Final Draft

Kenya National Coral Reef Restoration Protocol

A Guide for Coral Reef Restoration in Kenya

June 2018

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Organizations who provided Information

Coast Development Authority (CDA) is a state corporation established to plan and co-ordinate the implementation of integrated development projects in the whole of Coast region (Mombasa, Kwale, Kilifi, Lamu, Taita Taveta, Tana River Counties & the Southern part of Garissa County) and the Exclusive Economic Zone and for connected purposes.

Kenya Wildlife Service (KWS) is a state corporation that was established to conserve and manage wildlife in Kenya, and to enforce related laws and regulations. KWS undertakes conservation and management of wildlife resources across all protected areas systems in collaboration with stakeholders and encourages biodiversity conservation by communities living on land essential to wildlife, such as wildlife corridors and dispersal lands outside parks and reserves.

Kenya Marine and Fisheries Research Institute (KMFRI) is a State Corporation established to undertake research in "marine and freshwater fisheries, aquaculture, environmental and ecological studies, and marine research including chemical and physical oceanography", in order to provide scientific data and information for sustainable exploitation, management and conservation of Kenya's fisheries and other aquatic resources

National Environment Management Authority (NEMA) is established to exercise general supervision and coordination over all matters relating to the environment and to be the principal instrument of the Government of Kenya in the implementation of all policies relating to the environment.

Adaptation Fund (AF) is an international **fund** that finances projects and programs aimed at helping developing countries to **adapt** to the harmful effects of climate change. It is set up under the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC)

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Cover Image: Coral reef restoration in Wasini CCA Kenya (2016); photos by Jelvas Mwaura (KMFRI).

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Special appreciation goes to all the coral reef experts for reviewing the entire document and their inputs. The Coral reef Team at KMFRI and Reefolution provided all of the pictures used in the document.

Preamble

The Kenya Climate Change Adaptation Programme (KCCAP) is a National programme funded by the Adaptation Fund under the United Nations Framework Convention for Climate Change (UNFCCC). This integrated programme aim at building resilience and adaptive capacity to climate change of vulnerable communities in Kenya. Coast Development Authority is implementing the programme in Coast region, with the goal of increasing resilience to the effects of rise in sea level and shoreline changes through Integrated Shoreline and Mangrove Ecosystem Management. Coral reef conservation and protection is one of the key activities in the programme in the effort of rehabilitating the marine ecosystems.

Coral reefs have been called "tropical forests of the sea", with high productivity and biodiversity underpinning their strong economic and social values as sources of food, places for recreation and with recognition also of their importance as a reservoir of genetic resources. They provide shelter and food to numerous marine species in addition to other functions, including sediment stabilization. However, despite national and international efforts to conserve and mitigate threats to these ecosystems they are increasingly under threat. Threats include effects of, climate change (e.g. erratic and torrential rains which cause flooding and massive erosion/deposition), marine pollution (dumping of domestic and industrial waste), over exploitation of fisheries and other marine resources and unsustainable coastal development which leads to rapid degradation and loss of coral and sea grass habitats.

Conservation and management of coral reefs is important national issue to ensure that the ecosystems continuously provide the ecosystem services for present and future generations. In a bid to ensure this is achieved, Kenya Wildlife Service spearheaded the development of the National Coral Reefs and Seagrass Conservation Management Strategy (2015-2019). One of the objectives of the strategy is to secure, restore and maintain healthy and resilient coral reef and Sea grass ecosystems. The strategy provides for the development of coral reef restoration protocol, implementation, monitoring and evaluation of restoration activities.

This Protocol contains simple advice on coral reef rehabilitation for use by technical advisers and coastal and marine resource managers who may be involved and/or working with community-based marine management areas and, interested in undertaking reef restoration. Much of guidelines included are from reef restoration activities around the world and local experience gained during reef restoration research and community-based rehabilitation of reefs in Kenya.

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Final Draft

Table of Contents

List of Figures

List of Tables

Acronyms/Abbreviations

AF	Adaptation Fund
BMU	Beach Management Unit
CCA	Community Conserved Area
CDA	Coast Development Authority
EIA	Environmental Impact Assessment
GIS	Geographic Information System
GPS	Global Positioning System
ICZM	Integrated Coastal Zone Management
KCCAP	Kenya Climate Change Adaptation Programme
KMFRI	Kenya Marine & Fisheries Research Institute
KWS	Kenya Wildlife Service
M & E	Monitoring And Evaluation
MPA	Marine Protected Area
NCRRP	National Coral Reef Restoration Programme
NEMA	National Environment Management Authority
NGO	Non-Governmental Organization
PVC	Polyvinyl Chloride
SDF	State Department Of Fisheries
SDG	Sustainable Development Goals
UNFCCC	United Nations Framework Convention for Climate Change

Introduction

Coral reefs are among the ocean's most biologically diverse ecosystems in the world. These ecosystems provide numerous socio-economic, ecological, aesthetic, and cultural values e.g. fisheries, tourism, coastal protection. Importantly, they support the livelihoods of millions of people who directly or indirectly depend on them.

