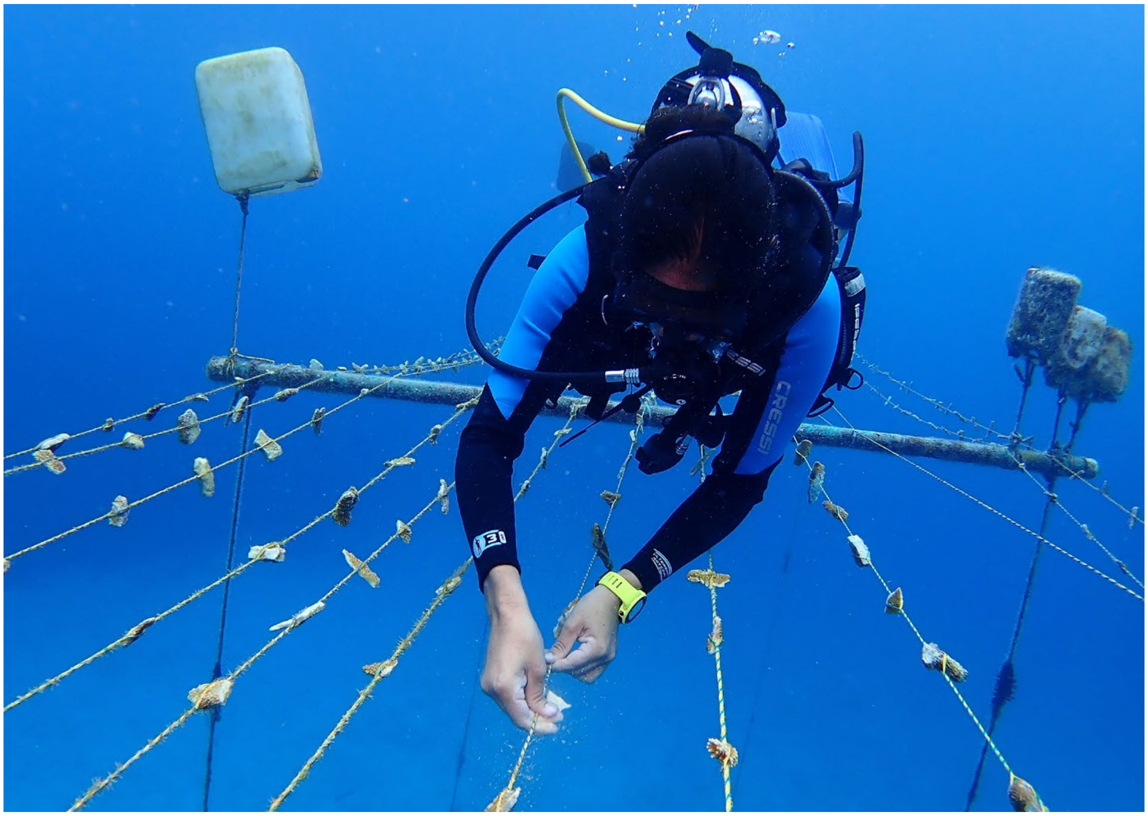
Though you may explicitly design your restoration interventions to consider future climate change, or may engage in strong adaptive management over the lifetime of the project, some may still question whether restoration should be undertaken in an era of climate change. For instance, if global temperatures continue to rise unchecked, restoration interventions may not be able to be sustained. Nevertheless, successful restoration projects may still be able to provide several key benefits, including:

- Assisting coral population recovery by promoting sexual reproduction and genetic diversity, and thus the potential for populations to adapt to climate change
- Helping prevent the extinction of certain coral species
- Supporting coral populations that act as critical stepping-stones for connectivity
- Encouraging the migration of species to new locations
- Supporting reefs to continue to provide critical ecosystem services
- Maintaining aesthetic quality of key tourism locations
- Generating new employment, economic, or tourism opportunities
- Providing opportunities for education and stewardship

Restoration as a Tool in a Coral Reef Manager's Toolbox

Diverse restoration interventions are being explored by reef scientists and managers around the world. **Restoration interventions** have been defined as genetic, physiological, coral population and community, and environmental activities meant to enhance the persistence and resilience of coral populations or reefs (National Academy of Sciences 2019). The United States National Academies of Sciences, Engineering, and Medicine (NASEM), in a comprehensive review of 23 restoration interventions, concluded that none have been implemented beyond experimental scales (NASEM 2019). For this reason, restoration should be carefully considered and implemented along with - and not instead of - management actions used to abate local and regional stressors.

With the distressing decline of coral reefs around the world, it is tempting to look at restoration as a silver bullet. However, natural ecosystems are complex, and restoration projects to assist natural recovery after disturbances or degradation can be challenging. Restoration in general can be a labor intensive, costly, and technically complex management intervention. For all of these reasons, restoration is far more likely to be successful if carefully planned. Early success will breed future successes for restoration programs. Lessons learned and shared during restoration projects will facilitate even more successful and efficient future restoration projects. Further, attention and support among decision-makers and communities will rapidly grow when all can see and participate in the success of restoration projects, highlighting the importance of stakeholder engagement. This Guide aims to support thoughtful planning and design of restoration projects prior to implementation to increase the chances that restoration projects and programs can be successful.



Cleaning a floating rope nursery in San Andres, Colombia.

Image: Corales de Paz

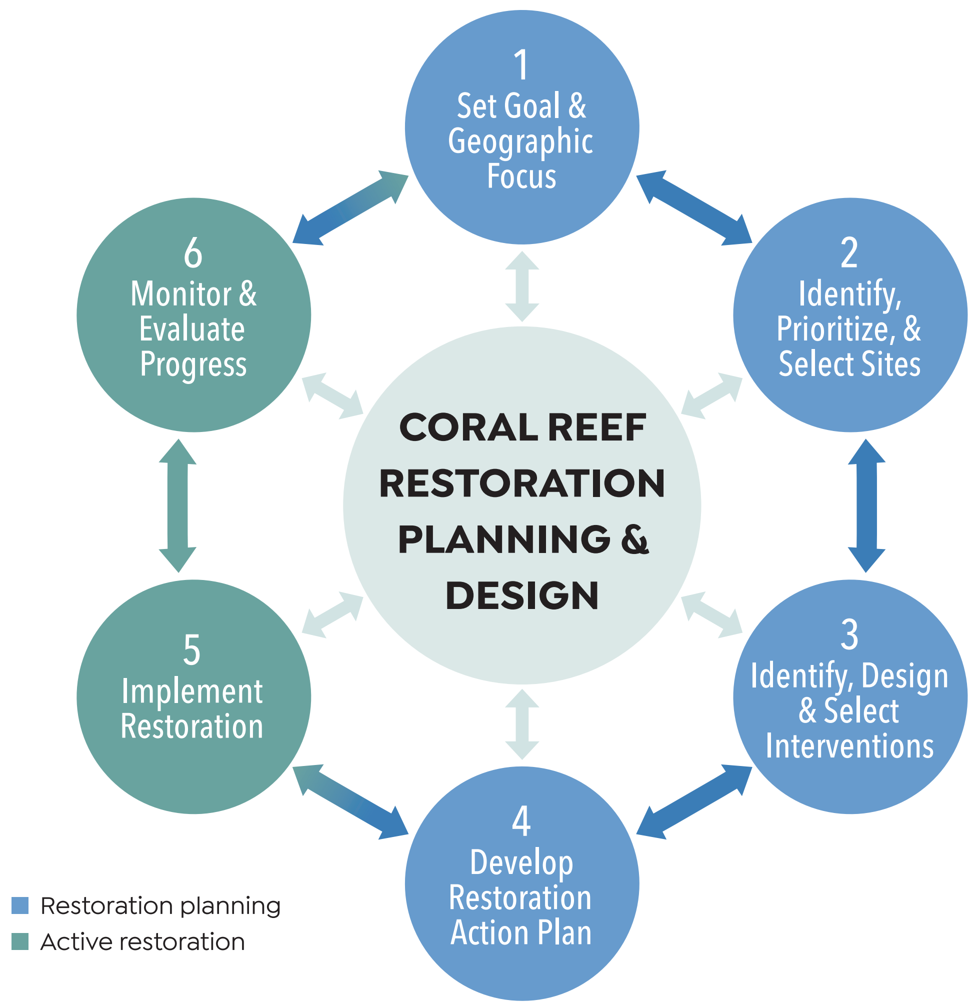
Coral outplanting in the Dry Tortugas, Florida, USA. Image: Carlton Ward Jr. | The Nature Conservancy

MANAGER'S GUIDE SUMMARY

A Manager's Guide Guide to Coral Reef Restoration Planning and Design aims to assist coral reef managers – together with their practitioner partners and stakeholders – in developing restoration projects for coral reefs in their location. For this Guide, **managers** are defined as government, nongovernment, and community leaders tasked with managing reefs and the resources they provide. Managers may also be **restoration practitioners** who plan, implement, and monitor restoration activities (Gann et al. 2019). By using information available about specific reefs in their locations, both managers and practitioners alike can use the planning process detailed in this Guide to make critical decisions about where and how restoration could be conducted.

Steps of the Planning Process

The Guide describes a six-step adaptive process for planning and implementing restoration interventions through a climate-smart lens (modified from West et al. 2018). These steps help managers design restoration projects to increase the likelihood of success and support learning throughout the implementation process. A hallmark of the process is the iterative nature of the cycle, where availability of new information at any one step is used to refine other steps and continuously improve restoration outcomes through time.



The first four steps of this Guide focus on goal-based planning and design of restoration interventions, culminating in the creation of a Restoration Action Plan (hereafter, 'Action Plan'). A key component of the Action Plan is an initial pilot phase to test the appropriateness of sites and interventions prior to full implementation investment. Active restoration using the Action Plan occurs in the final two steps, first through implementation and monitoring of a pilot phase, followed by full-scale implementation and long-term monitoring for effectiveness of the full plan. The planning and implementation cycle includes the following six steps:

1. *Set Goal and Geographic Focus*
2. *Identify, Prioritize, and Select Sites*
3. *Identify, Design, and Select Interventions*
4. *Develop Restoration Action Plan*
5. *Implement Restoration*
6. *Monitor and Evaluate Progress*

How to Use this Guide

We recommend that this Guide be used to develop an Action Plan for one priority goal at a time. In each planning step, we provide suggestions for how managers can best proceed through the material in this Guide. This includes background information for each step as well as a suggested process and key stakeholder groups to engage. After the first pass, you may find that subsequent iterations of working through the planning cycle may take less time, as much of the information can be used again, particularly where two goals have overlapping focus areas or the same interventions are considered.

Following the sequence of steps is a flexible process – you can start at any of the steps depending on the current status of restoration activities and planning in your location. You may come to this Guide feeling that some steps have already been completed, in which case you may wish to begin in the middle of the planning cycle. At the beginning of each step, we provide a box with "Assumptions" describing what you need to have already completed before beginning that step.

Planning Process Examples

Throughout this Guide, green boxes or text are used to indicate the use of an example that illustrates how the Guide may be used by managers to complete the planning steps. One example goal has been identified and is then carried through for all four planning steps. Note that the example is not meant to prescribe or advocate for any goal or intervention, but rather to exhibit how the steps can be used by managers going through the planning process.

It may be useful to work through the planning steps in the Guide within a group setting with a dedicated planning team. To do this, we suggest including members so the group has a collective expertise in the following topics:

- Local coral reef sites, conditions, and realities of working in or implementing restoration in different sites in the management jurisdiction or location
- Ongoing management of coral reef habitats in the location, including knowledge and access to scientific databases from monitoring programs

- Ongoing management of watersheds in the location as it relates to or may be connected with potential restoration sites
- Social-cultural complexities and context, knowledge of the private sector, and important local stakeholders to engage
- Location-specific vulnerabilities, such as to climate change impacts, coral disease outbreaks, or invasive or nuisance species

In addition to the core team members, a technical advisory group may be needed for some steps. This advisory group could include experts or scientists that the planning team feels are needed to complete any of the steps. It will also be important throughout this process to share progress on restoration planning with other key stakeholders, including those with decision-making authority. In each step of the Guide, we describe how planning teams can work through the material and engage with local stakeholder groups.

What about missing or incomplete data?

You may not have all of the information or data discussed in each of the steps. Depending on the information that is missing, you may wish to pause the planning process and obtain any relevant datasets or information before continuing. However, do not let incomplete data hinder your progress. Where possible, use the best judgment of technical experts in your local area to make informed decisions.

Corals growing on table and rope nursery in Belize. Image: Fragments of Hope

Supporting Documents

To assist planning teams in completing steps, two appendices have been included that can be used alongside the Guide: the Workbook and Action Plan Template.

- The **Workbook** (Appendix 1) provides a place to document the process, information, and decisions made during Steps 1-4 of the planning cycle that guide you toward developing an Action Plan. In the “Suggested Process” sections within each step of this Guide, we provide instruction for when to turn to the Workbook to complete activities with your planning team. The full Workbook can be retained as a reference document for evaluating and adapting the Action Plan over time. The Workbook can provide a comprehensive record of the information and assumptions made in developing your Action Plan and may provide valuable insights as new information becomes available or underlying assumptions change.
- The **Action Plan Template** (Appendix 2) is intended to help develop your Action Plan, which serves as the final output from completing the planning steps in this Guide. An Action Plan provides details on a project’s goals, objectives, sites, and actions to be undertaken (Figure 1). The template is intended to be populated from information summarized in your Workbook, and the labeled steps correspond with the Guide and Workbook. Not all of the information you have documented in the Workbook will go into your Action Plan. Rather, final decisions and summaries of your process to reach these decisions will be included and described. The Action Plan you develop may be used as part of a broader Restoration Strategic Plan that also includes plans for monitoring, operations, and individual work plans (see Figure 1). The Action Plan may also be useful for supporting a grant or project proposal, as an executive summary for more detailed strategies, or for reporting on the outcomes of the project. It is important to note that other strategic plans may already be in place in your location for reef management and conservation, and a restoration strategic plan should seek to align with these wherever possible.

Collecting coral spawn to fertilize new coral colonies.

Image: Paul Selvaggio | SECORE International

Figure 1. Developing an Action Plan for restoration as part of a broader strategic plan for restoration. Adapted from the *Open Standards for the Practice of Conservation* (CMP 2020).

Stabilized coral fragments in underwater nursery, Puerto Morelos, Mexico.

Image: Jennifer Adler

Coral tree nursery. Key Largo, Florida. Image: Alex Neufeld | Coral Restoration Foundation™

STEP 1: SET GOAL AND GEOGRAPHIC FOCUS

Overview

Articulating the goal of your restoration project and the geographic area of interest where you will work is the first step towards completing your Action Plan.

In Step 1A, you will identify priority restoration goals for your management region. You are encouraged to review the guidance in Step 1A and develop a well-articulated goal statement before moving on to Step 2, even if you have already identified the geographic focus area(s) and potential sites for your restoration intervention. In Step 1B, you will determine geographic focus area(s) for each restoration goal you have identified. These are areas where conducting restoration interventions would help to achieve the goal.

Step parts:

1A. Identify and Prioritize Goals

1B. Identify Geographic Focus for Each Goal

1C. Select Goal and Geographic Focus for Restoration Planning and Design

By the end of the step, you will select a single restoration goal and will define the geographic focus areas for this goal (Step 1C). Keep in mind that you can go through the planning process again for each of your priority goals. Potential sites within the geographic focus areas may begin to be recognized at this stage, but prioritization of specific sites and restoration interventions will occur in Steps 2 and 3, respectively.

Assumptions for Step 1

» Coral reef and watershed management plans are being actively implemented in the areas of interest for coral reef restoration.

» Any well-documented threats causing reef degradation have been identified and are currently or will be under effective management.

» A planning team has been assembled with the correct expertise to carry out restoration planning.

1A. IDENTIFY AND PRIORITIZE GOALS

A clearly articulated goal is an essential first step in the planning and design of a successful restoration project. This first step is intended to help reef managers avoid "trial and error" restoration interventions that are not grounded in a realistic and achievable vision for successful restoration. In conservation, a **goal** is a formal statement that details the desired impact you hope to achieve by conducting restoration interventions (CMP 2020). Goals should be thought of as being achieved over the medium-to-long term (CMP 2020), and reached through more concerted objectives that occur over shorter time intervals. Goals are important components of your Action Plan that will be defined in this step, while further details and objectives will be included and refined in subsequent steps in this Guide.

Importantly, the goals of broader coral reef management and conservation in the area(s) where restoration may occur can help guide your process for goal setting for restoration. Aligning restoration goals with other strategies already in place can ensure that restoration is contributing to larger efforts.

SUGGESTED PROCESS

1. ***Brainstorm and prioritize restoration goals.*** The primary aim of coral reef restoration is to recover a functioning and self-sustaining reef ecosystem. However, goals with a narrower focus may motivate reef managers and practitioners to conduct restoration as well.

   Starting with example restoration goals provided in Box 1.1, brainstorm and prioritize goals for your location. When doing so, it may be helpful to consider the level of maturity of your restoration program (i.e., whether you are just starting or have been doing restoration for a number of years). The goals in Box 1.1 are examples, and you may wish to combine or add to the list of goals as needed. We suggest initially limiting the list to three or fewer priority goals that will be your 'general goals'. You will then select just one of your specific goals in Step 1C to move forward with for the remaining planning steps.

Box 1.1. Examples of General Restoration Goals.

This list of general restoration goals is adapted from *Coral Reef Restoration as a Strategy to Improve ecosystem services* (Hein et al. 2020); *Coral Restoration – A Systematic Review of Current Methods, Successes, Failures and Future Directions* (Boström-Einarsson et al. 2020); and Coral *Reef Restoration Monitoring Guide: Methods to Evaluate Success from Local to Ecosystem Scales* (Goergen et al. 2020).

Ecological Goals

» Mitigate coral population declines and preserve biodiversity

» Re-establish reef ecosystem function and structure

Socio-Economic Goals

» Sustain local tourism opportunities

» Promote local coral reef stewardship

» Recover and sustain fisheries production

» Recover and sustain coastal protection

Disturbance-Driven Goals

» Respond to acute disturbances to accelerate reef recovery

» Mitigate anticipated coral loss prior to disturbance

Climate Change Adaptation Goals

» Mitigate impacts and promote reef resilience to climate change

2. ***Craft SMART Goals.*** For the remainder of the planning process, we suggest working with up to three priority goals. To convey what successful restoration would entail, it is useful to develop more specific language for your priority goals. To do this, we suggest using the **SMART** attributes, which are ***Specific***, ***Measurable***, ***Achievable***, ***Relevant***, and ***Timebound***, to craft your goals (see Table 1.1). For example, in Box 1.2, if a priority is to recover and sustain fisheries production services, what would success look like now and in the future considering climate change and ocean acidification? It may be useful to begin by describing the specific problems that would be addressed by the goal.

   At this stage, the language of the goal should be crafted to reflect the medium- to long-term vision of the restoration project (approximately 10-20 years). The shorter-term vision (one to five years) will be reflected in setting objectives in Step 4 that progress towards your goal.

   You may not be able to address every SMART attribute in your goal statement. For example, you may not be able to assign metrics to quantify the desired impacts, such as the percent increase in fish abundance. Some attributes can be addressed when you define SMART objectives for your goal in Step 4.

Documenting the process and providing any supporting rationale for identifying the details for each goal is important for sharing with decision-makers and stakeholders and when revisions of the Action Plan need to be made. Later in Step 4, the goal will be used to develop SMART objectives, which reflect interim outcomes in the one to 10-year timeframe.

Table 1.1. Attributes of SMART Goals and Objectives. Adapted from the *Open Standards for the Practice of Conservation* (CMP 2020). Examples are illustrative and not intended to be comprehensive.

Attribute	Description (from CMP 2020)	Examples
Specific	Clearly defined so that all people involved in the project have the same understanding of what the terms in the goal or objective mean	Identifies the restoration site, species or techniques to be used in the restoration intervention, or biophysical conditions
Measurable	Definable in relation to some standard scale (numbers, percentages, fractions, or all/nothing states)	Identifies the area to be restored (e.g., square m or km area), number of corals outplanted or percent survival compared to a baseline, or amount of reef crest accretion
Achievable	Practical and appropriate within the context of the project site and in light of the political, social, and financial context (especially relevant to objectives; goals may be more aspirational)	Considers numbers of corals or measurable outcomes that are feasible within the project scope, considers local and climate threats (e.g., land-based pollution, sea level rise) to restoration activities
Relevant	Ensures the significance of the outcome within regional or local management context	Coral species selected is particularly resilient, endangered, or ecologically critical
Timebound	Achievable within a specific period of time, generally 10-20 years for a goal and 1-10 years for an objective	Identifies deadlines considering biological and ecological parameters (e.g., year achieved)

Box 1.2. Developing a SMART restoration goal.

Example General Goal: Recover and sustain fisheries production

» **Define Problems:**

  » Loss of coral reef structure from bleaching and trampling of corals by tourist snorkelers is reducing available food and habitats for reef fishes

  » Loss of coral biodiversity results in reduced abundance and diversity of reef fishes

  » Loss of reef fishes reduces fisheries production locally

  » Loss of reef fishes locally negatively impacts fisheries regionally and globally as coral reefs support over 25% of the ocean's biodiversity.

Example SMART Goal: ***Within 10 years, restore diverse and structurally complex coral reef fisheries habitats that increase abundance of valued species and support local fisheries production and livelihoods.***

Workbook activity*: List and describe the priority goals for your management area. Summarize the process and decisions made in generating the list of goals. Rewrite your goals using specific language to make each goal SMART. Summarize key problems addressed by each goal and the process used to generate these specific goals.*

1B. IDENTIFY GEOGRAPHIC FOCUS FOR EACH GOAL

It is likely that in defining goals in Step 1A, you have already been making the connection between goals, geographic focus areas, and potential restoration sites. Here, a geographic focus area is a broad area where conducting restoration interventions would be most appropriate or relevant to achieving your goal. This could be the northeastern side of an island or multiple islands that are experiencing similar issues and where coral reef restoration might be needed and appropriate. Within these geographic focus areas, specific reef sites may then be identified and selected for restoration (in Step 2 of this Guide). In some cases, your geographic focus area(s) may already be known, such as when a restoration plan is being developed specifically for a marine protected area with boundaries already defined, or in response to an acute disturbance event. Despite this, completing this exercise is still important for determining whether these areas match your restoration goal, whether other areas should be considered, and if some areas are relevant for multiple goals.

For the example goal developed in Box 1.2 (i.e., restoring reef fisheries habitat), the geographic focus area might include shorelines where, or adjacent to where, local fishers fish. In some cases, a secondary goal may also be applicable within the geographic areas identified. For example, in areas where tourism resorts are threatened by loss of coral cover, a secondary restoration goal might be to also improve the quality of the reef experience for visitors. Places where multiple restoration goals overlap may be places where restoration can achieve multiple goals.

SUGGESTED PROCESS

1. ***Develop a technical advisory group.*** It is recommended that a technical advisory group of experts be convened to review each goal and identify the relevant geographic focus area(s). Some members of this group may be the same for all priority goals, others may not. For example, the goal of restoring reef fisheries habitat should include a group of experts who collectively have knowledge of local commercially important fisheries, fishing grounds, and coral reef species that provide adequate diversity and structure for the fisheries of particular interest. In addition, knowledge of other factors such as larval connectivity that may enhance fish recruitment to the chosen restoration area should be included. The technical advisory group should be invited to provide initial feedback on the goals and to identify any additional expertise that might be needed.

Outplants of *Acropora palmata*, Key Largo, Florida.

Image: Alex Neufeld | Coral Restoration Foundation™

2. Map the geographic focus area(s) for each priority restoration goal.

Using detailed maps of the region and expertise of the technical advisory group, identify areas in the region most relevant to each restoration goal. For example, a goal to restore reef biodiversity may have different geographic focus areas than a goal to restore coastal protection. After you have established the geographic focus area(s) for each goal, you can look across goals for opportunities where areas overlap and multiple goals can be addressed in the same area (Figure 1.1). It is recommended that this mapping exercise consist of two rounds of discussion and mapping for each goal, using the expert elicitation questions below (and repeating this process for each goal).

Round 1: Functionality and Benefits. Identify areas where reefs provide the functionality and benefits related to the goal. Experts discuss and provide responses by circling areas on the map.

- What areas currently or in the recent past have performed functions that are relevant to the goal?
- What areas are currently experiencing the problems that the goal seeks to address?
- Within these areas, where could reef restoration provide social and ecological benefits?.