In Kenya, coral reefs form a continuous fringing reef system stretching from Malindi to Vanga area bordering Tanzania; and a discontinuous patchy reef system extending from Lamu northwards to the Somalia border. However, the health and ecological integrity of these critical marine ecosystems have declined due to global climate change and many local stresses caused by human activities and poor governance structures in natural resource management. Effects of climate change, such as increasing ocean temperatures, ocean acidification and sea level rise, are already affecting coral reefs. Other climate related stressors to coral reefs are possible shifting of ocean currents; rise in ultraviolet light concentration; and, increase in hurricanes and cyclonic storms, which may cause excessive flooding, silt deposition, and wave damage. Increased sea surface temperatures stress corals and cause coral bleaching, frequently with large-scale mortality, reduced reproductive capacity and increased vulnerability to coral diseases. Ocean acidification reduces the capacity of corals and other calcifying organisms to make calcium carbonate skeletons. This acidification may also increase the susceptibility of corals to bleaching during thermal stress. Local stressors to coral reef ecosystems are caused by rapid population growth resulting to land use changes, urbanization and unplanned settlement along the coastal areas. Major threats caused by poor governance include pollution from land-based activities; pollution from maritime activities; destructive fishing practices; overexploitation and destruction of marine natural resources; coral and sand mining; port dredging operations; oil and gas exploration and, unregulated tourism practices.

Figure 1: Degraded coral reef vs healthy coral reef (Source: REEFolution, 2017)

Conservation strategies that aim at stopping or reducing the causes of degradation to coral reefs should always come first. However, in the event that a coral reef has undergone extensive destruction, active management through reef restoration is one way of accelerating their recovery. Reef-building corals form an important framework on which other reef organisms can depend on. Restoration plan that aim at building back the coral framework will be effective since it will enable the re-colonization of other reef organisms as well, such as reef fish.

Coral gardening is a potentially effective management tool for restoring degraded coral reefs and increase resilience against global climate change. It entails the cultivation of corals for restoration purpose. This process bypasses early coral growth stages when they are mostly vulnerable and stabilize degraded rubble patches. Coral fragments are grown in nurseries then replanted on the identified degraded coral reef sites. Conservation organizations who manages marine protected areas, research and learning institutions, NGOs and local communities who live close to the reef and depend on coral reefs for their livelihood should spearhead large-scale coral reef restoration programmes.

Justification

Most conservation efforts were previously passive yet the problem of coral reef deterioration is still evident. However, due to large scale degradation of coral reefs, there is need to put into practice active management of degraded sites. Restoration of degraded ecosystems is one of the strategic adaptive management tools that can be adopted to enhance ecosystem recovery and improve resilience to climate change. Farming of corals for reef restoration as a management tool for degraded reefs is relatively new in Kenya and it is still in experimental stage. Currently, there is no standard restoration approach for degraded sites hence restoration interventions are site specific

It is on this basis that this coral reef restoration guideline was developed to guide the envisaged National Coral Reef Restoration Programme (NCRRP) targeting locally managed community conserved areas (CCA's), and other identified degraded coral reef ecosystems along the Kenyan coast. The guideline was developed in response to the need for information to conserve and manage coral reefs in Kenya through securing, restoring and maintaining healthy and resilient coral reefs through means such as transplantation in order to provide guidance that may be helpful for coral reef restoration activities in Kenya as stipulated in the Kenya National Coral Reefs and Sea Grass Beds Conservation and Management Strategy 2015-2019; and the Integrated Coastal Zone Management (ICZM) National Plan of Action (2011-2015). The steps highlighted and the methods described in this guideline were developed based on best practices and experiences from ongoing pilot coral reef restoration projects in Kenya. The coral reef restoration guidelines provide an opportunity for capacity building of local communities to improve their marine resource management skills and develop a sustainable coral nursery gardening and replanting program The protocol is also geared towards contributing to achieving the SDG goal 14 target 5 of having at least 10% of coastal and marine areas conserved by the year 2020

Objectives

The overall objective of this protocol is to provide guidelines for developing sustainable coral reef restoration programs that will help to achieve increase in coral cover, sustainable fisheries, reef resilience to climate change, and enhance shoreline protection and biodiversity conservation. The specific objectives are:

i. To provide an alternative technique for rehabilitation of degraded coral reefs areas
ii. To guide and improve capacity and participation of local communities in coral reef restoration
iii. To provide harmonized procedures for coral reef restoration in Kenya
iv. To increase coral reef restoration efforts in Kenya
v. To promote sharing and dissemination of knowledge and technology in the response to climate change

Ten Simple Steps for Coral Reef Restoration

A basic framework of a restoration plan as shown below can be useful to promote discussions and provide options for the development of an effective reef restoration project.