Round 2: Management and Biophysical Context. For the areas where reefs perform functions relevant to the goal and where reef restoration could provide social and ecological benefits, describe the management and biophysical context in order to define challenges and opportunities. See Table 1.2 and Figure 1.1 for example knowledge areas and questions.

- What are the greatest management challenges in each area for achieving the restoration goal?
- What is the biophysical context in which these challenges will need to be addressed?
- What is the likelihood of overcoming these challenges? What are unique opportunities?

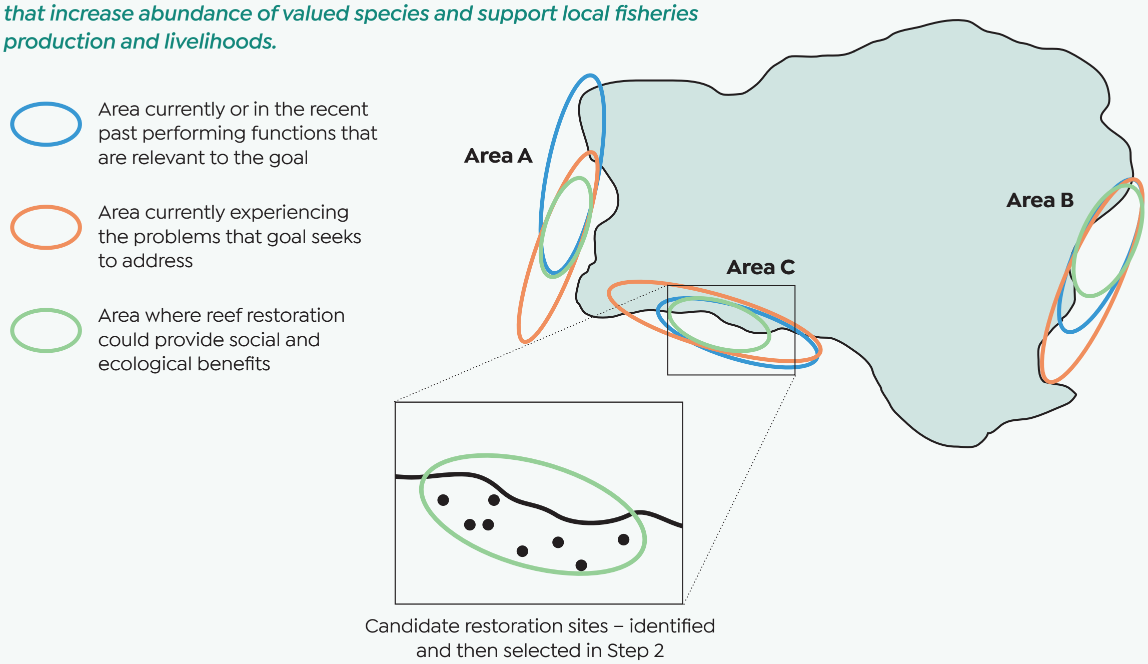
Each expert writes down or discusses relevant knowledge of the circled areas of the map. Using this information, the geographic focus area(s) for each goal can be set, considering areas where challenges can be overcome or unique opportunities exist.

Table 1.2. Example questions to consider in describing the management and biophysical context of geographic focus areas.

Management context	Biophysical context	
• What is the extent of land-based runoff, overfishing, tourism overuse, and other direct or indirect human uses in the area? • How effective is management of these uses? • Have there been previous attempts at coral reef restoration that could inform the current project? • What government policies and programs provide challenges or opportunities for coral reef restoration?	• Are there oceanographic conditios that may support recruitment? • Is there localized upwelling that may be a source of cool water? • Does the geomorphology of the area impact the residence time of water? • What is the extent of ecological connectivity between habitats? • How do watersheds and hydrological conditions contribute to water quality in the area?	• What are the historical and future projected incidence of coral bleaching, recovery, and disease in the area? • What factors in the area may contribute to or mitigate ocean acidification and its interactions with bleaching and disease? • How will increasingly intense storms affect wave energy, flooding, and volume and concentration of pollution runoff?

Example – Identifying the geographic focus area(s) for priority goals

Within 10 years, restore diverse and structurally complex coral reef fisheries habitats that increase abundance of valued species and support local fisheries production and livelihoods.



Determining the geographic focus area(s) should consist of two rounds of discussion:

1) Functionality and benefits	2) Management and biophysical context	
	Example knowledge areas	
• What areas currently or in the recent past have performed functions that are relevant to the goal? • What areas are currently experiencing the problems that the goal seeks to address? • Within these areas, where could reef restoration provide social and ecological benefits?	• Land-based runoff • Overfishing • Tourism overuse • Government policies and programs • Oceanographic processes • Geomorphology • Ecological connectivity	• Watersheds and hydrology • Ocean temperature, bleaching, and disease • Ocean acidification • Coastal flooding and inundation • Increased storm surge and runoff

Figure 1.1. Conceptual figure and example map describing how restoration goals relate to geographic focus areas, and how the focus areas can be determined through rounds of discussion. After going through this process for two or more of your priority goals, you may find that focus areas for some of your goals overlap. The example knowledge areas for the management and biophysical context are described in question form in Table 1.2.

***Workbook activity**: Describe and provide a labeled map of the geographic focus area(s) for each priority goal. Provide notes about the functionality and benefits, and management and biophysical context. Then, summarize the process used and experts consulted when determining the geographic focus area(s). This process should be completed for each goal.*

1C. SELECT GOAL AND GEOGRAPHIC FOCUS FOR RESTORATION PLANNING AND DESIGN

At this point, a single restoration goal and set of geographic focus area(s) related to that goal should be selected for continuing with the planning and design steps of this Guide. With a stated goal and geographic focus area(s), a rigorous site selection process can be undertaken in Step 2.

SUGGESTED PROCESS

1. ***Decide on one goal to continue with for planning.*** The planning team should review the outputs of Steps 1A and 1B and select a restoration goal and geographic focus area(s) to move forward with for planning and design of a restoration project. It may be useful to convene a technical advisory group to review the goals and focus areas and provide feedback on whether the options selected are viable. The project will take place at specific sites identified in Step 2 and will consist of one or more types of restoration interventions that will be selected in Step 3. This intervention selection step is where other practical factors will be considered, such as the availability of funding for the number of interventions and sites, stakeholder interest in supporting restoration efforts, and regional priorities. Finally, the suitability of the specific sites and selected interventions will be trialed during the pilot phase of implementation, as described in Step 4 of this Guide.

Workbook activity*: Describe the restoration goal your team selected to continue with for planning and design, as well as the final geographic focus area(s). Describe the process and rationale used to make this determination.*

Stakeholder Engagement

Stakeholders can be critical players in successful implementation of restoration activities and for ensuring the long-term sustainability of the project. It may be beneficial to have certain stakeholder groups serve as active participants during different steps of the planning process. Step 1 provides an opportunity to convene a technical advisory group to develop goals, determine the geographic focus area(s), and establish priorities.

In addition to technical expertise, a broad range of stakeholders can be involved in the planning and implementation of a restoration project. It is recommended that relevant stakeholders are identified early in this process. As more details of your restoration plan are determined during the subsequent steps of this Guide, you may need to revisit this exercise and consider changes to your stakeholder engagement strategy.

Workbook activity*: List technical experts, stakeholders, and partners including scientists, engineers, community members, and members of the private sector and national and local governments engaged to review and prioritize restoration goals and the geographic focus area(s). Provide a summary of stakeholder engagement activities to be taken for this step.*

Diver preparing substrate for outplanting corals in Grenada. Image: Tim Calver

STEP 2: IDENTIFY, PRIORITIZE, & SELECT SITES

Overview

Step parts:

2A. Identify Potential Restoration Sites

2B. Use Framework to Prioritize Sites

2C. Finalize Site Selection

Identifying and selecting sites where restoration will occur to meet the goal you have selected is the second step towards completing your Action Plan.

This step of the planning process involves identifying and prioritizing sites where restoration will occur to meet a specific restoration goal. In Step 2A, a technical advisory group will meet to: identify potential restoration sites within the geographic focus area(s) set during Step 1; discuss the framework for prioritizing sites; and agree on how the framework will be implemented, including whether it will be completed using semi-quantitative or quantitative data. The technical advisory group can be the same as in Step 1, or the group can be supplemented with additional managers, scientists and stakeholders as needed.

In Step 2B, a subset of the group with skills in data collection, analysis, data visualization, and mapping will complete the framework for assessing and prioritizing sites. The framework for prioritizing sites places emphasis on relevance to goal, the potential to improve site condition through restoration, and short- and long-term coral survivorship. Survivorship is assessed by combining projected future exposure to disturbances, resilience and the extent and severity of human impacts, which equates to assessing vulnerability to climate change and other interacting stressors. The end result is a ranking or classification of the potential restoration sites as high, medium, or low relative priority.

In Step 2C, the results will be shared in a workshop setting with the group involved in Step 2A, and potentially other decision-makers, manager colleagues, and reef stakeholders. The final sites will be selected at this meeting. Note that "final sites" refer to sites selected to test and start the restoration process, and the number of sites selected will likely be determined by available resources and capacity. As with every step in this guide, site selection might be refined as part of an iterative process through time. You may want to select a small number of sites for the pilot phase with a plan to expand to other sites in the next phase.

Assumptions for Step 2

- Restoration goals have been identified, and one priority goal has been selected to continue working with for planning and design of a restoration project (Step 1)
- Geographic focus areas have been identified where restoration interventions could help managers to achieve the set goal (Step 1)
- The management and biophysical context for restoration has been described for the geographic focus areas (Step 1)

2A. IDENTIFY POTENTIAL RESTORATION SITES

A **site** can be defined as an area of reef habitat that is within (i.e., not larger than) the geographic focus area determined in Step 1. Sites are likely to be a few hundred square meters of reef habitat and could take a variety of shapes depending on the habitat there and depth profiles. The geographic coordinates will need to be recorded for the approximate center of the site. In some cases, many candidate sites could be assessed and compared with sites set using GIS software to set a grid (e.g., 250x250 m cells) over the geographic focus area(s). In these cases there will be many sites, and the analysis (Step 2B) can be used to short-list candidates for final selection (Step 2C).

All sites compared using the framework should be of the same habitat type with similar depths and area. This ensures sites can be meaningfully compared. For example, values for some resilience indicators and human impacts would likely vary between a fore reef site 12-15 meters deep and a nearby lagoon site that is 1-3 meters deep. You would need to complete the framework for lagoon sites and then again for fore reef slope sites independently. You can then discuss and compare results within and among the habitat types during Step 2C when the final sites are selected.

Outplanting *Acropora* corals in the Dominican Republic.

Image: Paul Selvaggio | The Nature Conservancy

SUGGESTED PROCESS

*1. **Brainstorm potential restoration sites.*** In this step, it is important to list all potential sites where restoration could be conducted within the geographic focus area(s) set during Step 1. Alternately, GIS software can be used to set a grid over the focus area, and your team can determine the reef habitat cell or area size. Then, a framework for prioritizing sites (or habitat grid cells/areas) will be applied to set priority levels for each site to inform site selection. This step should be completed with your technical advisory group. Sites that should be considered are sites where some or all of the following are true:

1. **Management is in effect** – causes of reef degradation have been identified and are under effective management (now or in the future)
2. **Reef value is high** – reef provides important ecosystem services that offer multiple benefits in addition to the goal, or has high cultural value
3. **Data are or can become available** – long-term monitoring takes place, data and information on the site are available or accessible, or plans and resources are available to collect new data

*2. **Develop a site list or map.*** A list of sites (names or numbered codes) with center point coordinates should be developed as an output from the process above. Consider developing a map that shows the entire area under management, the geographic focus areas for the restoration goal (from Step 1), and the sites under consideration for restoration within the geographic focus areas (from Step 2A).

***Workbook activity**: List restoration sites within the geographic focus area(s) being considered for restoration. Document their location and provide a brief rationale for why each site was selected.*

Outplanting corals onto damaged reefs, US Virgin Islands.

Image: Tim Calver | The Nature Conservancy

2B. USE FRAMEWORK TO PRIORITIZE SITES

The framework for prioritizing sites enables a rigorous process for site selection. Collecting or compiling information to use the framework, and then presenting the information within data tables and maps, can help ensure that the sites eventually selected (in Step 2C) are those where:

- *Restoration will help to achieve the set goal ('Relevance to restoration goal')*
- *Restoration will most improve conditions at the site ('Potential to improve site condition')*
- *Short- and long-term coral survival potential is high ('Coral survivorship')*

This is where you may also want to consider connectivity, because restoration sites that are sources of coral larvae (rather than sinks) will increase the benefits for the larger reef system. High-resolution connectivity information is rarely available in reef areas, so it is likely that you may need to exclude connectivity. However, if connectivity information is available, all sites can be classified as relative sources or sinks, and a criterion can be set that weights sites that are sources as higher priority.

The framework is composed of five types of data or information under the categories of: *Relevance to Restoration Goal*, *Potential to Improve Site Condition*, and *Coral Survivorship*. Coral Survivorship is subdivided into *Future Exposure* to disturbances, the capacity of sites to show positive *Ecological Resilience*, and *Human Impacts* – these, in combination, equate to assessing vulnerability to climate change. The framework has been designed to be adaptable; all framework parts should be considered, but how each part is assessed is expected to vary among users.

1. **Relevance to Restoration Goal: To what extent would restoration at the site help to achieve the set goal?**

   Let's continue with the example goal:

   Within 10 years, restore diverse and structurally complex coral reef fisheries habitats that increase abundance of valued species and support local fisheries production and livelihoods.

   The sites closest to known fishing areas would have the greatest relevance to meeting this goal. Restoring sites close to known fish aggregation areas (nursery or spawning grounds) and accounting for local currents and connectivity patterns is also relevant and should be considered. For goals related to ecosystem services, consider using available tools such as the Mapping Ocean Wealth Portal (see Resources). There will probably be different spatial patterns in 'Relevance to Restoration Goal' for each of your different goals. This is why the framework for prioritizing sites needs to be repeated for each restoration goal (following setting a new geographic focus for each goal in Step 1 and identifying candidate sites in Step 2A). Note that it is possible that 'Relevance to Restoration Goal' will be considered to be equal for all of your candidate sites. In these cases, the Relevance to Restoration Goal part of the prioritization framework can be omitted.

2. **Potential to Improve Condition: To what extent will restoration improve site condition?**

   In many cases, the potential to improve condition at a site through restoration can be assessed as the change in coral cover or another metric of ecological condition (e.g., ratio between corals and macroalgae) over the last year due to a disturbance event, or over the last 3, 5, or 10 years due to several disturbance events combined with human impacts. In these cases, the potential to improve condition at a site would be greatest where the potential to reverse recent negative change in coral cover or another metric of ecological condition is greatest.

   It is important to remember that some sites will be able to recover naturally if there is sufficient recruitment of coral larvae. Sites where natural recovery potential is high should not be considered for restoration interventions, as interventions can be costly, and other traditional management actions may be more successful with supporting the site over the long-term.

3. **Coral Survival:** What is the short- and long-term likelihood that corals at the site will survive?

   Corals are more likely to survive where they are exposed to less frequent and/or severe future disturbances, at sites with greater resilience to disturbance, and at sites exposed to lower levels of pressure or stress from human activities (see Table 2.1).

Table 2.1. Factors influencing coral survivorship.

Future Exposure	Ecological Resilience	Human Impacts
What is the likely frequency and severity of future disturbances?	***What is the capacity of the site to resist and recover from disturbances?***	***What are the types and severity of human impacts affecting coral reef communities at the site, and which are or could be mitigated through management actions?***
Disturbance is a regular part of the dynamics of coral reefs. In all reef areas, there can be large spatial variations in impacts caused by disturbances. While many disturbances are unpredictable and hence difficult to include in the framework, some can be projected. Climate model projections suggest there will be great variation, even at local scales, in future exposure to coral bleaching events. Similarly, some reefs are more prone to coral predator outbreaks or sediment pulses from intense storms due to their location. Coral survivorship is likely greater where impacts to coral communities from future disturbances are less likely, may be less severe, or will occur much later as the climate changes.	Resilience can vary widely among reef sites, depending on the intactness of ecological processes that support resilience. Within any area of interest, reefs with greater relative resilience will have relatively high coral diversity and recruitment, high herbivore biomass, abundant crustose coralline algae, and low levels of coral predation, disease and macroalgae cover. These characteristics of relatively resilient reefs are 'resilience indicators' that can be assessed or quantified.	Even at the most remote reefs in the world, there are impacts caused by human activities. Human impacts reduce reef resilience; they reduce the capacity of reefs to resist disturbances and can lengthen recovery timeframes. The types and severity of human activities that impact each candidate reef site will vary. Examples of human impacts in reef areas include: marine-based pollution, watershed-based pollution, marine debris, overfishing, coastal development, tourism and shipping, among many others.

Coral bleaching in American Samoa

Image: The Ocean Agency | Coral Reef Image Bank

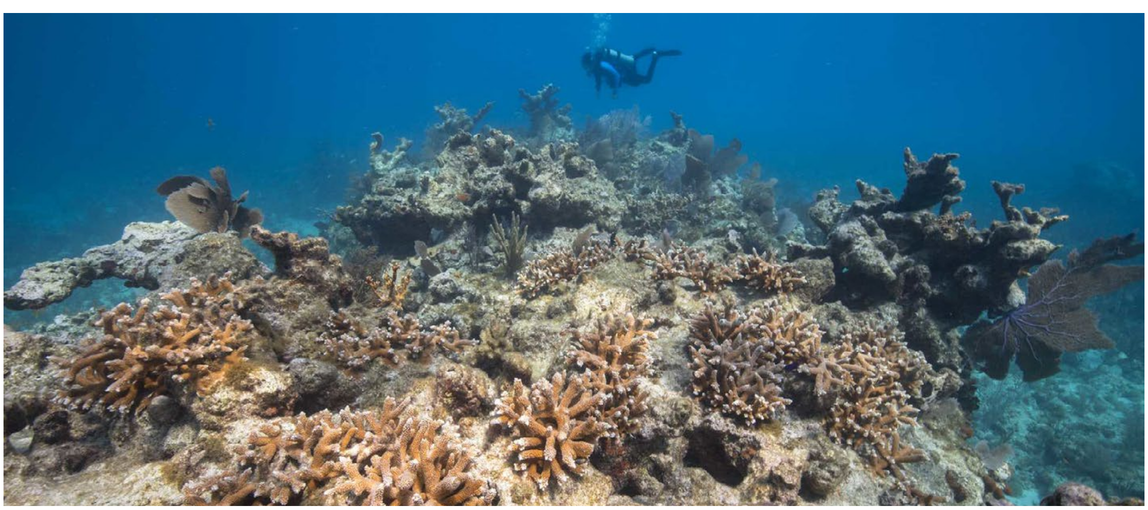
SUGGESTED PROCESS

1. ***Decide how to use the framework for prioritizing sites.*** The framework can be completed semi-quantitatively, using assessments and judgments from local experts, or quantitatively, using data from local and regional ecological and social monitoring programs. Deciding whether to complete the framework semi-quantitatively or quantitatively requires first reviewing available data. Using a strictly quantitative approach requires that data are available for each framework part. As a starting point, you can review the information used to set the geographic focus for the goal. List each framework part within a document or spreadsheet file and then list all available datasets. Examples of datasets to consider include:

    - Reef monitoring data on benthic cover and fish community structure, as well as coral predation and disease
    - Projections of future exposure to bleaching events (publicly accessible on the UN Environment Live, see Resources)
    - Extent and severity of impacts from recent disturbances
    - Patterns in impacts caused by other disturbances (e.g., crown-of-thorns starfish outbreaks, floods)
    - Human impacts data showing patterns and severity of impacts on reefs caused by human activities (e.g., ship groundings, overfishing)
    - Data on other uses of the area, such as a marine spatial plan, zoning plan, or MARXAN
    - Data from previous attempts at restoration in the area

    You should only list datasets that are sufficiently rigorous and recent, meaning the group is comfortable with how and when the data were collected. You should state on your list exact dates of data collection. Data more than 3-5 years old may not be representative of current spatial patterns in any of the variables for the framework parts, so should be considered with care. Your group can then discuss what data would be needed to fill in any gaps and whether you have the expertise, resources, and time to generate or collect those data.

    The next step is to consider whether to apply the framework quantitatively or semi-quantitatively (Table 2.2). For some, data limitations will result in the conclusion that completing the framework semi-quantitatively is the only option. For others, the framework could be completed either semi-quantitatively or quantitatively. That both are an option does not automatically mean that the framework should be completed quantitatively; each approach has different advantages and disadvantages.



Outplants of *Acropora cervicornis*, Key Largo, Florida.

Image: Alex Neufeld | Coral Restoration Foundation™

Table 2.2. Advantages and disadvantages of semi-quantitative and quantitative approaches.

Advantages	
Semi-Quantitative Framework *Site prioritization based on expert judgment*	**Quantitative Framework** *Site prioritization based on comprehensive datasets*
• Does not require extensive, detailed, rigorous and recent data on each framework part • Allows for input from local experts • No issues with data gaps in the identified restoration area • Can be easier to interpret than fully quantitative scoring • Relatively easy to analyze and present the response data • Less data, time, and resource-intensive than completing the framework entirely quantitatively	• Results in a way to compare sites within priority classes; i.e., five sites may end up 'high priority for restoration' and they can be ranked from 1 to 5 • More objective than human responses, which can be especially important for the Resilience category • Enables comparisons among several areas of interest within the same location (i.e., where groups of responses from different expert groups cannot be compared)

Disadvantages	
Semi-Quantitative Framework	**Quantitative Framework**
• Cannot compare sites within priority classes; i.e., five sites may end up 'high priority for restoration' with no objective way to determine which is the highest priority • Human responses can be highly subjective • Cannot easily compare areas within the same location • Masks detail as a single priority rating is used for resilience, which is a composite metric derived from many indicators in the quantitative analysis	• Requires extensive, detailed, rigorous and recent data on each framework part • Has potential to be very time- and resource-intensive • There may be data gaps at candidate sites requiring new data collection • Requires technical expertise in compiling and analyzing the data • Data rigor will be a common concern and spurious data (in a quantitative analysis) has the same limitations as subjective human responses

Semi-Quantitative Approach

For this approach, site prioritization is conducted based on expert judgment. Statements are developed for each framework part, and experts rate the level of agreement with each statement using a five-point scale (e.g., 5 = Strongly Agree; 1 = Strongly Disagree). The statements need to be developed in such a way that the direction of the scoring is the same for all framework parts; i.e., that a high score means higher relative priority for restoration and a low score means lower relative priority for restoration. The responses from local experts for each site and statement are averaged and can then be translated into relative classifications (e.g., low, medium, and high, for relative restoration priority).

SUGGESTED PROCESS

1. ***Develop framework part statements and record average responses.*** Each framework part is associated with a statement that is graded by local experts on a scale of 1-5. Example statements and a site rating sheet are provided in Table 2.3. The number values associated with each agreement level are then averaged for each framework part. Importantly, variance among the average scores should exceed 1 for sites to be considered different. If all sites have average scores within just 1 point, respondents do not think the sites are very different and all sites could be considered of equal priority level. This is likely to be a rare case, but in these cases all sites would be discussed in Step 2C as equal priority and a range of other considerations related to the social, cultural, political, and management context could be discussed and used to select sites.

Table 2.3. Example site rating sheet to record responses and rationale using a semi-quantitative approach.

SITE 1:							
Example Statements for Each Framework Part	Rating					Total (N)	Avg.
	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)		
1. **Relevance to Restoration Goal**: *Restoring this site is extremely and directly relevant to achieving our restoration goal.*	5,5,5	4,4	3	0	0	26 (6)	4.3
Document data or rationale provided.							
2. **Coral Survival**:							
a. **Future Exposure**: *This site is among those in our geographic focus that is likely to rarely be exposed to disturbances or is projected to be exposed to these disturbances much later.*							
Document data/rationale used for rating. **Considerations**: future exposure to cyclones, coral bleaching conditions, extreme low tides, predation, and other disturbance events.							
b. **Ecological Resilience**: *This site is relatively resilient, with great relative capacity to resist and recover from disturbances.* **Considerations**: common resilience indicators include: coral recruitment, coral diversity, herbivore biomass, macroalgae cover, CCA cover, coral predation, coral disease, and temperature variability.							
Document data/rationale used for rating.							
c. **Human impacts**: *Human impacts are relatively low at this site.* **Considerations**: common human impacts on reefs include reef fish fishing, marine-based pollution, watershed-based pollution, marine debris, coastal development, tourism, and shipping.							
Document data/rationale used for rating.							
2. **Potential to Improve Site Condition**: *Restoration will greatly improve condition at this site.* **Considerations**: extent to which ecological condition has declined or degraded in recent years.							
Document data or rationale provided.							