Step 1: Education and Awareness Creation

This stage aims at sensitizing the stakeholders and the public at large on coral reefs, its importance and threats. It is paramount to increase education and create awareness among stakeholders e.g. government agencies, boat operators, fishermen and hoteliers including the other local communities involved in the restoration activities to the success of the project.

1.1 Stakeholders mobilization and sensitization

Stakeholder mobilization and sensitization should be conducted through forums/barazas in order to raise awareness and increase knowledge on coral reefs. Stakeholder should be sensitized on chronic stress to corals arising from natural and anthropogenic threats, which include overfishing, destructive fishing practices, sewage pollution and bleaching events. There is evidence of widespread reef degradation in many areas along the coast; and recovery is unlikely or too slow without active intervention.

During these meetings, the importance and threats to coral reefs, as well as causes, prevention and mitigation measures of coral reef degradation should be identified. Area to be restored should be one where community have already identified and committed for conservation of marine resources.

Figure 2: Creating awareness to maximize enforcement of the coral restoration activities at Wasini village (Source: KMFRI)

1.2 Capacity building and Information Dissemination

Training and capacity building should be undertaken for the stakeholders at different levels so as to solicit their participation in planning, implementation and surveillance of the restored sites. This promotes ownership and sustainable use of the restored areas.. Awareness and information materials (e.g. Brochures, posters, press briefing etc.) on coral reef restoration should be produced and disseminated.

This stage also allows relevant stakeholders including the local community to establish goals and objectives of the project that must be clear, practical, achievable and address the ultimate objective of the project such as return of ecosystem's function or services.

Step 1 Output - Key stakeholders and local Community reach to a consensus on the need to participate in restoration activity. Goals and objectives of the intervention agreed upon.

Step 2: Identification of degraded reefs or area

2.1 Participatory mapping

Spatial mapping of coral reef ecosystem provides critical information to marine and coastal ecosystem management. Participatory mapping, which incorporates local participation to identify and develop spatial information, provides a means of engaging local resource users and stakeholders in data gathering and natural resource management. Participatory mapping using GPS is an appropriate tool to gather local knowledge regarding the location of coral reef sites, their health status and the threats affecting those sites.

2.2 Identify and stop causes of degradation

During the mapping exercise, the participants should identify the causes of degradation in each of the sites. This is important to ensure that as the restoration activities continue, human induced causes of degradation are eliminated.

2.3 Zonation

Zoning is system in which specific geographic areas are classified by providing guidance as to what can and cannot occur within sections of natural resource area with respect to its management, human use, resource use, visitor use, experience use, among other categories agreed upon by the stakeholders. Zonation allows stakeholders and resource users to set different goals to be achieved in different parts of natural resource areas which may include MPAs, community conserved areas and co - managed areas. Different conservation areas have different zonation schemes. MPAs have their zonation schemes outlined in their specific management plans.

This protocol has adopted a three tier zonation scheme that should be applied in the community conserved area and co-managed areas:

- *Coral Reef Restoration Zone*: This area should have restricted use to enable successful growth of coral nurseries and coral garden.
- *Resource Use Zone*: The resource use zones facilitate the integration of human activities and conservation goals with an aim of reducing resource use conflict.
- *The Ecotourism Zone*: Promote different types of visitor activities in different parts of the conservation area.

2.4 Prioritization

In order to implement effective coral reef management, specific actions should be taken at site-specific level to show tangible outcomes. Therefore, it is important to prioritize coral reef restoration sites based on baseline information derived from participatory mapping, ground truthing exercise, existing ecological assessment data and expert reviews.

The sites should be prioritized based on their ecological value, degree of threats to coral reefs, conservation viability and the potential for effective management by local communities. A table has been designed to facilitate the prioritization (see below). Each potential site to be restored is scored on several aspects. The site with the highest score will be most suitable for restoration. Ideally, the site chosen will have a score of 4 or higher. Depending on the scale and the status of management an Environmental Impact Assessment (EIA) should be conducted.