2. *Color code responses to facilitate discussion of priorities.* Next, the results need to be made intuitive to the people who will eventually select the restoration sites in Step 2C and need to consider and discuss the framework results. For this reason, average responses for each framework part can be color-coded based on the average level of agreement with the statement (Table 2.4).

Table 2.4. Coding system for converting average responses to prioritize sites using a semi-quantitative approach.

Level of Agreement	Conversion to Relative Restoration Priority	Color Code
Strongly Agree (5)	High (average values >4.1 and ≤5)	[Dark Blue]
Agree (4)	Med-high (average values >3.1 and ≤4)	[Light Blue]
Neutral (3)	Medium (average values >2.1 and ≤3)	[Light Orange]
Disagree (2)	Medium-Low (average values >1.1 and ≤2)	[Orange]
Strongly Disagree (1)	Low (average values ≤1)	[Red]

3. *Establish relative restoration priority level.* Finally, relative restoration priority levels are established by classifying reefs as 'high', 'medium', or 'low' priority for restoration. Average responses for each framework element are then converted to relative restoration priority levels with color codes for tables and maps. Either 2 or 3 priority levels are recommended but you could have more. Example criteria for 3 priority levels are provided in Table 2.5.

Table 2.5. Coding system to establish priority levels based on site prioritization.

Relative Restoration Priority Level	Conversion to Relative Restoration Priority	Color Code
HIGH priority for restoration	There are **MEDIUM-HIGH** or **HIGH** values for at least 3 of the 5 framework elements AND there are no **LOW** values for any element of the framework	[Dark Blue]
MEDIUM priority for restoration	There are no **LOW** values for any framework element and criteria for **HIGH** is not met	[Orange]
LOW priority for restoration	There are **LOW** values for one of the framework elements	[Red]

A completed table is shown over the page (Table 2.6), as a worked example to show how the criteria above result in a priority rating for each restoration site. Using a color scheme in a table enables readers to see which sites are high versus low priority and why, since all average values and relative classifications (low to high) are shown for each framework part. This table format also enables quick identification of sites with relatively high priority where a focus on management of human impacts would support the success of restoration interventions, or even change the ranking of the site. For example, in Table 2.6, Orchid Reef and Rose Reef have the same final average score (3.40), yet Rose Reef is considered a high priority reef, and Orchid Reef is medium priority. Both have high or medium-high value scores for at least 3 of the framework parts, but Orchid Reef has medium-high human impacts. If addressing those impacts is tractable through short-term management actions, Orchid Reef could be seen (for the purposes of site selection) as having lower human impacts, thereby moving it into the high priority category. Those discussions can take place among your group in Step 2C.

Table 2.6. Hypothetical site prioritization results using a semi-quantitative approach. Example analysis table for 15 reefs, using the criteria described above. In the color scheme used throughout the table, blue means higher restoration priority and red means lower (here, only 3 classes are used – low, medium, and high – see tables 2.4 and 2.6 for examples of use of 5 classes and colors). The sites are organized from highest to lowest priority level. Note that there is a high priority reef, Lily Reef, and a medium priority reef, Azalea Reef, where mitigating human impacts could support the success of restoration interventions (orange and red boxes for human impacts). The value in each cell is an average of the responses (with value from 1 to 5), so could be paired with variance to show level of agreement among respondents.

Reef Name	Priority Level FINAL	Average	Relevance to Goal	Potential to Improve Condition	Short and long-term Survivorship [Climate vulnerability]		
					Future Exposure	Resilience	Human Impacts
Geranium Reef	HIGH	4.52	4.92	4.92	4.92	4.92	2.92
Tulip Reef	HIGH	3.73	3.84	4.97	4.93	1.93	2.97
Lily Reef	HIGH	3.71	3.97	3.88	3.88	4.88	1.92
Periwinkle Reef	HIGH	3.71	2.91	3.91	3.91	3.91	3.91
Rose Reef	HIGH	3.35	1.95	3.95	3.95	1.95	4.95
Orchid Reef	MEDIUM	3.33	3.93	3.93	2.93	3.93	1.93
Petunia Reef	MEDIUM	2.27	1.87	1.87	1.87	2.87	2.87
Azalea Reef	MEDIUM	2.10	3.90	1.90	1.90	1.90	0.90
Chrysanthemum Reef	LOW	3.76	0.96	4.96	4.96	2.96	4.96
Lavender Reef	LOW	3.58	3.98	3.98	4.98	0.98	3.98
Hydrangea Reef	LOW	2.43	4.83	0.83	0.83	2.83	2.83
Daisy Reef	LOW	2.29	2.89	0.89	0.89	4.89	1.89
Marigold Reef	LOW	2.11	1.91	0.91	0.91	3.91	2.91
Buttercup Reef	LOW	1.70	0.97	0.96	0.84	3.89	1.84
Violet Reef	LOW	1.61	1.10	2.15	2.20	0.20	2.42

Quantitative Approach

If this approach is selected, continuous data are compiled for each framework part. Data for all framework parts must be set to a unidirectional standard scale. This requires dividing by the maximum value for each variable or indicator from among the sites being considered. This generates new data values between 0 and 1, with a maximum value of 1 (called 'normalizing' the data). This scale can be made unidirectional to ensure high scores equate to a relatively high priority for restoration; in some cases (e.g., human impacts, see below), this requires subtracting the normalized values from 1. With all scoring scales aligned and unidirectional, the scores for all framework parts can be averaged and compared.

SUGGESTED PROCESS

1. ***Develop metrics and units to support quantitative assessment of each framework part.*** For each framework part, at least one metric and unit should be defined. These will vary based on your planning team, but suggestions and examples are provided below.

   Relevance to Goal: In Step 2A you identified sites from within the geographic focus area(s) identified for the goal. This part of the prioritization framework is intended to further define site conditions needed to achieve the goal and metrics that can be used to prioritize these site conditions. For the example goal of ***"Within 10 years, restore diverse and structurally complex coral reef fisheries habitats that increase abundance of valued species and support local fisheries production and livelihoods"***, relevance to goal could be quantified as the proximity (in hundreds of meters or kilometers) of the candidate site to a known fishing area. Examples of other valuable metrics might include abundance of important fish and coral species or the proximity of sites to fish nursery habitats like seagrass beds and mangroves.

Potential to Improve Site Condition: The potential to improve site condition could be measured as the percent decline in absolute coral cover in the last five years (i.e., that decline could potentially be reversed). Declines can then be quantified and compared among sites; i.e., the sites where declines have been greatest, and which may benefit most from reversing degradation.

Future Exposure: Many different disturbances could affect reefs in the future. At the time of publication of this Guide, there are publicly accessible data on projected spatial variation in the likelihood, frequency and severity of cyclones/hurricanes and coral bleaching for all coral reefs. For coral bleaching, climate models have been used to project the date (between 2020 and 2100) when coral reefs will start to experience annual severe bleaching (ASB). These long-term projections provide an indication of coral bleaching conditions in the decades ahead. These differ from NOAA Coral Reef Watch products, which provide near real-time updates on thermal stress in reef areas as well as short-term outlooks (for the 3-6 months ahead). Given that reefs will degrade before annual bleaching events occur, ASB is a conservative estimate of when reefs will degrade and begin losing their capacity to provide ecosystem services. ASB dates can vary greatly on local scales (van Hooidonk et al. 2016). These projections have 4 km resolution and are available at the UN Environment Live website (see Resources), where data can be downloaded and extracted for the sites being considered for restoration (sites will only have differing values in the Projections Dataset if >4 km apart). Reefs projected to experience ASB later relative to other candidate sites may have greater potential for long-term coral survivorship. You may also want to consider floods, extreme low tide events, predator outbreaks, or disease epidemics.

Ecological Resilience: Indicators of ecological resilience in reef areas may include coral diversity, coral recruitment, herbivore biomass, and presence or cover of crustose coralline algae, all of which relate to ecological processes that can support short-term coral survivorship and the capacity for reefs to recover after disturbance. In contrast, coral predation, coral disease, and macroalgae cover are all indicators of ecological processes that will limit or hinder short-term survivorship. Readers may want to consider other indicators. The indicators listed here are examples of commonly used resilience indicators recommended within *A Guide to Assessing Coral Reef Resilience for Decision Support* (Maynard et al. 2017) which includes lists of indicators and appropriate metrics. Data for the indicators will come from ecological reef monitoring data collected locally or by regional/national monitoring teams. Data for each indicator are combined to produce a resilience score for each site.

Human Impacts: Examples of human impacts in reef areas include: marine-based pollution, watershed-based pollution, marine debris, overfishing, coastal development, tourism, and shipping. That is not an exhaustive list. There may be other human impacts on coral reefs in your area. Data for human impacts will come from ecological reef monitoring data collected locally or by regional/national monitoring teams. Human impacts risk information is also available from *Reefs at Risk Revisited* (Burke et al. 2011) at 500 meter resolution. These datasets include coastal development, marine-based pollution and damage, overfishing and destructive fishing, and watershed-based pollution, as well as those four combined into Integrated Local Threat (ILT). The ILT data (see Resources) can be used if quantitative data are not available for human impacts in your area and are available as projections of local threat severity for 2030 and 2050.

Image: Link Roberts | Marine Photobank

A single value or score must be generated for any framework part that has more than one variable or indicator (certain to be the case for resilience and human impacts). Each of these is an 'aggregate index'; these indices combine scores for a number of different indicators or metrics. The analysis steps are reviewed in detail in A Guide to Assessing Coral Reef Resilience for Decision Support (Maynard et al. 2017). For **Ecological Resilience** and **Human Impacts** data, the procedure is:

1. Normalize the data for each indicator or variable (e.g., human impact type) by dividing by the maximum value among the candidate sites; this sets a standard scale for all indicators and impacts of 0-1.
2. That scale is then made unidirectional in an intuitive way. With resilience, it makes sense to talk about high resilience being good. High scores equal 'high resilience', meaning the normalized values are subtracted from 1 for indicators where high values are bad for resilience (e.g., coral predation, coral disease, and macroalgae cover).
3. The scores for the indicators and impacts are then averaged.
4. The aggregate resilience and human impacts scores are then normalized to a scale of 0-1 by dividing by the maximum value.
5. The 'human impacts' aggregate scores are subtracted from 1, so that high scores are good scores for both resilience and human impacts.

2. Conduct quantitative assessment using metrics. A completed example is shown in Table 2.7. The steps to complete the framework include:

1. Average the scores for each framework part to generate the raw priority score.
2. Normalize raw priority scores, as was the case for resilience and human impacts, by dividing by the maximum value. This results in a final restoration priority score of 0-1 with the sites with greatest priority having a score of 1, and all other sites assessed as relative to those sites (i.e., a site with a score of 0.7 has 30% lower priority than the highest priority sites).
3. Establish relative restoration priority level using criteria for low, medium, and high priority level as shown in Table 2.5. Re-sort data from highest to lowest score within each priority level, and list the levels from highest to lowest priority (as in Table 2.7).
4. Rank sites from highest to lowest final priority scores from 1 to X (note: any number of sites can be included).
5. Use the color scheme for all scores for all framework parts, as follows (where avg is average and sd is standard deviation): high (≥avg+1sd), med-high (≥avg and <avg+1sd), med-low (≥avg-1sd and <avg), and low (<avg-1sd). Med-high and med-low can be combined into medium as in the example in Table 2.7.

The same example used for the semi-quantitative section (Table 2.6) is now shown for the quantitative approach in Table 2.7.

***Workbook activity**: List available datasets applicable to each part of the prioritization framework. Document any data or information that are missing or need to be collected. Describe the rationale for your decision to complete the framework quantitatively or semi-quantitatively, including the advantages and disadvantages in your case. Complete the framework, documenting steps in the analysis as described in the Workbook. Develop final tables with sites sorted by priority level with color-coding to distinguish low, medium, and high scores and rankings.*

Table 2.7. Hypothetical site prioritization results using a quantitative approach. Priority Level categories are the same as those used for the semi-quantitative approach (see Table 2.6). In the color scheme used throughout the table, blue means greater restoration priority and red means lower priority (where avg is average and sd is standard deviation): high (≥avg+1sd), med-high (≥avg and <avg+1sd), med-low (≥avg-1sd and <avg), and low (<avg-1sd). The sites are organized from highest to lowest priority level. Quantitative scoring, combined with criteria setting for priority levels, ensures that relative priority within the category is clearly seen, and that sites with high priority scores (averages) but a low score for a key category, are low priority (e.g., Chrysanthemum Reef which has low value to goal but the third-highest average score). See below table for variable codes.

Reef Name	Priority Level	Priority Score FINAL	Priority Score RAW	Relevance to Goal	Potential to Improve Condition	Short and long-term coral survival. [Climate Vulnerability]																
						Future Exposure	Resilience/ecological processes								Human Impacts							
							R	CD	HB	CR	CCA	CP*	CD	MA*	HI	MBP	WP	MD	OF	CD	T	S
Geranium Reef	HIGH	1.00	0.76	0.88	0.92	0.87	4.92	0.38	0.60	0.73	0.50	0.82	0.95	0.86	0.25	0.40	0.15	0.87	0.84	0.64	0.27	0.77
Tulip Reef	HIGH	0.96	0.73	0.83	1.00	1.00	1.93	0.79	0.70	0.57	0.65	0.14	0.19	0.00	0.25	0.97	0.50	0.23	0.75	0.88	0.11	0.47
Lily Reef	MEDIUM	0.92	0.70	0.78	0.82	0.77	4.88	1.00	0.99	0.65	0.45	0.91	0.68	0.74	0.12	0.73	0.38	1.00	0.54	0.35	1.00	0.60
Periwinkle Reef	MEDIUM	0.84	0.64	0.40	0.79	0.74	3.91	0.14	0.99	0.47	0.98	0.98	0.76	0.61	0.35	0.32	1.00	0.32	0.79	0.29	0.56	0.14
Rose Reef	MEDIUM	0.78	0.59	0.33	0.83	0.78	1.95	0.32	0.48	0.61	0.41	0.10	0.15	0.86	0.48	1.00	0.07	0.01	0.96	0.20	0.13	0.33
Orchid Reef	MEDIUM	0.70	0.54	0.82	0.54	0.49	3.93	0.51	0.40	0.98	0.05	0.04	0.97	0.00	0.29	0.98	0.02	0.46	0.91	0.23	0.83	0.30
Petunia Reef	MEDIUM	0.51	0.39	0.35	0.29	0.24	2.87	0.72	1.00	0.80	0.12	0.83	0.52	0.01	0.32	1.00	0.26	0.68	0.09	0.63	0.86	0.05
Azalea Reef	MEDIUM	0.47	0.36	0.78	0.25	0.20	1.90	0.87	0.34	0.28	0.55	0.51	0.00	0.42	0.00	0.43	0.99	0.99	0.34	0.75	0.97	0.76
Chrysanthemum Reef	LOW	0.90	0.69	0.13	1.00	0.95	2.96	0.80	0.45	0.05	0.70	0.00	0.51	0.94	0.72	0.68	0.32	0.09	0.10	0.04	0.04	0.20
Lavender Reef	LOW	0.90	0.69	0.86	0.89	0.84	0.98	0.28	0.47	0.80	0.06	0.21	0.55	0.12	0.36	0.05	0.91	0.48	0.15	0.62	0.69	0.44
Violet Reef	LOW	0.56	0.42	0.35	0.52	0.47	2.83	0.05	0.08	0.84	0.11	0.17	0.94	0.43	0.29	0.76	0.07	0.09	0.19	1.00	0.71	0.89
Daisy Reef	LOW	0.54	0.41	0.66	0.21	0.16	4.89	0.86	0.66	0.37	1.00	0.21	0.82	0.88	0.16	0.93	0.74	0.75	1.00	0.41	0.12	0.46
Hydrangea Reef	LOW	0.53	0.40	1.00	0.04	0.01	3.91	0.60	0.66	0.81	0.52	0.38	0.45	0.64	0.22	0.42	0.79	0.00	0.12	1.00	0.86	0.86
Buttercup Reef	LOW	0.42	0.32	0.20	0.20	0.15	3.89	0.44	0.74	0.92	0.76	0.53	0.97	0.43	0.15	0.97	0.35	0.17	0.96	0.89	0.71	0.40
Marigold Reef	LOW	0.41	0.31	0.34	0.08	0.03	0.20	0.49	0.46	1.00	0.57	0.55	0.87	0.74	0.25	0.06	0.19	0.70	0.67	0.37	0.91	1.00

R = resilience, CD = coral diversity, HB = herbivore biomass, CR = coral recruitment, CCA = crustose coralline algae, CP = coral predation, CD = coral disease, MA = macroalgae cover, HI = human impacts, MBP = marine-based pollution, WP = watershed-based pollution, MD = marine debris, OF = overfishing, CD = coastal development, T = tourism, S = shipping.

2C. FINALIZE SITE SELECTION

The aim of this step is to share the results of the site prioritization framework with members of the technical advisory group or other decision-makers, managers, community leaders, and stakeholders to ensure that site selection decisions are made collaboratively and through a transparent process, with additional perspectives and local site knowledge accounted for in the decision. For example, there may be social, cultural, political or regulatory constraints that make restoration at some of the highest priority sites either very attractive or unattractive or even not viable. This is also where other aspects of feasibility come into play, including costs, logistical constraints (e.g., site accessibility), and any other issues that could affect restoration success. There may also be important perspectives on variation in 'Relevance to Goal' and 'Potential to Improve Site Condition' that were not considered when completing the site prioritization framework. Another consideration is that recovery can occur naturally at some of the sites the framework suggested are highest priority. Discussing this may help your group determine relative restoration need, and you may then select from among the highest priority sites where restoration is considered most needed. Additionally, the number or size of sites selected at this stage will likely need to account for the resources and capacity available for this work.

Note that this section is about finalizing decisions about potential restoration sites. However, you may find that your program may need to adapt and make changes to the list of restoration sites based on the results and new insights gained from pilot phase activities.

SUGGESTED PROCESS

1. ***Facilitate a discussion to finalize site selection.*** The meeting may begin with review and discussion of the: 1) framework parts and methods used to complete the framework; 2) criteria used to set priority levels; and 3) results, with focus on the medium and high priority sites. Plan to facilitate two rounds of discussion, one to reduce the number of medium- and high-priority sites being considered and another to select a list of sites that is feasible for your program (for example, 3-5 sites). You can use the following points to guide the meeting:

   - Discuss the results from the site prioritization framework generally – how many low, medium, and high priority sites are there?
   - Discuss all medium- and high-priority sites. Why were each ranked medium- or high-priority? Are there additional considerations, such as regulatory, social or cultural constraints, that make one or more of these sites higher (or lower) priority than the others? Low priority sites probably should not be considered or discussed at length. The criteria are set in the site prioritization framework for high, medium, and low final priority levels such that sites considered low priority have a low score for at least one of the framework parts. Restoration should not be considered at sites where the 'Relevance to Goal' is low, 'Coral Survivorship' is low, or 'Potential to Improve Site Condition' is not expected to improve through restoration. For those reasons, you can focus on the medium- and high-priority sites, and potentially just the high-priority sites depending on how many there are.
   - Some may feel that one or more of the framework parts is more important than others and should be given greater weight during final site selection. Those discussions could result in your group viewing framework results from a new perspective or in the development of new criteria for rating the sites as low-, medium-, and high-priority. Such discussions are likely to help your group identify the highest priority sites.
   - Discussions at the meeting should be facilitated or directed towards the group agreeing on a smaller list of priority sites that is feasible for your program. To do this, you may need to narrow down the medium- and high-priority sites. A leader (or facilitator) could ask whether there are any medium- or high-priority sites that should be considered the highest priority, and why. They can also ask whether there are any medium- or high-priority sites that should be excluded from consideration and why. The color-coded tables and supplementary maps will inform these discussions and ensure that participants

understand why some medium- and high-priority sites are being given the greatest consideration. The final site or sites can then be selected from among the highest priority sites through further discussion and consideration of these sites to identify the sites considered the greatest priority right now, to meet the identified restoration goal.

- 'Human Impacts' will need to be considered and discussed for each of the sites being seriously considered for selection. 'Human Impacts' should be relatively low at the selected sites or managers can consider addressing any human impacts likely to affect short- and long-term coral survivorship. This ensures that this final site selection step prepares the planning team to identify actions that will support the success of any planned restoration interventions (Step 3: Identify, Design, and Select Interventions).

***Workbook activity**: Provide a brief description of the highest priority sites selected for restoration. Include the site name, general description of the site, and a summary (quantitative or qualitative) on how sites compare to others using the prioritization framework. You may also wish to indicate which site(s) might be suitable for the pilot phase. Develop a map of the geographic area of focus for the restoration goal with the final selected sites clearly marked. Then, provide a summary of the process used to finalize your list of restoration sites, including stakeholders or decision-makers involved.*

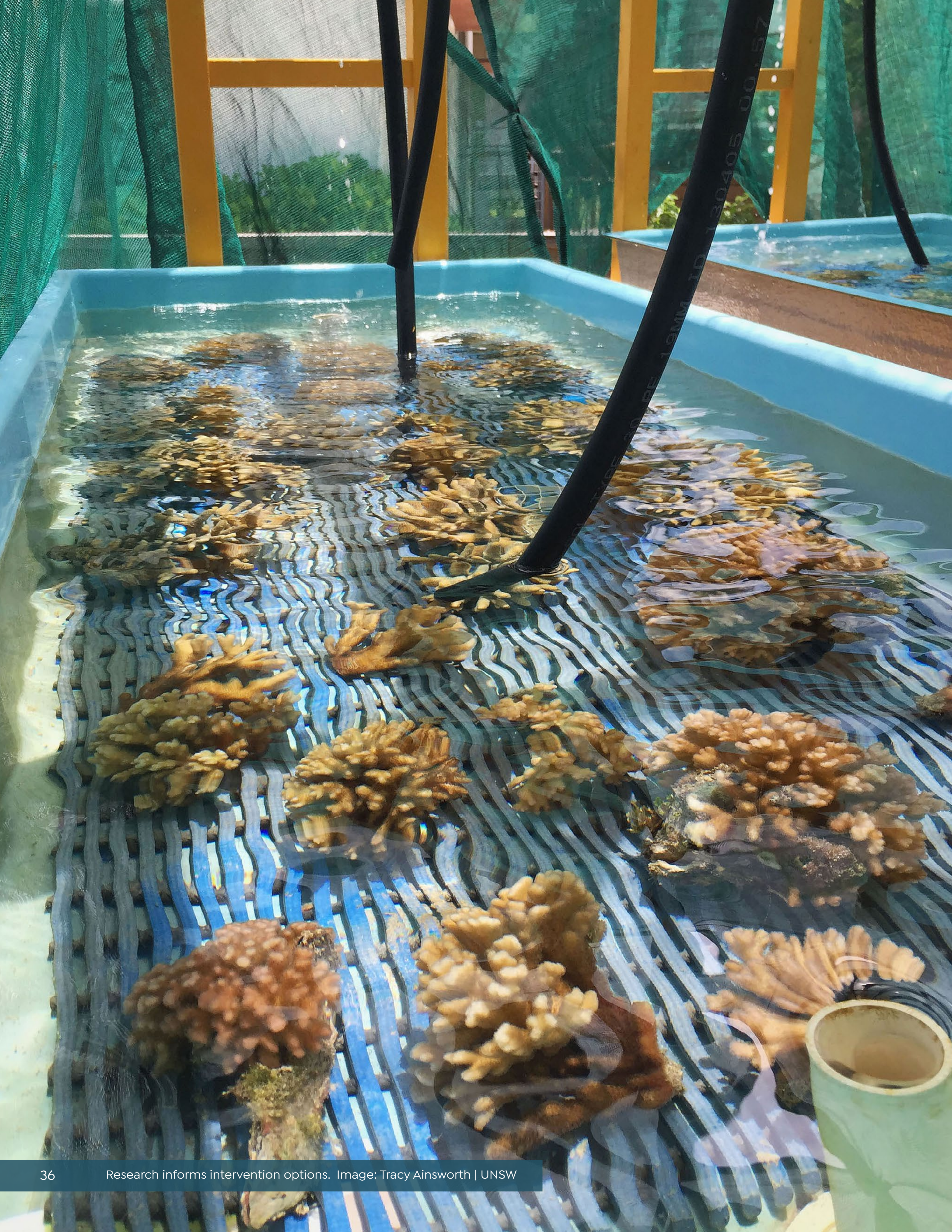
Stakeholder Engagement

Stakeholders will want to know where restoration will take place and why, which means engaging with stakeholders during Step 2 will be important. Opportunities can be made to engage stakeholders and benefit from stakeholder knowledge during each part of Step 2. Stakeholders can help identify sites during Step 2A. Stakeholders can then assist with data compilation or new data collection efforts when completing the framework for prioritizing sites during Step 2B. During Step 2C, stakeholders can provide valuable insight and fresh perspectives when reviewing and discussing the results from the framework for prioritizing sites. Stakeholder engagement during Step 2 will increase support for the restoration interventions identified and selected during Step 3.

***Workbook activity**: List technical experts, stakeholders, and partners including scientists, engineers, community members, and members of the private sector and national and local governments engaged to review and prioritize restoration goals and the geographic focus area(s). Provide a summary of stakeholder engagement activities to be taken for this step.*

Locals attach coral fragments, Pulau Hatamin, Indonesia.

Image: Martin Colognoli | Coral Guardian | Coral Reef Image Bank



Research informs intervention options. Image: Tracy Ainsworth | UNSW

STEP 3: IDENTIFY, DESIGN & SELECT INTERVENTIONS

Overview

Having defined your restoration goal and sites, you will now identify, design, and select interventions that will be used to achieve your restoration goal. This requires careful consideration of various design elements that may be needed to tailor a restoration intervention for use in your specific context. The identification of a variety of possible intervention options - and consideration of how they would need to be designed for maximum effectiveness both now and in the future - is a critical step to making informed decisions about which restoration interventions to select for priority action.

Step parts:

3A. Identify an Array of Intervention Options

3B. Apply Climate-Smart Design Considerations

3C. Evaluate and Select Interventions

In Step 3A, you will brainstorm options for restoration interventions that support the selected priority goal and specify how they would be applied at your specific sites. In Step 3B, you will examine basic design questions and then add climate-smart design considerations to ensure that future environmental changes are examined and incorporated into the design process. Armed with the resulting information about how different intervention options compare in their potential to be well-designed and effective, you will use five types of criteria to evaluate and select your final choice of restoration interventions in Step 3C.

The science and practice of coral reef restoration is evolving rapidly. Managers are advised to stay current with the literature to identify field-tested methodologies that may be appropriate for your area.

Similarly, climate science is also evolving rapidly both in global projections and regional and local observations. Managers are advised to periodically check the latest projections and observations as they relate to the planning and design of restoration interventions, and throughout subsequent implementation, monitoring, and evaluation.

Assumptions for Step 3

- A restoration goal has been selected to support the identification and design of restoration interventions (Step 1)
- The management and biophysical context for restoration has been described for the geographic focus area(s) that relate to the set goal (Step 1)
- Sites within the geographic focus area(s) have been identified, prioritized, and selected that are relevant to the goal, support coral survival and resilience, and have high potential to improve site condition (Step 2)

3A. IDENTIFY AN ARRAY OF INTERVENTION OPTIONS

In this step, you will create a list of intervention options to support your selected restoration goal. Each intervention option will then undergo a design process in the next section (Step 3B) to tailor it to your specific situation.

SUGGESTED PROCESS:

1. ***Brainstorm options for restoration interventions.*** Table 3.1 provides a list and descriptions of restoration interventions that are currently being applied in field programs, though many interventions have still only been successfully applied at small scales. This list has been adapted from several comprehensive reviews and includes those that are currently feasible and are "reactive" restoration interventions (see Hein et al. 2020). Note that this list may not be comprehensive and should not limit the creation of new options. You may also consider this table through the lens of information you already have on restoration interventions that may have been or currently are being trialed in your location.

Table 3.1. Coral reef restoration interventions currently feasible at local scales. This table is adapted from *A Research Review of Interventions to Increase the Persistence and Resilience of Coral Reefs* (NASEM 2019) and *Coral Restoration – A Systematic Review of Current Methods, Successes, Failures and Future Directions* (Boström-Einarsson et al. 2020).

Intervention	What it is
Coral Population Interventions	
Direct Transplantation	Transplanting coral colonies or fragments without an intermediate nursery phase
Coral Propagation and Outplanting	Enhancing coral population size through captive rearing and transplantation of coral colonies in the field, using an intermediate nursery phase; often called coral gardening or asexual propagation
Gamete and Larval Capture and Seeding	Collection and manipulation of gametes in the field and/or laboratory and release into the wild, either directly at the restoration site or by deploying settlement substrates with settled coral recruits; often called larval enhancement or sexual propagation
Managed Relocation	Increasing the abundance of desired colony types within a population range through removal, transport and re-attachment at other locations
Reef Community Interventions	
Coral Predator Management	Manual removal or culling of coral predators during or preemptively before outbreak events
Disease Management	Use of antibiotics or other compounds or methods to control pathogenic microbes
Reef Substratum Enhancement Interventions	
Substrate Addition	Addition of man-made structures for purposes of coral reef restoration, with or without corals attached
Substratum Stabilization	Repairing substratum or removing reef rubble to facilitate coral attachment and recruitment
Macroalgae Management	Manual or mechanical removal of macroalgae by humans or through the introduction of herbivores to facilitate coral recruitment or recovery
Environmental Interventions	
Seagrass Meadow and Macroalgal Bed Management	Facilitating nearby plant communities to reduce CO2 levels on adjacent reefs

Using Table 3.1 as a starting point for ideas, identify an array of restoration options that support achieving your restoration goal. If you are considering restoration at multiple sites, this process may need to be repeated for each site (or for a group of sites that face similar challenges to meeting the goal) because different types of interventions may be needed. For instance, in the case of our example goal of restoring reef fisheries production, the sites that you have selected in Step 2 to restore reef fisheries habitats may vary in the amount of existing structural complexity, live coral cover, or coral diversity, such that brainstormed interventions might look different depending on the site context.

Box 3.1. UN report on coral reef restoration interventions.

Another resource to help guide brainstorming and designing restoration interventions is the United Nations Report: *Coral Reef Restoration as a Strategy to Improve Ecosystem Services: A Guide to Coral Restoration Methods* (Hein et al. 2020). This report provides information on the suitability of different methods for coral reef restoration based on goals, including a method suitability index where methods currently applied in the field have been qualitatively ranked from least to most appropriate in fulfilling specific goals, based on the best-available current knowledge. This index is meant to assist managers, practitioners and decision makers in choosing methods depending on their initial goals. Note that the goals in this report follow those in Step 1 of this Guide in Box 1.1.

At this stage, it is important to think broadly about a full range of options; final selection of a more limited number of options for actual implementation will occur later in Step 3C after considering how well each potential option could be designed to be effective (in Step 3B). This is key because effectiveness-potential is an important factor to weigh when making your final selection of interventions. Box 3.2 provides some potential options based on our example goal ***"Within 10 years, restore diverse and structurally complex coral reef fisheries habitats that increase abundance of valued species and support local fisheries production and livelihoods."***

Box 3.2. Example intervention options tailored to the reef fisheries goal. In this scenario, we are assuming that we are working at a site where there is some existing reef structure.

Goal: Within 10 years, restore diverse and structurally complex coral reef fisheries habitats that increase abundance of valued species and support local fisheries production and livelihoods.

At the selected sites:

» **Option 1**: Propagate and outplant branching corals to increase structural complexity

» **Option 2**: Remove macroalgae to enhance natural recruitment

» **Option 3**: Supplement existing reef structure with artificial/engineered structure

» **Option 4**: Propagate and outplant massive and encrusting corals to add biodiversity

» **Option 5**: Relocate detached corals collected onsite or at other locations

» **Option 6**: Stabilize loose substrate to facilitate safe attachment and recruitment

» **Option 7**: Remove Crown-of-Thorns Starfish during outbreaks

A variety of novel techniques for enhancing coral reef resilience are under development and may be applicable to restoration efforts soon (see Box 3.2). Managers are encouraged to follow progress in these emerging areas of research and testing and consider new techniques when they become more widely feasible.

Box 3.3. Emerging restoration interventions.

Research and testing are being conducted on various emerging techniques. These emerging techniques have been reviewed in A Research Review of Interventions to Increase the Persistence and Resilience of Coral Reefs (NASEM 2019), including:

- **Managed Selection**: Creating increased frequencies of existing genes for stress tolerance
- **Outcrossing Between Populations**: Introducing diversity from other populations through managed breeding
- **Hybridization Between Species**: Creating novel genotypes through managed breeding
- **Coral Cryopreservation**: Frozen storage of gametes and other cells for later use and transport
- **Stress Exposure**: Using stress exposure prior to outplanting to make colonies more tolerant
- **Algal Symbiont or Microbiome Manipulation**: Changing algal symbionts to more tolerant types; maintaining/increasing abundance of the native or new beneficial microbes
- **Nutritional Supplementation and Antioxidant Use**: Using nutrients to improve coral fitness and increase stress tolerance; reducing oxidative stress using antioxidant chemicals
- **Cool Water Mixing**: Pumping cool water onto reefs to reduce heat stress
- **Abiotic Ocean Acidification Interventions**: Reducing CO_2 levels through chemical mechanisms

***Workbook activity**: List the full array of intervention options that could be applied towards your restoration goal, indicating how they connect to the goal where appropriate. Then, summarize the process used to make these decisions.*

3B. APPLY CLIMATE-SMART DESIGN CONSIDERATIONS

After brainstorming potential intervention options, the next step is to think about the specifics of how those interventions will be achieved. Consideration of climate change should be built into this thought process to ensure that interventions will be as effective as possible in the face of changing environmental conditions.

SUGGESTED PROCESS:

This is a two-fold process that involves first analyzing the basic design of each intervention, then incorporating climate change design considerations to enhance the effectiveness and resilience of the intervention to future conditions. We can then create a summary description of the climate-smart design needed for each intervention option. These descriptions will be used in Step 3C to evaluate and select a limited (and more realistic) number of priority interventions for implementation.

1. ***Address basic design questions.*** For each of the options you have brainstormed, there will be several methods or techniques from which to choose. For instance, propagating and outplanting corals can be done through asexual or sexual propagation, in a land- or field-based nursery, and with outplanting to natural or artificial substrates. Several guidance manuals and publications are available that can be used to help design details and best practices for certain restoration techniques (see Box 3.4). Managers are encouraged to review these resources and other existing literature for information when thinking through the details of their restoration interventions.

Box 3.4. Resources available to aid in the design of restoration interventions.

Below is a non-comprehensive list of resources that have been developed detailing common coral reef restoration techniques and methodologies. See the Resources section for links and information.

» ***Caribbean* Acropora *Restoration Guide: Best Practices for Propagation and Population Enhancement*** (Johnson et al. 2011, The Nature Conservancy)

» ***Reef Rehabilitation Manual*** (Edwards 2010, GEF)

» ***Guidance Document for Reef Management and Restoration to Improve Coastal Protection: Recommendations for Global Applications Based on Lessons Learned in Mexico*** (Zepeda-Centeno et al. 2018, The Nature Conservancy)

» ***Early Warning and Rapid Response Protocol: Actions to Mitigate the Impact of Tropical Cyclones on Coral Reefs*** (Zepeda-Centeno et al. 2019, The Nature Conservancy)

» ***Considerations for Maximizing the Adaptive Potential of Restored Coral Populations in the Western Atlantic*** (Baums et al. 2019)

Figure 3.1 below presents a series of questions to help you specify the design details to be incorporated into your intervention options when considering your specific goal, sites, and management context. Answer these questions for each of your brainstormed interventions as appropriate, noting that not every question applies to every intervention.

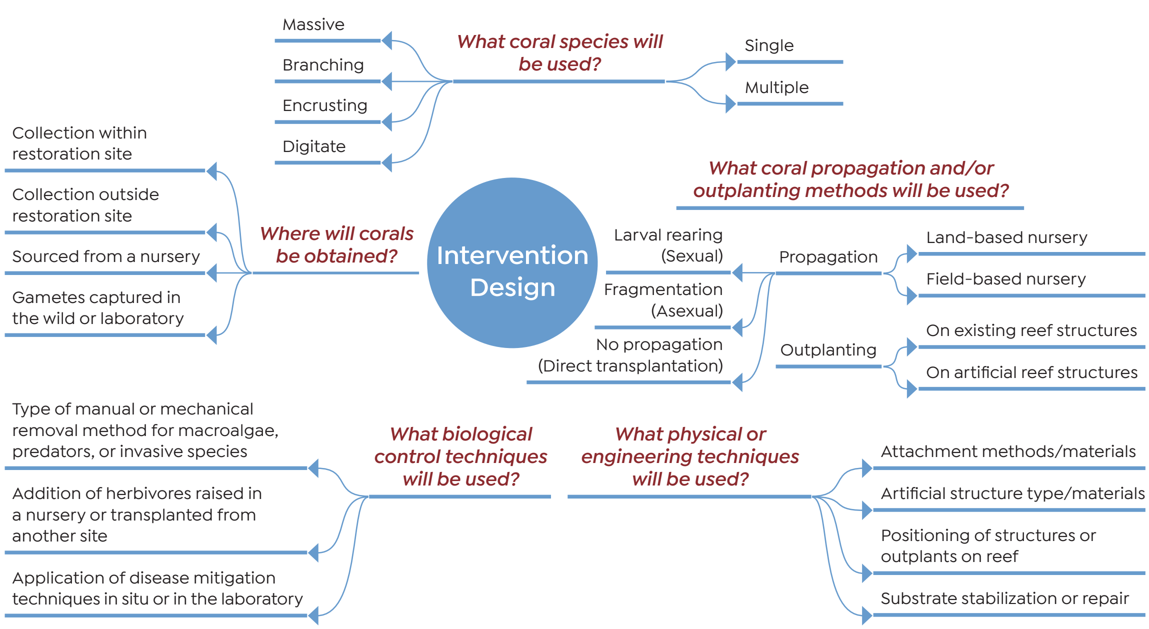


Figure 3.1. Intervention design questions. There may be additional questions to consider based on your specific situation; at the same time, not all questions will apply to every intervention.

A major question in the design of coral reef restoration is which corals to work with, including specific species, genotypes, or morphologies (e.g., growth forms such as branching, tabular, or massive). Box 3.5 presents a series of questions that can be used to help guide the initial selection of corals for restoration. Selections can then be refined as lessons are learned during pilot-phase projects. Refer to Box 3.5 as you work through the design questions in Figure 3.1.

Box 3.5. Guiding questions for selecting corals for restoration.

Coral reef restoration requires determining which types of corals to work with, such as coral species, genotypes, or morphologies (e.g., growth forms such as branching, tabular, or massive). Use the questions below to help guide your initial selection of corals for restoration. The corals selected can then be refined as pilot-phase projects are conducted.

What is the natural composition of corals in reefs in your area?

Is there a healthier nearby reef site in your area that can serve as a reference or model ecosystem? If so, this site can be surveyed to determine the natural composition of coral species being sought at the restoration site. Generally, restoring multiple coral species, genotypes, and growth forms may increase reef resilience by helping to spread the risk of coral loss due to any one disturbance event (Nyström 2006). Also consider that the type or ratio of coral species being restored may change in different phases of the project.

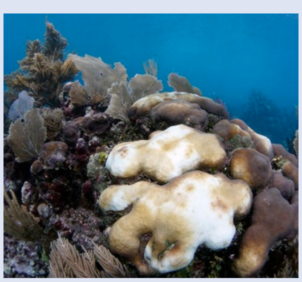
Are there particular corals that pertain to your restoration goal?

Does a particular coral species need to be restored due to population loss, or are certain growth forms more important for providing fisheries habitat or abating wave energy? Generally, corals on the reef crest provide the most wave energy reduction (Ferrario et al. 2014). However, fish communities supported by corals vary widely depending on the coral species and may require gathering data before coral species selection (Komyakova et al. 2018).

Is there sufficient genetic diversity in your area to restore a particular coral species?

Genetic diversity is critical for restoring coral populations, as it ensures higher success rates of sexual reproduction and allows coral populations to adapt to new conditions and environments over time. Generally, practitioners should collect genetically distinct coral colonies (or genets) by collecting from 10 different parent coral colonies, spaced at least 5 meters apart or from different habitats, that exhibit different traits such as size, color, or morphology (Baums et al. 2019).

Which corals appear more resilient to common threats in your area?



Are there particular coral species, genotypes, or growth forms that perform better after a certain disturbance? For bleaching, corals that are more resistant are characterized by massive growth forms, thick or less-integrated tissues, and slow growth rates; corals that are more susceptible include fast-growing species with fine-structured, branching, or tabular growth forms (Loya et al. 2001; Marshall and Schuttenberg 2006). Corals in sites that experience more varied temperatures may also be less susceptible to bleaching.

Table 3.2 provides example design answers for three of the restoration options that were brainstormed in Box 3.2. Note that this table includes three options for brevity; however, all of the options you brainstorm with your planning team should be included in your final exercise. Answers to these basic design questions are shown in **BLACK** text. The **BLUE** text will be explained in the next section, where we explore how climate-smart considerations can be folded into the intervention design.

As you answer the basic design questions, you may find yourself automatically incorporating some climate change considerations right away, and that is okay! You can double-check whether there are any more climate-smart ideas to add to your design elements in the next section. As per the examples in the bottom row of Table 3.2, it may be useful to document the sources of some of your ideas by including the citations for important reference documents or websites that you will need later for implementation.

Removing invasive algae from coral patch reefs in Kaneohe Bay, Hawai'i.

Image: Ian Shive | Hawai'i Department of Aquatic Resources

Table 3.2. Example intervention options with design information. Three options are shown here for brevity. Answers to basic design questions are shown in BLACK. Climate-smart design additions highlighted in BLUE will be discussed in the next section.

Goal: Within 10 years, restore diverse and structurally complex coral reef fisheries habitats that increase abundance of valued species and support local fisheries production and livelihoods.			
Design Questions	Restoration Interventions		
	OPTION 1 Propagate and outplant branching corals to increase structural complexity	OPTION 2 Remove macroalgae to enhance natural coral recruitment	OPTION 3 Supplement existing reef structure with artificial reef structure
What coral species will be used?	2 species of branching corals. Species A and B will be used because they are more resistant to bleaching while also being known to attract fish for food and habitat. Using more than one species will also allow for functional redundancy and increase the potential for resistance to other disturbances.	N/A	Local species
Where will corals obtained?	Other sites outside the restoration site that have sufficient numbers for collection. Corals will be collected from sites that have experienced past bleaching events such that corals are more likely to be acclimatized or have genes for increased stress tolerance.	N/A	Natural recruitment
What coral propagation and/or outplanting methods will be used?	Propagation method used will be asexual fragmentation followed by grow-out in a field-based nursery where corals will be exposed to temperature extremes to further acclimatize corals. Colonies will be outplanted onto existing reef structure across a range of depths where the coral species naturally occurs to spread the risk of impacts from potential bleaching events. A rapid response plan will be put into place for replenishment of corals lost to bleaching or storm events using new outplants.	N/A	N/A
What biological control techniques will be used?	Manual algal removal for substrate preparation prior to outplanting, and for coral maintenance and protection after outplanting. A plan will be put into place for more frequent maintenance of outplants through algal removal as increasing temperatures result in increased algal growth.	Use "Super Sucker" vacuum systems for mechanical removal of macroalgal cover. Plan for greater volume and frequency of algae removal that will be needed as growth rates increase with warmer water temperatures and increased nutrient runoff.	N/A
What physical or engineering techniques will be used?	Fragments will be attached with adhesive directly to the natural reef substrate. The specific adhesive will be marine epoxy, which has been shown to have the lowest detachment rate and thus should hold up the best against wave action (Dizon et al. 2008).	N/A	Reef structure will be built of wire with attached coral skeletons collected from rubble as substrate. The structure designs will mimic reef aesthetics and provide holes and crevices of different sizes to provide a range of habitats for different fish species. Wire will be installed on a welded steel frame with screw anchors embedded in the substrate to withstand high wave energy and storms (e.g., Reef Balls, see Resources). The structure will be oriented parallel to the direction of prevailing winds. Structures will be placed at a range of depths to spread the risk of impacts from bleaching and storm events. A rapid response plan will be created for repair or replacement of structures after storms.

2. Apply climate-smart design considerations. The next step is to ensure that you are being climate-smart with your designs. Applying climate-smart design considerations (Box 3.6) helps to determine and plan for the impacts of climate change on different restoration interventions. Since restoration interventions are designed as long-term actions, climate change impacts must be considered now and revisited regularly as new climate science emerges and conditions change. For any restoration intervention to be considered "climate-smart", two categories of design considerations must be examined - and appropriate adjustments made to the intervention — to maximize effectiveness both now and in the future.

Box 3.6. Adaptation Design Tool for coral reefs.

An Adaptation Design Tool and user guide (Parker et al. 2017, West et al. 2017, 2018) are available that provide a structure to break down Category 1 and Category 2 design considerations into a series of smaller, more tractable steps. An interactive self-paced course - *Corals & Climate Adaptation Planning: Adaptation Design Tool Online Course* - is also available (see Resources). Depending on time availability, you can use the tool to look at your intervention options in detail, or simply familiarize yourself with key principles of climate-smart design and how the tool works before using the simplified method here.

Here we have adapted the climate-smart design considerations of West et al. 2018 (*Adaptation Design Tool for Climate-Smart Management of Coral Reefs and Other Natural Resources*) within the context of restoration. You can use the following questions to guide your thinking and discussion to incorporate climate change considerations into your restoration intervention design.

- **Category 1 Climate-Smart Design Considerations**: How will climate change and its interaction with local stressors of concern impact the biological resilience of the restoration intervention? Example: increased temperature and precipitation may interact with local pollution runoff to exacerbate coral bleaching and macroalgae blooms.
- **Category 2 Climate-Smart Design Considerations**: How will climate change affect the physical functionality of the restoration intervention through direct impacts on structural components? Example: increasingly intense storms may threaten physical destruction of natural or artificial structures.

Use these questions to determine the implications of climate change and how the intervention should be adjusted in terms of species selection/manipulation, location, timing, or structural design to be climate-smart (e.g., maximize resilience) in the face of climate change. For example, it may be possible to adjust the species used, project placement, timing of outplanting (e.g., during cooler months), maintenance schedules, and/or construction materials to counteract vulnerabilities and improve long-term effectiveness and resilience.

The potential to make improvements based on climate-smart considerations should be examined for each design element. Table 3.3 provides examples of how these considerations can be folded into the basic design questions used in Figure 3.1. Once you have reviewed Table 3.3, you can go back to Table 3.2 to see how some climate-smart ideas have been added in BLUE text to the three restoration options featured. Table 3.3 is intended to help start your thought process; the design considerations that you use for your options will depend not only on your goal, but also on the types of vulnerabilities associated with your specific sites. The Workbook (Appendix 1) also features a checklist for Table 3.3 that can be used to support discussions about applying climate-smart considerations for each intervention option.

Table 3.3. Example climate-smart design considerations associated with the basic design questions of Figure 3.1. The relevance of these and other potential questions will depend on the specifics of your goal, option type, site and management context.

Design Questions	Climate-Smart Design Considerations	
	Category 1 *How will climate change and its interaction with local stressors of concern impact the biological resilience of the restoration intervention?*	**Category 2** *How will climate change affect the physical functionality of the restoration intervention through direct impacts on structural components?*
What coral species will be used?	• What is the vulnerability of the site to bleaching conditions? Are certain coral species more resistant to bleaching and disease? • How is climate change affecting sediment and nutrient transport to the site? Are certain coral species more tolerant? • What are the implications of ocean acidification for coral growth rates and skeleton density/strength? • Are enough coral species being used to account for genetic and functional diversity and redundancy to spread the risk of local losses from coral bleaching and disease?	• How much is wave energy expected to increase with increasingly intense storms? Are certain coral species less brittle or more robust against storm damage?
Where will corals obtained?	• Are there in situ sites where corals have naturally been acclimatized to bleaching or poor water quality? • Are there genotypes with special characteristics with respect to climate change-related stressors specific to the restoration site?	• Are there sites that have experienced intense storm events from which corals that have withstood damage could be collected?
What coral propagation and/or outplanting methods will be used?	• Are there nursery sites in the field where corals could be acclimatized during propagation? • Is there a lab with options for pre-treating corals to acclimate them to variations in temperature or other stressors? • How often will it be necessary to outplant more corals to replace losses from bleaching?	• How much is wave energy expected to increase with increasingly intense storms? Does this affect the decision whether to use natural substrate or build an artificial substrate? (Also see engineering question below.) • How often will it be necessary to outplant more corals to replace losses from storms? • Will materials or methods used to outplant corals be able to withstand wave energy from storms? • How will the laboratory where corals will be propagated be safeguarded to withstand intense storms? Are structures and water intake fortified? Is there back-up power generation?
What biological control techniques will be used?	• How will climate change affect predator or algal outbreaks? Will this affect the frequency or intensity with which removal techniques will need to be used? Will removal techniques be able to keep up with algal growth under changing conditions? • How is climate change affecting environmental conditions for valued herbivore populations? Will regular replenishment of herbivores be needed? • How will climate change affect the frequency and severity of disease outbreaks? Will this affect the type, method, or frequency of treatments needed? Should it affect the coral species chosen?	• Will certain predator or algal removal techniques be difficult to do in areas of increasingly high wind and wave energy? Will this limit the time of year or efficiency (amount that can be done in a given time) with which the technique can be used? • How will the laboratory where herbivores will be reared be safeguarded to withstand intense storms? Are structures and water intake fortified? Is there back-up power generation?
What physical or engineering techniques will be used?	• Is there anything about the coral attachment methods or materials that could render corals more or less susceptible to climate change-related stress?	• Will the chosen materials be able to stand up to increasingly intense wave energy and storms? • Will increasing water temperatures have any effect on the lifetime of epoxy or other adhesives? • At what depth should structures be placed to account for sea level rise given coral growth rates?

You have already collected quite a bit of information in your earlier work that will be helpful for developing your climate-smart design considerations. In Step 1, you described the management and biophysical context for your restoration goals by assessing existing threats and projected future impacts of climate change. In Step 2, you identified and selected sites within your geographic focus areas to support survival of restored corals, which included looking at resilience and vulnerability to climate change. All this information is helpful now for applying climate-smart design considerations to your specific intervention options. You'll want to develop-out the information you already have with additional information based on:

- Expected climate change effects (temperature, precipitation, storm intensity, etc.) and interactions with local stressors of concern (sediment, nutrients, disease/predator/algae outbreaks, ocean acidification, etc.) that could threaten the biological resilience of your restoration options. This should include information on the direction, magnitude, and mechanism of changes along with levels of uncertainty.
- Anticipated timing of when climate change will affect stressors of concern. This informs sequencing with other actions (important for Step 3C) and the timeframe under which effectiveness should be evaluated (Step 4A).
- Anticipated timing and severity of physically destructive aspects of climate change (flooding, storm damage to natural or man-made structures). This can include consideration of any tipping points at which the intensity of climate change may eventually be so frequently and severely destructive as to render an intervention no longer effective or feasible.
- How monitoring (frequency, location, duration, etc.) might need to be modified given how climate change may affect biological and physical aspects of the restoration. This includes beginning to identify management targets and metrics to assess technical performance (effectiveness) of the intervention (important for Step 4).

Outplanting seedling units on the reef, Curaçao.

Image: SECORE | Reef Patrol

3. ***Prepare a summary description of each restoration option.*** A clear and concise description of each restoration option can now be prepared that provides a more explicit name for the intervention based on the design choices and a detailed summary of the climate-smart design. These descriptions will be used in Step 3C to evaluate and make the final selection of interventions to implement. Box 3.7 provides illustrative descriptions for our example options in Table 3.2.

Box 3.7. Summary descriptions of example restoration options. Again, you would complete this exercise for all your brainstormed options in Box 3.2.

OPTION 1: Asexually propagate and outplant branching corals onto existing reef structure to create structural complexity.
Branching coral species A and B will be collected from locations that have experienced past bleaching events, propagated through fragmentation, and grown-out in a field-based nursery where corals will be exposed to temperature extremes to acclimatize corals. Fragments will be cemented to existing reef substrate using marine epoxy that can withstand wave energy. Outplants will be placed at a range of depths where the coral species naturally occur to spread the risk of impacts from potential bleaching events. Manual removal of algae will be undertaken to prepare the substrate before outplanting and protect the corals after outplanting, with a plan for more frequent maintenance as increasing temperatures lead to increased algal growth. Corals lost to bleaching or storm events will be replenished with additional outplants based on a rapid response protocol.
OPTION 2: Mechanically remove macroalgae to enhance natural recruitment on existing reef structure.
Divers with Super Suckers will be deployed for one week annually during the calm season to mechanically remove macroalgal cover. Scheduling adjustments will be made as needed for greater frequency, intensity and time investment for algae removal in subsequent years as algal growth rates increase with warmer water temperatures and greater nutrient runoff.
OPTION 3: Supplement existing reef structure with artificial reef structure for natural recruitment.
Artificial reef structures will be constructed of wire with attached coral skeletons collected from rubble to serve as substrate. The structure designs will mimic reef aesthetics and provide holes and crevices of different sizes to provide a range of habitats for different fish species. The wire structures will be installed on welded steel frames with screw anchors embedded in the substrate to withstand high wave energy and storms, and oriented parallel to the direction of prevailing winds and waves to reduce stress on the frames. The structures will be placed at a range of depths to spread the risk of impacts from potential bleaching and storm events. A plan will be developed for replacement of structures lost to storm events.

Points for Consideration:

- During the design process, you might begin to identify that some interventions are interdependent with each other or need to be employed in a sequence. Record these insights, as they will be important for the evaluation and selection process in Step 3C.
- Recognition of interdependencies could even lead you to go back and add more intervention options to your list. For example, in the case of Option 2 (mechanical removal of macroalgae) you might realize that this option will not succeed unless it is used in combination with seeding of the reef with urchin larvae as an herbivore replenishment intervention.
- Addressing design questions could even lead you to re-evaluate your site selections from Step 2. Given the potential for effective intervention design, are all the selected sites still the most suitable for these interventions? This is a natural and appropriate question that illustrates the nonlinear, iterative nature of this process, where new information can prompt a return to previous steps to re-evaluate assumptions and make improvements to decisions.

***Workbook activity**: For each intervention option, use the Step 3B table provided to record your answers to the basic design questions that apply. After reviewing the climate-smart design considerations in Table 3.3 (and adding any further questions appropriate to your situation), build climate-smart improvements into all relevant design elements in your Step 3B table. Add additional Option columns until all brainstormed intervention options from 3A above have been designed. Use the checklist of climate-smart design considerations to indicate which questions apply to each intervention option to support discussion of climate-smart improvements. Add questions as necessary to address Category 1 and 2 considerations. Finally, prepare a summary description of each intervention option, synthesized from the detailed design information that you have developed.*

Coral tree nursery in Jamaica.

Image: The Nature Conservancy

3C. EVALUATE AND SELECT INTERVENTIONS

The array of restoration interventions identified and designed in Step 3A and Step 3B can now be evaluated and compared to determine which interventions to implement. While the previous step focused on identifying a range of possible options and assessing their potential for effective design, this section focuses on narrowing down the possibilities and selecting a more limited combination of priority interventions to carry out. An informal, consensus building process can be used to achieve prioritization but can be hampered if different stakeholders have different priorities or use different criteria to make decisions. This makes it difficult to achieve transparency and consensus and can lead to setting priorities based solely on available funding or opportunistic convenience. As a result, the best restoration intervention for the goal might not be selected.

Therefore, it is helpful to use a common set of evaluation criteria (e.g., Figure 3.2) to engage stakeholders in selecting priority restoration interventions. A multicriteria evaluation framework provides a structured process that can be used to discuss and document stakeholder input. Five common categories of criteria are typically used for evaluating and selecting among management interventions: effectiveness, feasibility, flexibility, urgency, and external benefits. Within each of these evaluation categories there can be a variety of criteria applied (see Figure 3.2 for examples).

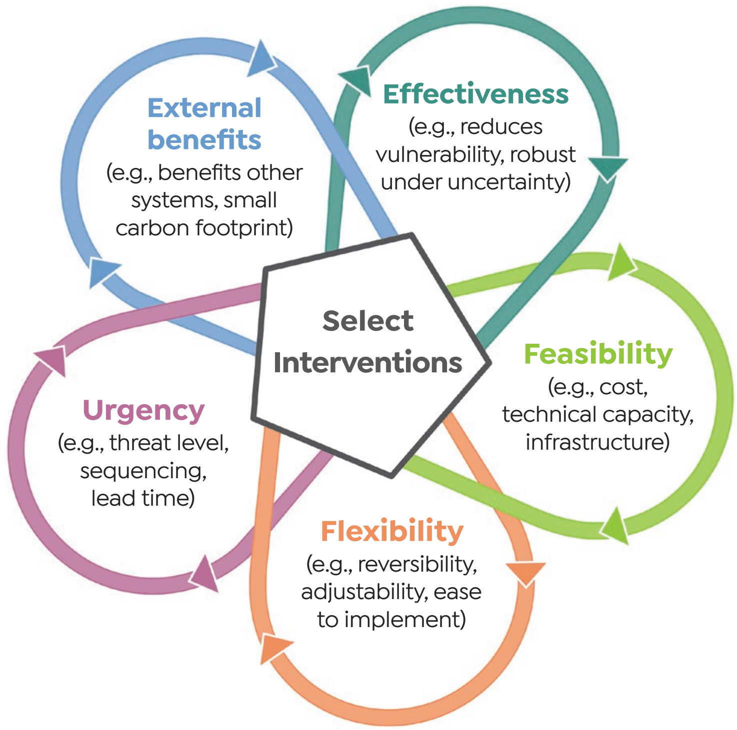


Figure 3.2. Suggested categories of evaluation criteria for selecting restoration interventions.

SUGGESTED PROCESS:

1. ***Develop evaluation criteria and process.*** Use Table 3.4 as a starting point to describe the criteria and rating system you will use for your evaluation process. You may use some of the example criteria provided, and/or you can craft your own. Criteria may be chosen and weighted in importance according to the preferences of the stakeholders and decision-makers involved. You may consider conducting one or several activities to support evaluation and selection, such as:
   - One-on-one meetings with federal, state, and local officials to identify any permitting issues or environmental reviews and timing needed to provide input on the feasibility of the interventions
   - A technical advisory group meeting to provide input on evaluation process and criteria and to discuss and rank the restoration options
   - Broader stakeholder engagement such as through a workshop to seek input from government, private, and nongovernmental entities as well as community members

   An Intervention Criteria Evaluation Tool has also been developed to assist managers in using or adapting Table 3.4. This tool can be accessed on the NOAA CoRIS website alongside this Guide.

Table 3.4. Example evaluation criteria and rating scale for restoration options. Insert additional columns to accommodate your full number of brainstormed options.

Evaluation Criteria	Restoration Intervention Ratings Strongly Agree (5), Agree (4), Neutral (3), Disagree (2), Strongly Disagree (1)		
	Option 1	Option 2	Option 3
Effectiveness			
Intervention will be technically effective at achieving restoration goal			
Intervention will be climate-smart in addressing changing conditions and uncertainties in climate change projections			
Average rating			
Rationale			
Feasibility			
Costs of implementation and maintenance are feasible			
Technical capacity will be in place to implement intervention (data, technical knowledge, number of staff)			
Physical infrastructure is achievable to implement intervention (e.g., land-based laboratory)			
Required government regulations and permits are obtainable within the implementation timeline			
Strong community, political, and private sector acceptance/support for intervention is available			
Average rating			
Rationale			
Flexibility			
Intervention is designed to be adjustable to accommodate changing conditions and incorporate learning			
Intervention is reversible if needed			
Average rating			
Rationale			
Urgency			
Degree of threat and cost of inaction is high if intervention is not implemented			
There is an immediate opportunity associated with implementing the intervention based on availability of partnerships, funding, or leveraging other existing efforts			
Results from the intervention can be achieved in a timeframe aligned with urgency of threat			
Average rating			
Rationale			
External Benefits			
Intervention achieves benefits outside of the target system, to other ecosystems, and/or human communities (e.g., economic, coastal protection, biodiversity, larval source, education, or research benefits)			
Intervention minimizes unintended negative consequences, including carbon footprint			
Average rating			
Rationale			
Interactions			
Are there interdependencies, sequencing requirements, or conflicts with other options?			

It is recommended that the technical advisory group be convened to review and refine the criteria and propose any weighting as needed. A description of each restoration intervention option should be provided for review by the technical advisory group, based on your descriptions in Step 3B. At first, each option should be discussed and evaluated on its own merit and not relative to the other options. It is, however, important to document whether each option has any interdependencies, sequencing requirements, or conflicts with other options, as this can figure into final selections at the end. The rationale for the rating for each of the criteria should be documented for each option (see Table 3.4) to support the selection of restoration interventions that will be included in the implementation plan. More important than an absolute rating or number will be the documentation of the rationale for selection. As you work through the criteria with the technical advisory group, you will likely begin to identify factors that will be relevant to establishing performance metrics in Step 4.

2. ***Select restoration intervention(s) and document rationale.*** After completing the evaluation process, the core planning team can discuss all the inputs received and select the restoration intervention(s) that will be implemented in the pilot phase and later in the scaling-up phase to support the goal. Some interventions may be selected individually, but others may be selected as combinations. This is because the evaluation process may lead you to select multiple interventions together that are positively interdependent, or to combine details of multiple intervention options to create a new and improved intervention.

   For instance, in the case of the three example options in Box 3.7, we might decide after careful evaluation that Option 1 ("Asexually propagate and outplant branching corals onto existing reef structure to create structural complexity") by itself will not succeed because there is too little existing reef structure available for the number of outplants needed to build up the reef. Likewise, we might judge that Option 3 (Supplement existing reef structure with artificial reef structure for natural recruitment) by itself will not work due to insufficient larval supply to the site for natural recruitment. However, we might conclude that merging elements of the two options into one combined option will succeed at achieving the necessary amount and pace of reef structure build-up to reach the goal. A statement of the combined option might look like the example in Box 3.8.

Box 3.8. Example restoration intervention combining multiple interventions into a mixed approach.

OPTION 1 + OPTION 3

Supplement existing reef structure with artificial reef structure and outplant asexually-propagated branching corals onto both substrates to create structural complexity.

Artificial reef structures will be constructed of wire with attached coral skeletons collected from rubble to serve as supplemental substrate. The structure designs will mimic reef aesthetics and provide holes and crevices of different sizes to provide a range of habitats for different fish species. The wire structures will be installed on welded steel frames with screw anchors embedded in the existing substrate to withstand high wave energy and storms, and oriented parallel to the direction of prevailing winds and waves to reduce stress on the frames. The structures will be placed at a range of depths to spread the risk of impacts from potential bleaching events. Branching coral species A and B will be collected from locations that have experienced past bleaching events, propagated through fragmentation, and grown-out in a field-based nursery where corals will be exposed to temperature extremes to acclimatize corals. Fragments will be cemented throughout both the artificial and existing reef substrates using marine epoxy that can withstand wave energy. Manual removal of algae will be undertaken to prepare the substrate before outplanting and protect the corals after outplanting, with a plan for more frequent maintenance as increasing temperatures lead to increased algal growth. A rapid response protocol will be developed for replacement of structures and replenishment of corals lost to storms and bleaching events.

Once you have selected and refined your more limited set of priority options to implement, you can proceed with developing specific measurable objectives and finalizing your Action Plan in Step 4.

***Workbook activity**: Describe the evaluation criteria used to select restoration interventions and provide a summary of how these details were determined. Record ratings for each evaluation criteria (scale from 1-5) for each intervention option, using criteria from Table 3.4 and/or criteria developed by your planning team. Add additional columns until all brainstormed intervention options have been evaluated. Then, document the intervention(s) that best support the priority goal as well as the process and rationale used during your evaluation process.*

Stakeholder Engagement

The process outlined in this step should allow you to make decisions with a number of diverse stakeholders and be transparent about the decisions made about restoration interventions. You can use Table 3.4 or a similar table or figure to present a summary of the evaluation and selection process and share the rationale behind decisions for your location. It will be useful to document the process of engaging stakeholder groups in this process as well to show how diverse interests were incorporated.

***Workbook activity**: List technical experts, stakeholders, and partners including scientists, engineers, community members, and members of the private sector and national and local governments engaged to review and prioritize restoration goals and the geographic focus area(s). Provide a summary of stakeholder engagement activities to be taken for this step.*

Corals growing on artificial reef structure in Kenya.

Image: REEFolution

Coral reseeding at the Great Barrier Reef, Australia. Image: Biopixel | James Cook University

STEP 4: DEVELOP RESTORATION ACTION PLAN

Overview

The next step in the planning process is to define SMART objectives and develop activities needed to complete your Action Plan.

In Step 4A, you will define SMART objectives detailing how the project will achieve progress toward the goal. This includes identifying performance metrics that will allow you to monitor progress. In Step 4B, you will develop activities for each objective and an implementation timeline needed to complete restoration interventions. Key activities include not only those required for the restoration project, but also management and community engagement activities needed to support the project. In both Steps 4A and 4B, special emphasis is placed on defining an objective and activities to support a pilot phase as a proof of concept for the restoration intervention. These steps, as well as the information gathered through the previous four steps in this Guide, are then used in Step 4C to build your Action Plan.

Step parts:

4A. Define SMART Objectives

4B. Develop Activities and Implementation TImeline

4C. Build Restoration Action Plan

Assumptions for Step 4

- Restoration goal and site(s) have been selected (Steps 1-2)
- Restoration interventions have been identified, designed to include consideration of climate change, and prioritized for implementation at the selected restoration sites to specifically meet the goal (Step 3)

4A. DEFINE SMART OBJECTIVES

Objectives are formal statements of the interim outcomes (over a one to 10-year timeframe) along the path to recovery as your restoration project moves towards reaching the goal (Gann et al. 2019, CMP 2020). Objectives allow you to set and reach targets for a project like rungs on a ladder, with the restoration goal being met at the top of the ladder. We suggest defining SMART objectives, where objectives are written to be Specific, Measurable, Achievable, Relevant, and Timebound (see Table 1.1). A final test of your objective is whether it is understandable to all stakeholders and provides a picture of what success looks like. Because objectives are time-bound and occur over shorter time periods, you may consider developing multiple SMART objectives that together reach the project goal. For instance, if your goal is defined at 20 years, multiple objectives may be set for every one to five years during this timeframe. An initial objective, within the first two to three years, may be to validate your intervention on a smaller scale during a pilot phase, before moving to full-scale implementation.

Objectives are measured by specific performance metrics. **Performance metrics** are quantifiable and relate to a specific information need (CMP 2020). Performance metrics are used to quantify the desired results of restoration interventions and monitor progress. Measuring performance through metrics is key for determining if the restoration intervention is achieving the desired outcome.

SUGGESTED PROCESS:

1. ***Identify potential performance metrics relevant to the restoration goal and intervention(s).*** Your restoration goal and interventions provide the framework to identify potential performance metrics. You will consider these metrics in crafting SMART objectives. You can use Table 4.1 below to assist with this process. This table was developed using information from Coral Reef Restoration Monitoring Guide: Methods to Evaluate Success from Local to Ecosystem Scales (Goergen et al. 2020) (see Box 4.3) and the list of example restoration goals presented in Step 1 (Box 1.1). Example goals from Step 1 have been highlighted in the table in **BLUE**. Questions to consider in identifying potential performance metrics related to your restoration goal and intervention may include:

   - Which metrics are we already monitoring in the restoration site(s)?
   - Which metrics do we know how to monitor but are not monitoring now?
   - What additional metrics are relevant to the restoration goal and intervention?

   You will revisit this list and Table 4.1 as you craft SMART objectives.

Restored coral at Pulau Haramin, Indonesia. Image: Martin Colognoli | Coral Guardian | Coral Reef Image Bank

Table 4.1. Example indicators and data that can be used to develop metrics for different restoration goals. Adapted from Goergen et al. 2020.

Goals	Indicators	Data Outcomes
Ecological Goals		
Coral Population Enhancement • Mitigate coral population declines and preserve biodiversity	Abundance and Cover	• Changes in abundance and cover of restored corals • Rates of coral recruitment
	Reproductive Capacity and Survival	• Observations of timing, genotype variability, and percent of corals spawning • Survival rate of transplanted corals
	Coral Condition	• Presence/absence of corals • Prevalence of coral conditions • Percent tissue loss
	Species Richness and Diversity	• Species richness, diversity, and evenness
Community and Habitat Enhancement • Re-establish reef ecosystem function and structure • Recover and sustain fisheries production services.	Invertebrate Community	• Invertebrate abundance/density • Presence/absence • Species richness, diversity, and evenness
	Reef Fish Community	• Species richness, diversity, and evenness • Abundance • Size distribution
	Reef Structure and Complexity	• Mean coral height • Mean structure height
	Habitat Quality	• Water quality parameters • Sedimentation rates and characterization • Secchi disk depth • Percent cover and diversity of functional groups • Abundance, diversity, and survival of coral recruits
Socio-Economic Goals		
Economic Benefits • Recover and sustain coastal protection services • Recover and sustain fisheries production services • Sustain local tourism opportunities	Coastal Protection	• Wave energy reduction/attenuation • Shoreline erosion over time • Costs associated with coastal protection and economic benefits
	Fisheries Production	• Catch per unit effort • Sales of local fish
	Eco-Tourism Opportunities	• Number of participants • Trends in participation and revenue generated • Job creation
Socio-Cultural Benefits • Promote local coral reef stewardship	Cultivating Stewardship	• How many participants return • Which events created the most reach • Change in volunteer opinion on restoration
	Capacity Building	• Retention of volunteers • Presence of program financial plan
	Reef-User Satisfaction	• Reef-user perception of restoration
Event-Driven Goals		
Disease and Bleaching • Respond to acute disturbances to accelerate reef recovery	Post-Impact Change	• Number of colonies impacted • Rates of recovery of colonies impacted • Types and rates of diseases present
Physical Impacts • Respond to acute disturbances to accelerate reef recovery	Post-Impact Change	• Damage extent • Determination if restoration is feasible
Climate Change Adaptation Goals		
Improved Reef Resilience • Mitigate impacts and promote reef resilience to climate change	Coral Thermal Tolerance	• Corals with tolerance to certain stressors • Percent of corals manipulated that show increased tolerance • Water temperature
	Disturbance Response	• Reduced losses due to bleaching (e.g., increased resistance) • Recruitment and recovery post-bleaching

2. ***Craft SMART Objectives.*** Craft objectives that use the SMART approach, looking back to Step 1 (Table 1.1) for more information as needed. Again, developing a SMART statement means that it should be Specific, Measurable, Achievable, Relevant, and Timebound. Multiple objectives may be needed for a single restoration intervention which requires a critical path of activities. For example, if the restoration intervention requires establishing a field-based nursery and successfully growing corals for outplanting, a restoration objective should describe these specific activities. The development of multiple objectives will help organize activities and establish the timeframe for implementation (see Step 4B).

   In crafting SMART objectives, you may start by developing a qualitative statement of intermediate results for the goal and interventions. Intermediate results statements for the goal should be aligned with longer timeframes. Intermediate results for the restoration interventions should be aligned with timeframes for pilot phase testing and scaling up restoration interventions over time.

   It is recommended that you craft one or more SMART objectives for your pilot phase activities. A pilot phase objective would serve as statement of immediate-term results for activities designed to address unknowns or uncertainties related to your restoration intervention. These unknowns and uncertainties are likely to require testing before conducting the intervention at large, more resource-intensive scales. A pilot phase objective will enable you to evaluate whether you have successfully addressed the uncertainties and if activities are ready for scaling-up. To craft a SMART objective for the pilot phase, brainstorm the unknowns and uncertainties that would require testing. In cases where there are only a few aspects that need investigation, work with scientists and technical experts to develop hypotheses and conduct research to test these questions. If there are many uncertainties, you can conduct a small-scale version of the restoration intervention to develop an understanding of its efficacy overall. See Box 4.1 for an example of uncertainties that would be addressed through a pilot phase for our example restoration goal and intervention.

Box 4.1. Example uncertainties requiring a pilot phase.

Goal: Within 10 years, restore diverse and structurally complex coral reef fisheries habitats that increase abundance of valued species and support local fisheries production and livelihoods.

Intervention: Supplement existing reef structure with artificial reef structure for natural recruitment.

Uncertainties about intervention requiring pilot phase:

» Materials of artificial structures: What materials will encourage settlement by corals and other benthic organisms? What materials will be sustainable over the long-term, including during increasingly intense storms?

» Design and attachment of artificial structures: What design will encourage use by reef fishes? What design can withstand storm surge from a Cat 4 hurricane?

» Number and configuration of artificial structure placement on reefs: How many structures and what configuration on the reef will achieve the goal of increasing fisheries productivity?

» Method for securing artificial structures onto reefs: What method will ensure structures won't become dislodged, including during increasingly intense storms?

Now, revisit the potential performance metrics you identified in Step 4 and Table 4.1. You may wish to use the framework in Table 4.2 to list performance metrics you identified in Step 4A and record your intermediate results statements.

Table 4.2. Example framework for crafting objectives and making the objectives SMART.

Goal: Within 10 years, restore diverse and structurally complex coral reef fisheries habitats that increase abundance of valued species and support local fisheries production and livelihoods.				
Objectives	**Time (Years)**			
	1 – 3	**4 – 6**	**7 – 10**	**10 – 20**
Potential Performance Metrics *(from Step 4A)*	• Number of coral fragments propagated • Percent of corals manipulated that show increased tolerance • Survival rate of propagated corals	• Number of coral fragments outplanted • Percent of corals manipulated that show increased tolerance • Survival rate of transplanted corals • Rates of coral recruitment • Fisheries species abundance and diversity	• Fisheries species abundance and diversity • Reef height and rugosity • Survival rate of transplanted corals • Changes in abundance and cover of restored corals	• Fisheries species abundance and diversity • Reef height and rugosity • Survival rate of transplanted corals • Changes in abundance and cover of restored corals • Fish catch per unit effort • Sales of local fish • Reef-user (fishermen) satisfaction
Intermediate Results *(Goal)*			• Fisheries species abundance and diversity increased • Reef structure improved and maintained	• Fisheries productivity improved • Reef structure improved and maintained
Intermediate Results *(Intervention)*	• Nursery established producing corals for propagation	• Corals outplanted survive and support local recruitment of fisheries species and corals		

Finally, craft SMART objectives by considering specific, measurable, achievable and relevant metrics and targets. For each intermediate result described in Table 4.2, you need to ask questions about how many, when, and why. For example, how many coral fragments would need to be propagated and at what rate to support the restoration at the site? Is it achievable? Example SMART objectives are provided in Box 4.2 building on our example goal and intervention from Step 3.

Box 4.2. Example questions to consider for making SMART objectives

Goal: *Within 10 years, restore diverse and structurally complex coral reef fisheries habitats that increase abundance of valued species and support local fisheries production and livelihoods.*

Questions to identify metrics for medium to long-term objectives related to the goal

- Which valued fish species will be targeted?
- How much and what type of reef habitat needs to be restored to support an increase in targeted fish species?
- What is the current and desired abundance of target fish species at the restoration site?
- By what timeframes should we expect to see increases in the abundance of target fish species from these interventions?

Activity to Address Information/ Data Gaps

- Determine the area and type of reef habitat that needs to be restored to increase the abundance of valued fish species at the site
- Determine the current and desired abundance of valued fish species compared to baseline

Intervention (from Box 3.8): *Supplement existing reef structure with artificial reef structure and outplant asexually propagated branching corals onto both substrates. Artificial reef structures will be constructed of wire with attached coral skeletons collected from rubble to serve as supplemental substrate. The wire structures will be installed on welded steel frames with screw anchors embedded in the existing substrate to withstand high wave energy and storms, and oriented parallel to the direction of prevailing winds and waves to reduce stress on the frames. The structure designs will provide holes and crevices of different sizes to provide a range of habitats for different fish species. The structures will be placed at a range of depths to account for sea level rise and spread the risk of impacts from potential bleaching events. Digitate coral species A and B will be collected from locations that have experienced past bleaching events, propagated through fragmentation, and grown-out in a field-based nursery where corals will be exposed to temperature extremes to acclimatize corals. Fragments will be cemented throughout both the artificial and existing reef substrates using marine epoxy that can withstand wave energy. A rapid response protocol will be developed for replacement of structures and replenishment of corals lost to storms and bleaching events.*

Questions to identify metrics for short-term and medium-term objectives related to propagation

- Which coral species should be selected to maximize fish recruitment to the restored area?
- How many coral species A and B can be propagated per year?
- How many nurseries will be required? Where should the nurseries be established to achieve desired pre-conditioning?
- How many colonies of coral species A and B should be propagated in nurseries to account for future losses of corals?

Activity to Address Information/ Data Gaps

- Conduct monitoring of potential nursery sites for potential desired pre- conditioning environment

Questions to identify metrics for short-term and medium-term objectives related to outplanting

- How many artificial structures must be deployed to achieve sufficient habitat for a variety of fish species? What type of storm event must the artificial structures be able to withstand? How many outplanted corals can each structure support?
- How many colonies of coral species A and B each must be outplanted to natural and artificial substrates to achieve sufficient habitat for commercially-important fishes

Activity to Address Information/ Data Gaps

- Conduct interviews with local fishermen to determine which fish species are critical to their livelihoods
- Conduct monitoring of fish abundance and diversity of potential restoration sites and modelling for connectivity with fish nursery habitats like mangroves and seagrass beds

Example SMART Objectives

- **Objective 1 (pilot phase):** Within 3 years, 500 fragments each of coral species A and B haven been preconditioned annually in two field-based nurseries and 10% outplanted with 80% survival on existing reef and artificial reef prototypes within one site to demonstrate proof of concept.
- **Objective 2**: Within 5 years, coral propagation and outplanting is scaled up to 1000 fragments each of coral species A and B outplanted on natural reef substrate and 50 artificial structures annually with an 80% survival rate within each of three sites. Abundance of target fish species has increased by 25% compared to prior to restoration.
- **Objective 4**: Within 10 years, abundance of target fish has increased by 30%. Over 75% of fishermen and other reefs users are satisfied with the outcomes from the restoration project.

List of Metrics for Performance Monitoring: Number of fragments propagated/outplanted, percent of corals manipulated that show increased tolerance, survival rate, fish abundance, fish diversity, reef height and rugosity, water temperature.

The technical advisory group established in Step 1 should be convened to review the restoration objectives. This group should review each objective based on the SMART criteria, suggest revisions as needed, and document the assumptions and rationale for each objective.

***Workbook activity**: Identify potential performance metrics and intermediate results for the priority goal and restoration intervention(s) selected in Step 3C. Craft SMART objectives and metrics that will be used to monitor performance of the restoration intervention(s) towards the goal.*

4B. DEVELOP ACTIVITIES AND IMPLEMENTATION TIMELINE

Activities are developed to accomplish objectives and ultimately the restoration goal. These activities represent the key tasks you need to accomplish and are not as detailed as a work plan. You may find that you will need to include activities to answer questions you did not have answers for in crafting your SMART objectives. For each activity, the timeframe and methods for completing the activities should also be included (CMP 2020).

SUGGESTED PROCESS:

Restoration activities are developed for each objective along with timelines for completing this work. In addition to restoration activities, you may need to also consider whether any additional activities should be conducted including management actions or community engagement that will support the restoration project.

1. ***Identify Restoration Activities.*** In this step, restoration activities are defined for each objective along with the timeline and the responsible party or person (see Table 4.3). Activities should be organized according to your SMART objectives. Activities in the pilot phase should test the viability of specific details of your restoration interventions, such as sites and methods. For example, to determine the best location for field-based nurseries or species to use for asexual propagation and outplanting, you may need to conduct pilot studies in multiple locations and for several species. Phase 2 activities include those that will be conducted after piloting and during full-scale restoration. These activities can be defined at this time but may need modification based on the results of pilot studies.

Snorkelers checking on seeding units in floating coral rearing pools.

Image: Ari Bickel | SECORE

Table 4.3. Example activities and timeline for a restoration project, using objectives from Box 4.2.

	Activities	Timeframe
Goal: Within 10 years, restore diverse and structurally complex coral reef fisheries habitats that increase abundance of valued species and support local fisheries production and livelihoods.		
Objective 1 (pilot phase): Within 3 years, 500 fragments each of coral species A and B have been preconditioned annually in two field-based nurseries and 10% outplanted with 80% survival on existing reef and artificial reef prototypes within one site to demonstrate proof of concept.		
1.1	Conduct interviews with local fishermen to confirm target fish species, fishing gear and methods, and fishing areas critical to their livelihoods, and to establish baseline and historical catch rates	Year 1
1.2	Develop propagation and outplanting protocol	Year 1
1.3	Obtain permits for field activities	Year 1
1.4	Conduct monitoring of potential nursery sites for potential desired pre-conditioning environment	Year 1
1.5	Conduct baseline monitoring of fish abundance and diversity of potential restoration sites and modelling for connectivity with fish nursery habitats like mangroves and seagrass beds	Year 1 – 2
1.6	Establish nursery and develop and test propagation protocol	Year 1 – 3
1.7	Develop and test artificial reef prototypes and test outplanting protocol	Year 1 – 3
1.8	Develop and test manual removal of algae to prepare the substrate before outplanting and protect the corals after outplanting	Year 1 – 3
1.9	Monitor coral survival, artificial reef viability, and environmental conditions that could impact results (e.g. bleaching, wave events, land-based runoff)	Year 2 – 3
1.10	Analyze pilot phase results and conduct comprehensive evaluation with technical advisory group and make any adjustments in coral species, outplanting techniques, sites, and metrics	Year 2 – 3
1.11	Develop a rapid response protocol to replace structures and replenish corals lost to storms and bleaching events	Year 2 – 3
Objective 2: Within 5 years, coral propagation and outplanting is scaled up to 1000 fragments each of coral species A and B outplanted on natural reef substrate and 50 artificial structures annually with an 80% survival rate within each of three sites. Fish abundance and diversity has increased by 25% compared to prior to restoration.		
2.1	Review and refine Restoration Action Plan adjusting SMART objectives, metrics, and activities as needed based on pilot phase results and evaluation	Year 3
2.2	Update existing or obtain new permits for field activities	Year 3
2.3	Refine propagation and outplanting protocol and schedule	Year 3
2.4	Continue algae maintainance as needed	Year 3
2.5	Develop and implement long-term monitoring and evaluation plan	Year 3
2.6	Scale-up nursery operations	Year 3 – 4
2.7	Scale-up outplanting operations	Year 3 – 4
2.8	Monitor coral survival, fish abundance, catch unit effort, and environmental conditions that could impact results (e.g. bleaching, wave events, land-based runoff)	Year 2 – 5
2.9	Analyze results and conduct comprehensive evaluation with technical advisory group and make any adjustments in coral species, outplanting techniques, sites, and metrics	Year 3 – 5
Objective 3: Within 10 years, the abundance of target fish species has increased by 30%. Over 75% of fishermen and other reefs users are satisfied with the outcomes from the restoration project.		
3.1	Maintain nursery and outplanting operations to support ongoing reef restoration	Year 5 – 10
3.2	Continue algae maintainance as needed	Year 5 – 10
3.3	Maintain rapid response protocol	Year 5 – 10
3.4	Continue to monitor coral survival, fish abundance, catch per unit effort, and environmental conditions that could impact results (e.g. bleaching, wave events, land-based runoff)	Year 5 – 10
3.5	Analyze results and evaluate success of restoration efforts	Year 5 – 10

The pilot phase of the Action Plan allows practitioners to experiment with different technologies, coral species, or other details of an intervention (e.g., depth, placement, or materials used for coral nursery structures) and experience unforeseen events like bleaching or storm events without the threat of losing the entire project or all invested resources. A pilot phase can either be smaller-scale versions of the restoration interventions outlined in your Action Plan, or experiments that test specific research questions to answer any unknowns or uncertainties about the restoration interventions. To be most effective, the pilot phase should use principles of standard experimental design, including control sites where restoration activities are not occurring, but environmental conditions are as similar as possible. This is the only way to attribute changes observed in the reef site to the restoration intervention rather than unknown factors. To develop sound experimental designs such that data can be accurately analyzed, we recommend that the technical advisory group includes scientists, such as coral reef ecologists.

A pilot phase that is set up to answer specific research questions (e.g., how growth and mortality rates differ among outplanted corals of two different species) will require data to be collected to test the hypothesis. For pilot studies that are smaller versions of your restoration intervention, monitoring should be conducted based on plans developed in the Action Plan and conducted over at least one year to ensure any seasonal variations are experienced. At the conclusion of the pilot phase, evaluate whether the intervention continues to put the project on the right track towards the pilot phase objectives and restoration goal. If the pilot phase fails, you will need to reevaluate conducting that specific intervention or determine whether your planning team should return to Step 3 of this Guide. In addition, this process may cause you to need to return to your goals and objectives and adjust accordingly. In the process of evaluating restoration interventions, you may need to further refine your vision of what success looks like.

Your list of performance metrics serves as the basis for developing a more detailed monitoring plan for the restoration work in your location. A Monitoring Plan should include details on information needs, performance metrics (or indicators), the methods you will use to measure the metrics, spatial scale and locations, timeframe, and project personnel roles and responsibilities for collecting data (CMP 2020). To develop a monitoring program, we recommend using *Coral Reef Restoration Monitoring Guide: Methods to Evaluate Success from Local to Ecosystem Scales* (Goergen et al. 2020) (see next section, Moving into Action).

2. ***Identify Supporting Management and Community Engagement Activities.*** A key assumption from Step 1 is that current coral reef and watershed management are in place in the geographic focus area(s) and being implemented to ensure that local and regional threats to reefs are addressed. Managers of these ongoing efforts should be regularly consulted to determine if this assumption remains valid throughout the implementation of restoration activities. These ongoing efforts should be part of restoration planning discussions but are not included as part of the Action Plan.

   In addition to ongoing efforts, additional management and community engagement activities may be required to assist and promote coral reef restoration interventions. For example, activities may be needed to advocate for revised fishing rules to support the goal of increasing reef fisheries production, or engage local community groups to assist in long-term monitoring of catch per unit effort at the restoration sites. These additional activities, along with an implementation timeframe, should be included and SMART objectives developed to the extent practicable in your Action Plan.

Workbook activity*: Prepare a table describing restoration activities with the timeframe and responsible party for completing each activity. Then, prepare a table with this information for any supporting management and community engagement activities.*

4C. BUILD ACTION PLAN

Now that you have completed the four planning steps in this Guide, you are ready to build your Action Plan. The Action Plan Template, provided with this Guide and aligned with the Workbook, can be found in Appendix 2. In this template, you will find sections labeled with the corresponding steps in this Guide. Not all of the information you have documented in the Workbook will go into your Action Plan. Rather, final decisions and summaries of your process to reach these decisions will be detailed.

It is recommended that the full Workbook be retained as a reference document for evaluating and adapting the Action Plan over time. The Workbook can provide a comprehensive record of the information and assumptions made in developing your restoration interventions and may provide valuable insights as new information becomes available or underlying assumptions change.

Your Action Plan should be shared with the Technical Advisory Group and any critical stakeholders or decision-makers to obtain their support and approval.

***Workbook activity**: Develop your Action Plan (you can use Appendix 2 as a template). Provide an overview of the process used to develop your plan.*

A land-based coral nursery growing coral fragments. St. Croix, US Virgin Islands.

Image: Paul Selvaggio | The Nature Conservancy

Stakeholder Engagement

The process outlined in this step should allow you to make decisions with a number of diverse stakeholders and be transparent about the decisions made about restoration interventions. You can use Table 3.4 or a similar table or figure to present a summary of the evaluation and selection process and share the reasons and rationale behind decisions for your location. It will be useful to document the process of engaging stakeholder groups in this process as well to show how diverse interests were incorporated.

***Workbook activity**: List technical experts, stakeholders, and partners including scientists, engineers, community members, and members of the private sector and national and local governments engaged to review and prioritize restoration goals and the geographic focus area(s). Provide a summary of stakeholder engagement activities to be taken for this step..*

After restoration: the community's reefs are now thriving.

Image: Martin Colognoli | Coral Reef Image Bank

Outplanting corals using ropes in Belize. Image: Fragments of Hope

MOVING INTO ACTION

Congratulations! With the creation of your Action Plan, you have completed the planning phase of the cycle and are ready to implement active coral reef restoration. Your Action Plan will serve as a basis for securing funding, communicating with stakeholders, building out your broader Restoration Strategic Plan, and moving into action.

Building a Strategic Plan

As discussed in the Introduction of this Guide, a Strategic Plan encompasses the overarching plan for a project, including an Action Plan, Monitoring Plan and Operational Plan (Figure 1; CMP 2020). This Guide helps you develop the Action Plan, part of which also involves identifying your process to develop a Monitoring Plan.

An initial Monitoring Plan is needed for the pilot phase described in your Action Plan to assess the suitability of the chosen sites and the stability and short-term effectiveness of interventions before scaling them up to the full project scope. The list of performance metrics from your Action Plan supports this and provides a basis for building out a more detailed, long-term Monitoring Plan that assesses how reefs recover at your restoration sites. Your plan will need to include details on information needs, targets for performance metrics, the methods you will use to measure the metrics, spatial scale and locations, timeframe, and project personnel roles and responsibilities for collecting data. To develop a monitoring program, we recommend using the *Coral Reef Restoration Monitoring Guide: Methods to Evaluate Success from Local to Ecosystem Scales* (Goergen et al. 2020) (see Box 5.1). In addition to monitoring progress towards your objectives and goals, regular status assessments of the project should be conducted to identify needs for maintenance. Checking the status of the project will likely need to be done more regularly than data collection.

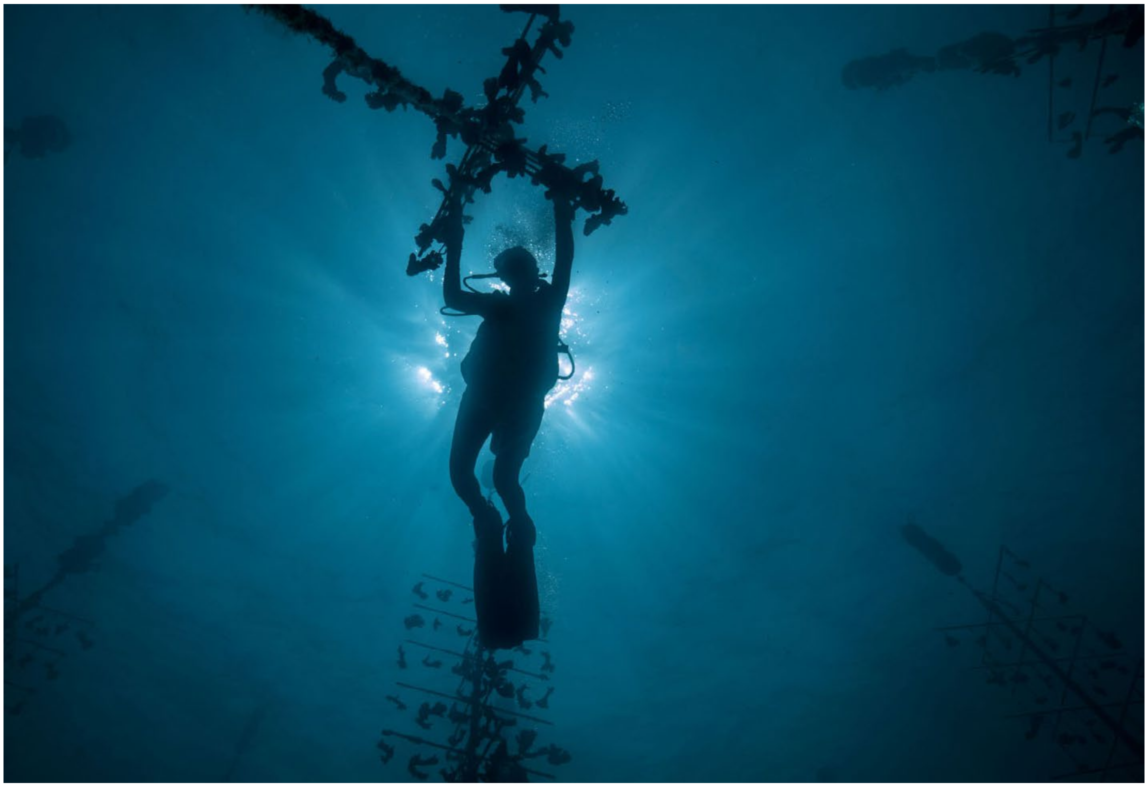


Image: Alex Neufeld | Coral Restoration Foundation™

Coral Restoration Foundation coral tree nursery, Florida Keys.

Box 5.1. Developing a Monitoring Plan for coral reef restoration.

Coral Reef Restoration Monitoring Guide: Methods to Evaluate Success from Local to Ecosystem Scales **(Goergen et al. 2020).**

The *Coral Reef Restoration Monitoring Guide* (Goergen et al. 2020) has been developed by the Coral Restoration Consortium's Monitoring Working Group to assist restoration practitioners and managers with monitoring coral reef restorations and evaluating success. It provides a hypothesis- and data-driven monitoring framework to support informed decisions about data and metrics necessary to monitor and describe the effectiveness of a restoration goal or objective. The Monitoring Guide describes two types of monitoring metrics: Universal Metrics and Goal-Based Performance Metrics. Universal Metrics are described as basic requirements for monitoring for all restoration projects regardless of the goal, to improve our collective ability to compare projects and learn from others. The four Universal Metrics are: Landscape/Reef-Level, Population-Level, Colony-Level, and Genetic/Genotypic Diversity. Goal-Based Performance Metrics provide information on monitoring for five distinct goal categories (i.e., Ecological, Socio-Economic, Event-Driven, Climate Change Adaptation, and Research Goals). A Coral Restoration Database and Evaluation Tool has also been developed to complement and be used with this Guide.

The *Coral Reef Restoration Monitoring Guide* can be used alongside this Guide for planning and design to develop a monitoring plan that is complementary of the Action Plan and part of an overall Restoration Strategic Plan.

Web links for the Coral Restoration Consortium can be found in the Resources section.

This brings us to the third component of the overall Strategic Plan: the Operational Plan. An Operational Plan analyzes and documents the resources required to complete the work (funding, capacity, skills, etc.); risks involved and plans for addressing or mitigating them; and an exit strategy including plans for long-term sustainability of the project if needed. It lays out responsibilities and budgets for implementation (Step 5), as well as a structure for regularly scheduled forums to review progress, analyze results, adapt plans and share lessons learned (Step 6). For more information on how to develop an Operational Plan, see the *Open Standards for the Practice of Conservation* (CMP 2020, Chapter 2).

Monitoring using a combination of transects and quadrats.

Image: Tom Moore | NOAA

Finally, a Work Plan, often created annually, lays out what aspects of each of the three pieces will be accomplished in the next period (e.g., in the near-term). This includes tasks, roles and responsibilities, and timelines for accomplishing the work of the upcoming year.

CONSIDERATIONS FOR STEP 5: IMPLEMENT RESTORATION

Based on the Restoration Strategic Plan, implementation of a restoration project will occur over a period of several years, during which the interventions are piloted, scaled up, and monitored to determine if and when the restoration goal has been achieved. It is highly recommended to identify proper control sites that are similar to your restoration sites so you can compare them over time, as this is the only way you will be able to attribute changes in the reef state to restoration interventions rather than natural recovery processes. A common method for this is called a BACI (Before-After-Control-Impact) experiment (Smith 2014). It is important to remember that natural recovery of reef ecosystems can take years to decades, so implementation and monitoring should also occur over this timeframe. For this reason, implementation and monitoring should be viewed as occurring simultaneously and iteratively rather than sequentially.

As with planning, stakeholders will likely be critical players in successful implementation of restoration activities and for ensuring the long-term sustainability of the project. Some stakeholder groups may become partners in implementing restoration activities and allowing projects to achieve larger scales when funding resources are limited. Such partnerships can provide essential support for the project while boosting shared ownership and interest in the restoration project. Several case study examples of restoration programs engaging community groups are available on the Reef Resilience Network Case Study database (see Resources).

Community-based monitoring may also be especially helpful to managers. This may include actively engaging communities in monitoring activities, to assist with collection of regular monitoring data through citizen science projects and to help “keep an eye” on projects in their local areas. It is advisable to consider conducting regular meetings with local community members and stakeholders about restoration projects. Providing updates on the progress of the restoration project allows involved stakeholder groups (those both positively or negatively affected by or partnering directly on the project) to remain knowledgeable of constraints, setbacks, or limitations to the project and what revisions need to be made and why. Sharing this knowledge may lead to solutions to problems, or else simply help to set and keep reasonable expectations.

CONSIDERATIONS FOR STEP 6: MONITOR & EVALUATE PROGRESS

As mentioned above, monitoring is occurring throughout and simultaneously with restoration implementation. In the beginning phases of implementation, monitoring will involve assessing shorter-term effects of the restoration interventions, such as tracking the fate of outplanted corals or the efficacy of certain methods. Over time, monitoring should switch to examining reef-scale effects that take longer timeframes to occur, such as ecosystem recovery (e.g., coral cover, coral recruitment), as they are relevant to your restoration goal. Performance metrics to be monitored during this process should include those identified from your SMART objectives.

Remember that other forms of data collection are important during restoration implementation, such as information on the operations of your restoration program (e.g., financial costs and budgeting). You may also want to periodically review the state of knowledge on restoration and climate science. Techniques for coral reef restoration and our ability to predict future impacts of climate change are rapidly evolving. It may also be helpful to remain aware of events or changes that occur around the restoration site that may affect the project, such as the broader context of natural resource management around your restoration project (e.g., watershed management).

As relevant data and information are compiled, periodic analysis is required to review project progress. **Data analysis** is the process of transforming raw data into useful information that typically answers a specific research question (CMP 2020). Remember that SMART objectives were developed to serve as benchmarks towards your selected restoration goal. These benchmarks include specific performance metrics to be met by certain dates. You should consider discussing the methods or models used to analyze data with scientists or other technical experts before monitoring begins. This will ensure selected analyses inform you of progress towards one of your objectives or answer a specific research question.

Once monitoring data have been analyzed, you will be able to evaluate progress towards your objectives and overall programmatic efficiency. This will allow you to identify whether changes need to be made to adjust either the interventions being used or the objectives. You can refer to documentation in the Workbook (Appendix 1) and your Action Plan developed from the template (Appendix 2) and review the process and underlying assumptions used to make these decisions. Then, determine what aspects of the Action Plan need to be revised. You can use the following questions to help frame your thoughts during this process:

- Have you been consistently meeting the objectives you previously set in your Action Plan? If not, why? If the reason is out of your control, consider redefining your objectives to set more accurate expectations of what you can achieve. If the reason can be altered, consider making these improvements and updating your restoration objectives and overall goal.
- What happened that was not planned for or anticipated? Are there specific problems with the intervention that need to be addressed? What are possible mechanisms to address these problems and improve progress towards the objective? Are these mechanisms possible?
- If you have multiple interventions and thus multiple objectives, how is progress going across all interventions? Should more time or focus be moved to any one intervention?
- At this time, do adjustments need to be made to the Action Plan? Have other needs for restoration surfaced and do other restoration goals need to be designed through this planning process? If so, consider returning to the Action Plan planning process in this Guide (Steps 1-4).

Remember that the cycle of coral reef restoration planning and design is a constantly evolving and iterative process, where you may need to return to previous steps in the process in any order that matches the needs of your program. This is consistent with an adaptive management approach, where management activities provide learning through monitoring and evaluation, so that improvements can be made as new information becomes available.

Divers outplanting corals onto a reef in the Dominican Republic.

Image: Paul Selvaggio | The Nature Conservancy

CONCLUSION

In *A Manager's Guide to Coral Reef Restoration Planning and Design*, you have followed an adaptive cycle to develop an Action Plan for coral reef restoration for your location that thoughtfully considers and plans for the future. The planning steps are followed by important considerations for implementing and monitoring restoration interventions in order to assess project progress. For any management process to be truly adaptive, it should not stop after analysis and evaluation. To continue improving the restoration project and its chances of success, you will need to continually make changes based on what has been learned, and refine strategies, plans, and the various restoration interventions, as well as the associated monitoring and stakeholder engagement.

For managers ready to embark on coral reef restoration, it is important to remember that restoration does not supercede reducing threats to reefs from human activities. Restoration, strong management of local threats to reefs, and climate change mitigation will all be needed and likely used in combination to give coral reefs around the world the best chance of coping with climate change.

As a global community, we have an opportunity to build our collective capacity to plan and implement restoration. Users of this Guide are encouraged to share results and lessons learned with others in their regions and globally. Restoring coral reef ecosystems in the face of a changing climate and increasing human populations will be a journey for us all, and we must share our successes and failures along this journey to help the field of restoration improve as quickly as possible. In this way, we may all be better equipped to conduct and tailor interventions when armed with knowledge of what does and does not work for the wide range of situations and circumstances within which coral reef restoration will be conducted.

To share with others, the Reef Resilience Network (reefresilience.org) and the Coral Restoration Consortium (crc.reefresilience.org) are global communities of practice that support collaboration and communication amongst coral reef managers, restoration practitioners, and experts. Consider becoming a member of these communities and sharing your lessons learned with others in these groups.

Good luck with your work in planning and implementing restoration activities! The authors and sponsors of this Guide hope that the planning process and accompanying Workbook and Action Plan Template prove to be useful resources for your current and future restoration efforts.

Nursery structure growing *Acropora* corals in the Dominican Republic. Image: Paul Selvaggio | The Nature Conservancy

REFERENCES

Anthony, K., Bay, L.K., Costanza, R., Firn, J., Gunn, J., Harrison, P., Heyward, A., Lundgren, P., Mead, D., Moore, T. and Mumby, P.J., 2017. New interventions are needed to save coral reefs. *Nature Ecology & Evolution*, 1(10), pp.1420-1422.

Baums, I.B., Baker, A.C., Davies, S.W., Grottoli, A.G., Kenkel, C.D., Kitchen, S.A., Kuffner, I.B., LaJeunesse, T.C., Matz, M.V., Miller, M.W. and Parkinson, J.E. 2019. Considerations for maximizing the adaptive potential of restored coral populations in the western Atlantic. *Ecological Applications*, 29(8), p.e01978.

Boström-Einarsson, L., Babcock, R.C., Bayraktarov, E., Ceccarelli, D., Cook, N., Ferse, S.C., Hancock, B., Harrison, P., Hein, M., Shaver, E., Smith, A., Suggett, D., Stewart-Sinclair, P.J., Vardi, T., and McLeod, I.M. 2020. Coral restoration–A systematic review of current methods, successes, failures and future directions. *PloS one*, 15(1), p.e0226631.

Burke, L., D. Bryant, J. McManus, and Spalding, M. 2008. *Reefs at Risk*. World Resources Institute (WRI), Washington, D.C. 56 p.

Burke, L.M., Reytar, K., Spalding, M. and Perry, A. 2011. *Reefs at Risk Revisited*. World Resources Institute, Washington D.C.

Conservation Measures Partnership (CMP). 2020. *Open Standards for the Practice of Conservation*, Version 4.0.

De'ath, G., Fabricius, K.E., Sweatman, H. and Puotinen, M. 2012. The 27–year decline of coral cover on the Great Barrier Reef and its causes. *Proceedings of the National Academy of Sciences*, 109(44), pp.17995-17999.

Dizon, R.M., Edwards, A.J., and Gomez, E.D. 2008. Comparison of three types of adhesives in attaching coral transplants to clam shell substrates. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 18(7), pp.1140-1148.

Edwards, A.J. (ed.). 2010. *Reef Rehabilitation Manual*. Coral Reef Targeted Research & Capacity Building for Management Program: St Lucia, Australia. pp.166.

Ferrario, F., Beck, M.W., Storlazzi, C.D., Micheli, F., Shepard, C.C. and Airoldi, L. 2014. The effectiveness of coral reefs for coastal hazard risk reduction and adaptation. *Nature Communications*, 5(1), pp.1-9.

Gann, G.D., McDonald, T., Walder, B., Aronson, J., Nelson, C.R., Jonson, J., Hallett, J.G., Eisenberg, C., Guariguata, M.R., Liu, J., Hua, F., Echeverría, C., Gonzales, E., Shaw, N., Decleer, K., and Dixon, K.W. 2019. *International principles and standards for the practice of ecological restoration*. Second edition: November 2019. Society for Ecological Restoration, Washington, D.C. 20005 U.S.A.

Goergen, E.A., Schopmeyer, S., Moulding, A., Moura, A., Kramer, P., and Viehman, S. 2020. *Coral reef restoration monitoring guide: Methods to evaluate success from local to ecosystem scales*. NOAA NOS NCCOS Technical Memoradum 279.

Hein, M., McLeod, I., Shaver, E., Vardi, T., Pioch, S., Boström-Einarsson, L., Ahmed, M, and G. Grimsditch. 2020. *Coral reef restoration as a strategy to improve ecosystem services: A guide to coral restoration methods*. Report to the United Nations Environmental Programme.

Hughes, T.P., Kerry, J.T., Álvarez-Noriega, M., Álvarez-Romero, J.G., Anderson, K.D., Baird, A.H., Babcock, R.C., Beger, M., Bellwood, D.R., Berkelmans, R. and Bridge, T.C. 2017. Global warming and recurrent mass bleaching of corals. *Nature*, 543(7645), pp.373-377.

International Panel on Climate Change (IPCC). 2018. *Global warming of 1.5°C*. Geneva, Switzerland: World Meteorological Organization. https://www.ipcc.ch/sr15/

Jackson, J.B.C., Donovan, M.K., Cramer, K.L., Lam, V.V. (editors). 2014. *Status and Trends of Caribbean Coral Reefs: 1970-2012*. Global Coral Reef Monitoring Network, IUCN, Gland, Switzerland.

Komyakova, V., Jones, G.P. and Munday, P.L. 2018. Strong effects of coral species on the diversity and structure of reef fish communities: A multi-scale analysis. *PloS one*, 13(8), p.e0202206.

Loya, Y., Sakai, K., Yamazato, K., Nakano, Y., Sambali, H. and Van Woesik, R. 2001. Coral bleaching: the winners and the losers. *Ecology Letters*, 4(2), pp.122–131.

Maynard, J.A., Marshall, P.A., Parker, B., Mcleod, E., Ahmadia, G., van Hooidonk, R., Planes, S., Williams, G.J., Raymundo, L., Beeden, R., and Tamelander, J. 2017. *A Guide to Assessing Coral Reef Resilience for Decision Support*. Nairobi, Kenya: UN Environment.

Marshall, P., and Schuttenberg, H. 2006. *A Reef Manager's Guide to Coral Bleaching*. Townsville, Australia, Great Barrier Reef Marine Park Authority.

McDonald, T., Gann, G., Jonson, J. and Dixon, K., 2016. *International standards for the practice of ecological restoration–including principles and key concepts*. Society for Ecological Restoration: Washington, DC, USA.

Mcleod, E., Anthony, K.R., Mumby, P.J., Maynard, J., Beeden, R., Graham, N.A., Heron, S.F., Hoegh-Guldberg, O., Jupiter, S., MacGowan, P. and Mangubhai, S., 2019. The future of resilience-based management in coral reef ecosystems. *Journal of environmental management*, 233, pp.291–301.

National Academies of Sciences, Engineering, and Medicine. 2019. *A Research Review of Interventions to Increase the Persistence and Resilience of Coral Reefs*. Washington, DC: The National Academies Press.

Nyström, M. 2006. Redundancy and response diversity of functional groups: implications for the resilience of coral reefs. *AMBIO: A Journal of the Human Environment*, 35(1), pp.30–35.

Parker, B.A., West, J.M., Hamilton, A.T., Courtney, C.A., MacGowan, P., Koltes, K.H., Gibbs, D.A., and Bradley, P. 2017. *Adaptation Design Tool: Corals and Climate Adaptation Planning*. Silver Spring, MD: NOAA Coral Reef Conservation Program. NOAA Technical Memorandum CRCP 27, 58 pp.

Possingham, H.P., Bode, M. and Klein, C.J., 2015. Optimal conservation outcomes require both restoration and protection. *PLoS biology*, 13(1), : e1002052.

Smith, E.P., 2014. *BACI Design*. Wiley StatsRef: Statistics Reference Online.

Tompkins, E.L. and Adger, W.N., 2004. Does adaptive management of natural resources enhance resilience to climate change? *Ecology and Society*, 9(2).

Van Hooidonk, R., Maynard, J., Tamelander, J., Gove, J., Ahmadia, G., Raymundo, L., Williams, G., Heron, S.F. and Planes, S. 2016. Local-scale projections of coral reef futures and implications of the Paris Agreement. *Scientific Reports*, 6(1), pp.1–8.

Van Oppen, M.J., Gates, R.D., Blackall, L.L., Cantin, N., Chakravarti, L.J., Chan, W.Y., Cormick, C., Crean, A., Damjanovic, K., Epstein, H. and Harrison, P.L., 2017. Shifting paradigms in restoration of the world's coral reefs. *Global Change Biology*, 23(9), pp.3437–3448.

West, J.M., Courtney, C.A., Hamilton, A.T., Parker, B.A., Julius, S.H., Hoffman, J., Koltes, K.H. and MacGowan, P., 2017. Climate-smart design for ecosystem management: A test application for coral reefs. *Environmental management*, 59(1), pp.102–117.

West, J.M., Courtney, C.A., Hamilton, A.T., Parker, B.A., Gibbs, D.A., Bradley, P. and Julius, S.H., 2018. Adaptation Design Tool for Climate-Smart Management of Coral Reefs and Other Natural Resources. *Environmental management*, 62(4), pp.644–664.

Wilkinson, C. (ed.). 2004. *Status of Coral Reefs of the World: 2004. Volume 1*. Australian Institute of Marine Science. Townsville, Queensland, Australia. 301 p.

Young, C.N., Schopmeyer, S.A. and Lirman, D. 2012. A review of reef restoration and coral propagation using the threatened genus *Acropora* in the Caribbean and Western Atlantic. *Bulletin of Marine Science*, 88(4), pp.1075–1098.

RESOURCES

Caribbean *Acropora* Restoration Guide: http://reefresilience.org/wp-content/uploads/Johnson-et-al.-2011-Caribbean-Acropora-Restoration-Guide.pdf

Considerations for Maximizing the Adaptive Potential of Restored Coral Populations in the Western Atlantic: https://esajournals.onlinelibrary.wiley.com/doi/epdf/10.1002/eap.1978

Coral Restoration Review, Visualization, and Database
https://www.gbrcoralrestoration.org/restoration-database

Coral Restoration Consortium: http://crc.reefresilience.org

Corals & Climate Adaptation Planning: Adaptation Design Tool Online Course:
https://www.conservationtraining.org/course/view.php?id=52

Early Warning and Rapid Response Protocol: Actions to Mitigate the Impact of Tropical Cyclones on Coral Reefs: http://reefresilience.org/wp-content/uploads/Early-Warning-and-Rapid-Response-Protocol_compressed.pdf

Guidance Document for Reef Management and Restoration to Improve Coastal Protection: Recommendations for Global Applications based on lessons learned in Mexico:
http://reefresilience.org/wp-content/uploads/Guidance-for-reef_ene_digital_low.pdf

Mapping Ocean Wealth Map Explorer Tool: http://maps.oceanwealth.org

Reef Ball Foundation: A Step-by-Step Guide for Grassroots Efforts to Reef Rehabilitation:
http://www.reefball.org/stepbystepguidetoreefrehabilitation/DraftGuide.pdf

Reef Rehabilitation Manual: http://reefresilience.org/pdf/Reef_Rehabilitation_Manual.pdf

Reef Resilience Network Community-Based Climate Adaptation Module:
http://reefresilience.org/community-based-climate-adaptation/

Reef Resilience Network Case Study Database http://reefresilience.org/case_studies/

Reef Resilience Network Case Study: *Fiji: Using Coral Restoration and Ecotourism to Increase Local Participation and Financial Benefits of Resource Management Efforts* http://reefresilience.org/case-studies/fiji-ecological-restoration/

Reef Resilience Network Restoration Online Course https://reefresilience.org/online/

Reef Resilience Network Restoration Module: http://reefresilience.org/restoration/

Reefs at Risk Revisited, Integrated Local Threat Data. World Resources Institute:
https://wriorg.s3.amazonaws.com/reefs/reefs_at_risk_revisited_local_threats.zip

Restoration Resource Center, Society of Ecological Restoration: https://www.ser-rrc.org

United Nations Decade on Ecosystem Restoration: https://www.decadeonrestoration.org

United Nations World Environment Situation Room: https://environmentlive.unep.org/

Outplants of *Acropora cervicornis*, Key Largo, Florida. Image: Alex Neufeld | Coral Restoration Foundation™

A Manager's Guide to **Coral Reef Restoration** Planning and Design

APPENDIX 1: GUIDE WORKBOOK

Elizabeth Shaver[1], Catherine A. Courtney[2], Jordan M. West[3], Jeffrey Maynard[4], Cherie Wagner[1], Ian Mcleod[5], Lisa Boström-Einarsson[6,7], Petra MacGowan[1], Jason Philibotte[7], Kristine Bucchianeri[7], Lyza Johnston[8], Jennifer Koss[7]

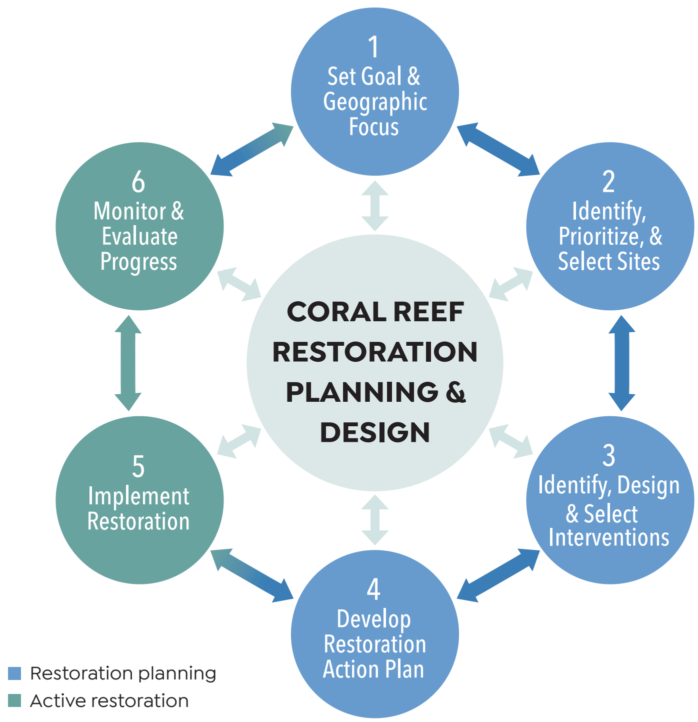
[1]The Nature Conservancy, [2]TetraTech, [3]United States Environmental Protection Agency, [4]SymbioSeas, [5]TropWATER, James Cook University, [6]Lancaster Environment Centre, Lancaster University, [7]United States National Oceanic and Atmospheric Administration Coral Reef Conservation Program, [8]Johnston Applied Marine Sciences

INTRODUCTION TO THE MANAGER'S GUIDE WORKBOOK

This Workbook accompanies the strategic planning process described in *A Manager's Guide to Coral Reef Restoration Planning and Design*. The Manager's Guide describes four key steps intended to help managers develop an Action Plan for coral reef restoration in their location. The four planning steps include:

- **Step 1:** Set Goal and Geographic Focus
- **Step 2:** Identify and Select Sites
- **Step 3:** Identify, Design, and Select Interventions
- **Step 4:** Develop Objectives and Action Plan

These steps are illustrated by a cycle, but it should be noted that these steps can be completed in any order and may often be iterative as new information becomes available through time.



The Manager's Guide Workbook provides a place to document the process, information, and decisions made during the planning process that guide you to developing your specific Restoration Action Plan. In the "Suggested Process" sections within each Guide step, we indicate when to turn to the Workbook to complete activities with your planning team. It is recommended that the full Workbook be retained as a reference document for evaluating and adapting the Restoration Action Plan over time. The Workbook can provide a comprehensive record of the information and assumptions made in developing your Action Plan and may generate valuable insights as new information becomes available or underlying assumptions change.

The Workbook Icon is used throughout the Manager's Guide to indicate when there is an accompanying Workbook Activity to conduct.

STEP 1: SET GOAL AND GEOGRAPHIC FOCUS

1A. IDENTIFY AND PRIORITIZE GOALS

List and describe the priority goals for your management area. Summarize the process and decisions made in generating the list of goals.

Priority restoration goals:
Summary of process:

Rewrite your goals using the SMART approach. Summarize key problems addressed by each goal and the process used to generate the details of these goals. We suggest working with up to three priority goals as a starting point.

SMART goals:	Key problems addressed by the goal:
Summary of process:	

1B. IDENTIFY GEOGRAPHIC FOCUS FOR EACH GOAL

Describe and provide a labeled map of the geographic focus area(s) for each priority goal. Provide notes about the functionality and benefits, and management and biophysical context. Then, summarize the process used or experts consulted for this work.

GOAL 1:	
Geographic Focus: Round 1 – Functionality and Benefits • *What areas currently or in the recent past have performed functions that are relevant to the goal?* • *What areas are currently experiencing the problems that the goal seeks to address?* • *Within these areas, where could reef restoration provide social and ecological benefits?*	
1) What areas have reefs that are currently, or in the recent past, performing functions that are relevant to the goal?	
2) What areas are currently experiencing the problems that the goal seeks to address?	
3) Within these areas, where could reef restoration provide social and ecological benefits?	
Map:	

Geographic Focus: Round 2 – Management and Biophysical Context • *What are the greatest management challenges in each area for achieving the restoration goal?* • *What is the biophysical context in which these challenges will need to be addressed?* • *What is the likelihood of overcoming these challenges? What are unique opportunities?*			
Context	Area A	Area B	Area C
Management Context			
• Land-based pollution • Overfishing • Tourism Overuse • Government Policies & Programs			
Context	Area A	Area B	Area C
Biophysical Context			
• Oceanographic processes • Geomorphology • Ecological connectivity • Watersheds and hydrology • Ocean temperature, bleaching & disease • Ocean acidification • Sea level rise • Storm surge & runoff			
Summary of process used:			

Describe and provide a labeled map of the geographic focus area(s) for each priority goal. Provide notes about the functionality and benefits, and management and biophysical context. Then, summarize the process used or experts consulted for this work.

GOAL 2:

Geographic Focus: Round 1 – Functionality and Benefits

- *What areas currently or in the recent past have performed functions that are relevant to the goal?*
- *What areas are currently experiencing the problems that the goal seeks to address?*
- *Within these areas, where could reef restoration provide social and ecological benefits?*

1) What areas have reefs that are currently, or in the recent past, performing functions that are relevant to the goal?	
2) What areas are currently experiencing the problems that the goal seeks to address?	
3) Within these areas, where could reef restoration provide social and ecological benefits?	

Map:

Geographic Focus: Round 2 – Management and Biophysical Context • *What are the greatest management challenges in each area for achieving the restoration goal?* • *What is the biophysical context in which these challenges will need to be addressed?* • *What is the likelihood of overcoming these challenges? What are unique opportunities?*			
Context	Area A	Area B	Area C
Management Context			
• Land-based pollution • Overfishing • Tourism Overuse • Government Policies & Programs			
Context	Area A	Area B	Area C
Biophysical Context			
• Oceanographic processes • Geomorphology • Ecological connectivity • Watersheds and hydrology • Ocean temperature, bleaching & disease • Ocean acidification • Sea level rise • Storm surge & runoff			
Summary of process used:			

Describe and provide a labeled map of the geographic focus area(s) for each priority goal. Provide notes about the functionality and benefits, and management and biophysical context. Then, summarize the process used or experts consulted for this work.

GOAL 3:

Geographic Focus: Round 1 – Functionality and Benefits

- *What areas currently or in the recent past have performed functions that are relevant to the goal?*
- *What areas are currently experiencing the problems that the goal seeks to address?*
- *Within these areas, where could reef restoration provide social and ecological benefits?*

1) What areas have reefs that are currently, or in the recent past, performing functions that are relevant to the goal?	
2) What areas are currently experiencing the problems that the goal seeks to address?	
3) Within these areas, where could reef restoration provide social and ecological benefits?	

Map:

Geographic Focus: Round 2 – Management and Biophysical Context • *What are the greatest management challenges in each area for achieving the restoration goal?* • *What is the biophysical context in which these challenges will need to be addressed?* • *What is the likelihood of overcoming these challenges? What are unique opportunities?*			
Context	Area A	Area B	Area C
Management Context			
• Land-based pollution • Overfishing • Tourism Overuse • Government Policies & Programs			
Context	Area A	Area B	Area C
Biophysical Context			
• Oceanographic processes • Geomorphology • Ecological connectivity • Watersheds and hydrology • Ocean temperature, bleaching & disease • Ocean acidification • Sea level rise • Storm surge & runoff			
Summary of process used:			

1C. SELECT GOAL AND GEOGRAPHIC FOCUS FOR RESTORATION PLANNING AND DESIGN

Describe the restoration goal your team selected to continue with for planning and design, as well as the final geographic focus area(s). Describe the process and rationale used to make this determination.

Goal:

Geographic focus:

Summary:

STAKEHOLDER ENGAGEMENT

List technical experts, stakeholders, and partners including scientists, engineers, community members, private sector, and federal and local government engaged to review and prioritize restoration goals and geographic focus area(s).

Technical Expertise	Key Stakeholders

Provide a summary of stakeholder engagement activities to be taken for this step.

STEP 2: IDENTIFY AND SELECT SITES

2A. IDENTIFY POTENTIAL RESTORATION SITES

List restoration sites within the geographic focus area being considered for restoration. Document their location and provide a brief rationale for why each site was selected.

Alternately, GIS software can be used to set a grid over the geographic focus area(s) and your team can determine the reef habitat cell/area size and make a map showing the gridded area and describing the number of grid cells.

Site Name:	Coordinates:	Rationale:

2B. USE FRAMEWORK TO PRIORITIZE SITES

List available datasets applicable to each part of the prioritization framework. Document any data or information that are missing or need to be collected.

Technical Expertise	Key Stakeholders
Relevance to Restoration Goal: *To what extent would restoration at the site help to achieve the set goal?*	
Potential to Improve Condition: *To what extent will restoration improve site condition?*	
Future exposure: *What is the likely frequency and severity of future disturbances?*	
Resilience/ecological processes: *What is the capacity of the site to resist and recover from disturbances?*	
Human impacts: *What are the types and severity of human impacts affecting coral reef communities at the site, and which are or could be mitigated through management actions?*	
Remaining data needs:	

Describe the rationale for your decision to complete the framework quantitatively or semi-quantitatively, including the advantages and disadvantages in your case.

Develop a statement for each framework part to be graded by local experts (first column; you may use the statements in the table below as examples). Record responses (on a scale from 1-5) and calculate the average. Complete this process for EACH site. You can use the table below or create a similar spreadsheet.

SITE NAME:

Example Statements for Each Framework Part	Rating					Total (N)	Avg.
	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)		
1. **Relevance to Restoration Goal**: *Restoring this site is extremely and directly relevant to achieving our restoration goal.*	5,5,5	4,4	3	0	0	26 (6)	4.3
Document data or rationale provided.							
2. **Coral Survival**:							
a. **Future Exposure**: *This site is among those in our geographic focus that is likely to rarely be exposed to disturbances or is projected to be exposed to these disturbances much later.*							
Document data/rationale used for rating. **Considerations**: future exposure to cyclones, coral bleaching conditions, extreme low tides, predation, and other disturbance events.							
b. **Ecological Resilience**: *This site is relatively resilient, with great relative capacity to resist and recover from disturbances.* **Considerations**: common resilience indicators include: coral recruitment, coral diversity, herbivore biomass, macroalgae cover, CCA cover, coral predation, coral disease, and temperature variability.							
Document data/rationale used for rating.							
c. **Human impacts**: *Human impacts are relatively low at this site.* **Considerations**: common human impacts on reefs include reef fish fishing, marine-based pollution, watershed-based pollution, marine debris, coastal development, tourism, and shipping.							
Document data/rationale used for rating.							
2. **Potential to Improve Site Condition**: *Restoration will greatly improve condition at this site.* **Considerations**: extent to which ecological condition has declined or degraded in recent years.							
Document data or rationale provided.							

For each site, average the values for all framework parts, so each site has one numerical score. Use color coding to denote relative restoration priority. Develop your criteria for low, medium and high priority or use the criteria in Step 2B of the Guide (Tables 2.3 and 2.4).

Create a table with the average values for each framework part for all candidate restoration sites. Table 2.6 in the Guide provides an example of a completed table.

Reef Name	Priority Level FINAL	Average	Relevance to Goal	Potential to Improve Condition	Short and long-term survivorship [Climate Vulnerability]		
					Future Exposure	Resilience	Human Impacts

COMPLETING THE FRAMEWORK QUANTITATIVELY

Develop metrics and units to support quantitative assessment of each framework part. For each framework part, at least one metric and units should be defined.

Framework Part	Metrics and Units
Relevance to Restoration Goal: *To what extent would restoration at the site help to achieve the set goal?*	
Potential to Improve Condition: *To what extent will restoration improve site condition?*	
Future exposure: *What is the likely frequency and severity of future disturbances?*	
Resilience/ecological processes: *What is the capacity of the site to resist and recover from disturbances?*	
Human impacts: *What are the types and severity of human impacts affecting coral reef communities at the site, and which are or could be mitigated through management actions?*	

Document the process used to decide on the metrics to be used to quantify each framework part.

*Use the analysis steps that follow to build a **Final Results Table** similar in format to the completed example in Table 2.7 of the Guide. Start with a Raw Data Table. The columns 'Priority Level', 'Priority Score Final', and 'Priority Score Raw', 'R' (for final Resilience score) and 'HI' (for final human impacts score) will all be blank to start. As you proceed, document each analysis step by copying this table and adding notes above or to the side.*

*Develop a **Normalized Data Table**. Normalize values to a 0-1 scale for each framework part and sub-parts (for resilience and human impacts). Copy the Raw Data table but have blank cells. Calculate the maximum value for each metric, indicator, variable and impact in the row that is just below your last site. Use spreadsheet software, such as MS Excel, to calculate the maximum value using the formula '= max (cell range)'. Fill in the blank table using formulas to divide all cell values for each metric, indicator, variable and impact by the maximum value that you calculated. This will generate new data values in each cell that will range from 0-1. Document this analysis step with notes on the process.*

*Develop a **Uni-directional Resilience Indicators Table**. Copy the data table from above. The data for resilience indicators will need to be unidirectional such that a high score is a good score. Subtract the normalized values you calculated in the previous step from 1 (this reverses their direction) for indicators such as macroalgae cover and coral disease (where high values for raw data are bad scores). Copy across all of the other data as is. Document this analysis step with notes on the process.*

Develop a ***Final Resilience Scores Table****. Copy the data table from above. Calculate the resilience score (filling in the blank 'R' column) by averaging the unidirectional normalized scores for the resilience indicators. Then, normalize that raw resilience score by dividing all the raw scores by the maximum value. This sets resilience for the group of candidate restoration sites as relative to the site with the greatest raw resilience score. Document this analysis step with notes on the process.*

Develop a ***Final Human Impacts Scores Table****. Copy the data table from above. The human impacts score can be calculated by averaging the human impacts scores. Those scores were purposefully not set to the same uni-directional scale as the resilience scores. It is intuitive that high scores mean high human impacts. This ensures color shading can be used to highlight whether each type of impact is relatively low or high at a site. However, the composite human impacts score needs to have the same direction as resilience, so you will need to average human impacts scores, normalize by dividing by the maximum value, and then subtract those values from 1. Document this analysis step with notes on the process.*

*Develop **Final Priority Scores** for each candidate site. Calculate the raw priority score by averaging the final values for Relevance to goal; Projected future exposure; Resilience; Human impacts; and Potential to improve condition. The 'Final Priority Score' is the raw priority scores normalized by dividing by the maximum value. Use a stop-light color scheme to color shade all data in your table. For the framework parts and any indicators or variables combined into a final framework part score (e.g., for resilience), use three categories (where avg is average and sd is standard deviation): high (>avg+1sd - [**Blue**]), medium (<avg+1sd and >avg-1sd - [**Orange**]), and low (<avg-1sd - [**Red**]). Color shade the final priority scores and set the final priority levels, following the criteria below or similar criteria developed by your team. A high score will not always mean higher final priority level (low, medium or high). This is because sites with low scores for any one of the framework parts should be lower priority, unless a score for a framework part is judged to be correctable through management action, thereby changing the perceived priority level. Develop criteria for low, medium and high final priority or use the criteria described in the Guide. Document this analysis steps with notes on the process.*

*Develop the **Final Results Table**, which will be similar to Table 2.7 in the Guide. Write the final priority level into the 'Priority Level' cells and re-sort the table by priority level (this ensures the sites with the highest priority scores are at the top of each priority level). Document this analysis steps with notes on the process.*

2C. FINAL SITE SELECTION

Provide a brief description of the highest priority sites selected for restoration. Include the site name, general description of the site, and a summary (quantitative or qualitative) on how each site compared to other sites using the prioritization framework. You may also use this table to indicate which site(s) might be suitable for the pilot phase.

Site Name	Site Description and Area	Comparison to Other Sites (based on framework parts)	Pilot Phase?

Develop a map of the geographic area of focus for the restoration goal with the final selected sites clearly marked.

Provide a summary of the process used to finalize your list of restoration sites, including stakeholders or decision-makers involved.

STAKEHOLDER ENGAGEMENT

List technical experts, stakeholders, and partners including scientists, engineers, community members, private sector, and federal and local government engaged to review and prioritize restoration goals and geographic focus.

Technical Expertise	Key Stakeholders

Provide a summary of stakeholder engagement activities to be taken for this step.

STEP 3: IDENTIFY, DESIGN AND SELECT INTERVENTIONS

3A: BRAINSTORM AN ARRAY OF INTERVENTION OPTIONS

List the full array of intervention options that could be applied towards your restoration goal, indicating how they connect to the goal where appropriate. Then, summarize the process used to make these decisions.

Goal:
Intervention Options:
Process:

3B: APPLY CLIMATE-SMART DESIGN CONSIDERATIONS

For each intervention option, use the Step 3B table provided to record your answers to the basic design questions that apply. After reviewing the climate-smart design considerations in Table 3.3 (and adding any further questions appropriate to your situation), build climate-smart improvements into all relevant design elements in your Step 3B table. Add additional Option columns until all brainstormed intervention options from 3A above have been designed.

Goal:

Design Questions	Restoration Interventions		
	OPTION 1	OPTION 2	OPTION 3
What coral species will be used?			
Where will corals be obtained?			
What coral propagation and/or outplanting methods will be used?			
What biological control techniques will be used?			
What physical or engineering techniques will be used?			

For each intervention option, use the Step 3B table provided to record your answers to the basic design questions that apply. After reviewing the climate-smart design considerations in Table 3.3 (and adding any further questions appropriate to your situation), build climate-smart improvements into all relevant design elements in your Step 3B table. Add additional Option columns until all brainstormed intervention options from 3A above have been designed.

Design Questions	**Category 1:** How will climate change and its interaction with local stressors of concern impact the biological resilience of the restoration intervention?				**Category 2:** How will climate change affect the physical functionality of the restoration intervention through direct impacts on structural components?			
	Indicate (X) which questions apply to the option to support discussion and development of climate-smart improvements.	Option 1	Option 2	Option 3	*Indicate (X) which questions apply to the option to support discussion and development of climate-smart improvements.*	Option 1	Option 2	Option 3
What coral species will be used?	*What is the vulnerability of the site to bleaching conditions? Are certain coral species more resistant to bleaching and disease?*				*How much is wave energy expected to increase with increasingly intense storms? Are certain coral species less brittle or more robust against storm damage?*			
	How is climate change affecting sediment and nutrient transport to the site? Are certain coral species more tolerant?							
	What are the implications of ocean acidification for coral growth rates and skeleton density/strength?							
	Are enough coral species being used to account for genetic and functional diversity and redundancy to spread the risk of local losses from coral bleaching and disease?							
Where will corals be obtained?	*Are there in situ sites where corals have naturally been acclimatized to bleaching or poor water quality?*				*Are there sites that have experienced intense storm events from which corals that have withstood damage could be collected?*			
	Are there lab-designed species or genotypes with special characteristics with respect to climate change-related stressors specific to the restoration site?							
	Are there enough broodstock genetic diversity to maximise chances of long-term survival and potential to scale-up efforts in the long-term?							

What coral propagation and/or outplanting methods will be used?	*Are there nursery sites in the field where corals could be acclimatized during propagation?*				*How much is wave energy expected to increase with increasingly intense storms? Does this affect the decision whether to use natural substrate or build an artificial substrate? (Also see engineering question below.)*			
	Is there a lab with options for pre-treating corals to acclimate them to variations in temperature or other stressors?				*How often will it be necessary to outplant more corals to replace losses from storms?*			
	How often will it be necessary to outplant more corals to replace losses from bleaching?				*At what depths should outplants be placed given projected rates of sea level rise?*			
					Will materials or methods used to outplant corals be able to withstand wave energy from storms?			
					How will the laboratory where corals will be propagated be safeguarded to withstand intense storms? Are structures and water intake fortified? Is there back-up power generation?			
What biological control techniques will be used?	*How will climate change affect predator or algal outbreaks? Will this affect the frequency or intensity with which removal techniques will need to be used? Will removal techniques be able to keep up with algal growth under changing conditions?*				*Will certain predator or algal removal techniques be difficult to do in areas of increasingly high wind and wave energy? Will this limit the time of year or efficiency (amount that can be done in a given time) with which the technique can be used?*			
	How is climate change affecting environmental conditions for valued herbivore populations? Will regular replenishment of herbivores be needed?				*How will the laboratory where herbivores will be reared be safeguarded to withstand intense storms? Are structures and water intake fortified? Is there back-up power generation?*			
	How will climate change affect the frequency and severity of disease outbreaks? Will this affect the type, method, or frequency of treatments needed? Should it affect the coral species chosen?							
What physical or engineering techniques will be used?	*Is there anything about the coral attachment methods or materials that could render corals more or less susceptible to climate change-related stress?*				*Will the chosen materials be able to stand up to increasingly intense wave energy and storms?*			
					Will increasing water temperatures have any effect on the lifetime of epoxy or other adhesives?			
					At what depth should structures be placed to account for sea level rise given coral growth rates?			

Prepare a summary description of each intervention option, synthesized from the detailed design information that you have developed. Each intervention option should be specifically tailored to the goal, address all relevant design elements, and include climate-smart design details as appropriate. Add additional rows to include all of your brainstormed intervention options.

Goal:
Option 1:
Option 2:
Option 3:

3C. EVALUATE & SELECT RESTORATION INTERVENTIONS

Describe the evaluation criteria used to select restoration interventions and provide a summary of how these details were determined.

Record ratings for each evaluation criteria (scale from 1-5) for each intervention option, using criteria from Table 3.4 and/or criteria developed by your planning team. Add additional columns until all brainstormed intervention options have been evaluated.

Evaluation Criteria	Restoration Intervention Ratings Strongly Agree (5), Agree (4), Neutral (3), Disagree (2), Strongly Disagree (1)		
	OPTION 1	OPTION 2	OPTION 3
Effectiveness			
Intervention will be technically effective at achieving restoration goal			
Intervention will be climate-smart in addressing changing conditions and uncertainties in climate change projections			
Average rating			
Rationale			
Feasibility			
Costs of implementation and maintenance are feasible			
Technical capacity will be in place to implement intervention (data, technical knowledge, number of staff)			
Physical infrastructure is achievable to implement intervention (e.g., land-based laboratory)			
Required government regulations and permits are obtainable within the implementation timeline			
Strong community, political, and private sector acceptance/support for intervention is available			
Average rating			
Rationale			
Flexibility			
Intervention is designed to be adjustable to accommodate changing conditions and incorporate learning			
Intervention is reversible if needed			
Average rating			
Rationale			

Record ratings for each evaluation criteria (scale from 1-5) for each intervention option, using criteria from Table 3.4 and/or criteria developed by your planning team. Add additional columns until all brainstormed intervention options have been evaluated.

Evaluation Criteria	Restoration Intervention Ratings Strongly Agree (5), Agree (4), Neutral (3), Disagree (2), Strongly Disagree (1)		
	OPTION 1	OPTION 2	OPTION 3
Urgency			
Degree of threat and cost of inaction is high if intervention is not implemented			
There is an immediate opportunity associated with implementing the intervention based on availability of partnerships, funding, or leveraging other existing efforts			
Results from the intervention can be achieved in a timeframe aligned with urgency of threat			
Average rating			
Rationale			
External Benefits			
Intervention achieves benefits outside of the target system, to other ecosystems and/or human communities (e.g., coastal protection, biodiversity, larval source, education, or research benefits)			
Intervention minimizes unintended negative consequences, including carbon footprint			
Average rating			
Rationale			
Interactions			
Are there interdependencies, sequencing requirements, or conflicts with other options?			

Document the intervention(s) that best support the priority goal as well as the process and rationale used during your evaluation process.

Goal 1:
Selected Intervention(s):
Process and Rationale:

STAKEHOLDER ENGAGEMENT

List technical experts, stakeholders, and partners including scientists, engineers, community members, private sector, and federal and local government engaged to review and prioritize restoration goals and geographic focus.

Technical Expertise	Key Stakeholders

Provide a summary of stakeholder engagement activities to be taken for this step.

STEP 4: DEVELOP RESTORATION ACTION PLAN

4A: DEFINE SMART OBJECTIVES

Identify potential performance metrics and intermediate results for the priority goal and restoration intervention(s) selected in Step 3C.

Objectives	Time (Years)			
	1– 3	4 – 6	7 – 10	10 – <20
Potential Performance Metrics (from Step 3A)				
Intermediate Results (Goal)				
Intermediate Results (Restoration Intervention)				

Craft SMART objectives and metrics that will be used to monitor performance of the restoration intervention(s) towards the goal.

Identify targets for metrics of medium to long-term objectives related to the **goal**:	Activity to Address Information/Data Gaps:
Intervention(s):	
Identify targets for metrics of short-term and medium-term objectives related to the **intervention**:	Activity to Address Information/Data Gaps:

List SMART Objectives	Corresponding Performance Metrics
Objective 1:	
Objective 2:	
Objective 3:	

4B: DEVELOP ACTIVITIES AND IMPLEMENTATION TIMELINE

Prepare a table describing restoration activities with the timeframe and responsible party for completing each activity.

Goal:		
SMART Objective 1:		
Performance metrics:		
Activities		**Timeframe**
1.1		
1.2		
1.3		
1.4		
1.5		
SMART Objective 2:		
Performance metrics:		
2.1		
2.2		
2.3		
2.4		
2.5		
SMART Objective 3:		
Performance metrics:		
3.1		
3.2		
3.3		
3.4		
3.5		

Prepare a table with this information for any supporting management and community engagement activities.

Management Activities		Timeframe
M.1		
M.2		
M.3		
M.4		
M.5		
Community Engagement Activities		Timeframe
C.1		
C.2		
C.3		
C.4		
C.5		

4C: BUILD ACTION PLAN

Develop your Action Plan (you can use Appendix 2 as a template). Provide an overview of the process used to develop your plan.

STAKEHOLDER ENGAGEMENT

List technical experts, stakeholders, and partners including scientists, engineers, community members, private sector, and federal and local government engaged to review and prioritize restoration goals and geographic focus.

Technical Expertise	Key Stakeholders
Provide a summary of stakeholder engagement activities to be taken for this step.	

Coral nursery in Grand Anse, Grenada. Image: Tim Calver | The Nature Conservancy

A Manager's Guide to **Coral Reef Restoration** Planning and Design

APPENDIX 2: RESTORATION ACTION PLAN TEMPLATE

Action Plan for Coral Reef Restoration in [insert jurisdiction name]

[Insert date]

[List all major contributors and affiliations]

Project Description

Provide a brief description of the project and stakeholders engaged in the development of the action plan, including how the plan fits into existing and ongoing coral reef and watershed management efforts in the geographic scope of the project. Describe the process for identifying the top priority goals; list all of the priority goals and discuss how the priority goal chosen for this action plan was selected.

*If this plan is in DRAFT, describe the process for sharing the plan with decision-makers and stakeholders.

Priority Restoration Goal

[Planning Step 1]

List the highest priority goal used during the planning process.

The priority goal selected for this restoration action plan is:

Sites Selected for Restoration

[Planning Step 2]

Provide a brief description of the highest priority sites for restoration. Include for each site: site name, general description of the location, and a summary (quantitative or qualitative) of how each site compared to other sites in the following categories: Relevance to Restoration Goal, Potential to Improve Condition, Future Exposure, Resilience/Ecological Processes, and Human impacts (delete or write 'UNKNOWN' for any categories for which you did not have data or information). Include a map of selected restoration sites in Appendix 1 below.

Below is a brief description of the priority site(s) selected for restoration intervention.

Site 1 name; geographic focus area; coordinates:

- Relevance to Restoration Goal:
- Potential to Improve Condition:
- Future Exposure:
- Resilience/Ecological Processes:
- Human Impacts:

Site 2 name; geographic focus area; coordinates:

- Relevance to Restoration Goal:
- Potential to Improve Condition:
- Future Exposure:
- Resilience/Ecological Processes:
- Human Impacts:

Site 3 name; geographic focus area; coordinates:

- Relevance to Restoration Goal:
- Potential to Improve Condition:
- Future Exposure:
- Resilience/Ecological Processes:
- Human Impacts:

Rationale for Site Selection

Provide a summary of the rationale behind setting these as 'highest priority', including the data sets used and any discussions held during final site selection.

The rationale behind determining these sites as the highest priority sites includes:

Ongoing Management

Provide a summary of management actions and regulations already in place at the selected restoration sites.

The management actions and regulations already in place at this site are:

Restoration Interventions

[Planning Step 3]

Provide a summary describing the climate-smart restoration interventions that were designed and selected for restoration at each site, including the rational for selecting these interventions. Include information about pilot studies that are required as appropriate.

Below is a description of the planned restoration interventions at each priority restoration site:

[Insert Site 1 name; insert description of restoration intervention(s); insert rationale for selecting interventions]

[Insert Site 2 name; insert description of restoration intervention(s); insert rationale for selecting interventions]

[Insert Site 3 name; insert description of restoration intervention(s); insert rationale for selecting interventions]

[Include additional sites as needed]

Objectives and Performance Metrics

[Planning Step 4]

Describe specific objectives and performance metrics that will be used to assess project progress, including objectives that support any pilot studies needed before scaling up the restoration intervention are as follows.

The specific objectives and performance metrics that will be used to assess project progress are as follows. A summary is provided in Appendix 2 of this Action Plan detailing the site(s), lead personnel or agencies, partners, and timeframe to complete each of these activities.

Objective 1.1: [List the SMART objective]

Performance Metrics: [Describe the performance metrics identified for Objective 1.1]

Activities: [Describe restoration activities as well as supporting management and community engagement activities for Objective 1.1]

Objective 1.2: [List the SMART objective]

Performance Metrics: [Describe the performance metrics identified for Objective 1.2]

Activities: [Describe restoration activities as well as supporting management and community engagement activities for Objective 1.2]

Objective 1.3: [List the SMART objective]

Performance Metrics: [Describe the performance metrics identified for Objective 1.3]

Activities: [Describe restoration activities as well as supporting management and community engagement activities for Objective 1.3]

[Copy the description above for additional objectives as needed]

Stakeholder Engagement and Outreach

[All Planning Steps]

Provide a description for your stakeholder engagement plans for this coral reef restoration action plan, including plans for accessing any additional or needed technical support, sharing our experiences with others locally, and collaborating with ongoing management efforts in the area.

Our strategy for stakeholder engagement for this coral reef restoration plan includes:

Appendix 1. Map of Priority Sites

Appendix 2. Action Plan Summary Matrix

[Complete the table below for the priority goal (Goal 1)]

Goal (Step 1):		
SMART Objective 1 (Step 4):		
Performance metrics (Step 4):		
Activities		Timeframe
1.1		
1.2		
1.3		
1.4		
1.5		
SMART Objective 2 (Step 4):		
Performance metrics (Step 4):		
2.1		
2.2		
2.3		
2.4		
2.5		
SMART Objective 3 (Step 4):		
Performance metrics (Step 4):		
3.1		
3.2		
3.3		
3.4		
3.5		

[Copy the format of the table for additional objectives as needed]

U.S. Department of Commerce
Wilbur L. Ross
Secretary of Commerce

National Oceanic and Atmospheric Administration
Neil A. Jacobs
Acting Under Secretary of Commerce
for Oceans and Atmosphere and
NOAA Administrator

National Ocean Service
Nicole LeBoeuf
Acting Assistant Administrator