Table 1: Criteria for prioritizing sites for coral reef restoration

Criteria	*Site 1*	*Site 2*	*Etc.*
State (1 =healthy reef; 5 = severely degraded reef)			
Recovery (1 =natural recovery present; 5 = no recovery)			
History (1 = coral never present; 5 = dead or eroded coral present)			
Environment (1 = environmental conditions unsuitable; 5 = environmental conditions suitable). *E.g. depth, current*			
Human threats (1 = ongoing local degradation; 5 = no threats)			
Ecological threats (1 = high risk of ecological threats; 5 = no threats). *E.g. outbreaks of coral-predating animals*			
Physical threats (1 = high risk of physical threats; 5 = no threats). *E.g. storms, bleaching or sedimentation*			
Management (1 = no management possible; 5 = effective management possible)			
Local knowledge (1 = no restoration wanted; 5 = restoration highly desired)			
Expert review (1 = restoration not advised; 5 = restoration highly recommended)			
SUM OF SCORES			

Step 2 Output - Specific areas for restoration identified. Causes of degradation identified and stopped

Step 3: Baseline survey of the targeted area for restoration

Figure 3: Ecological baseline surveys at targeted restoration sites (REEFolution Foundation, 2017)

A baseline survey should be done to characterize the targeted area for restoration before any restoration activities are performed. This allows stakeholders to keep track of improvements and changes that are brought about by the restoration project. A permanent monitoring team should be installed consisting of members with sufficient ecological and scientific knowledge to perform the surveys. This monitoring team is responsible for the baseline survey as well as successive monitoring as described in step 10.

3.1 Fish abundance

A belt transect is used to count fish. To perform a belt transect, a snorkeler swims 50 meters along the reef and notes and counts all fish within 2.5 m on either side. A second snorkelers swims behind, lays out a tape measurer and gives a sign when the 50 meters are covered. The observed fish can be categorized in groups/ families, depending on the available knowledge. It is recommended to perform multiple (~ 5) belt transects in the area to be restored to get a good overview of the state of the area.

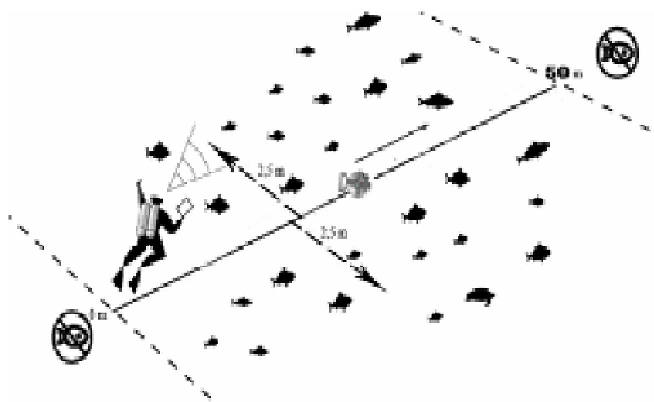


Figure 4: Point intercept transect layout (Source: English et al. 1997)

Materials needed:

- 50 meter tape measurer
- Snorkel equipment
- Slate and pencil

3.2 Benthic cover

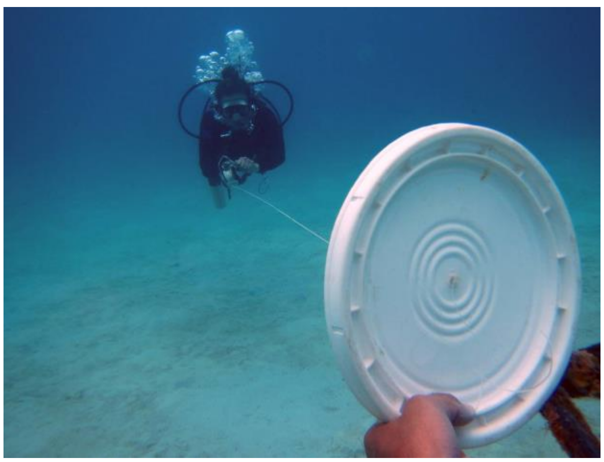
For MPAs, benthic survey should be conducted as described in the standardized ecological monitoring field manual for Kenya's conservation areas. For community

conserved areas, a point intercept transect is used to describe the seafloor. A 20-meter transect line is carefully laid out over the bottom. A snorkeler notes down the type of substrate directly below the line at every half a meter (so at meters = 0 – 0.5 – 1 – 1.5 up to 20). Commonly used categories of substrate include: sand, seagrass,
live hard coral, dead hard coral, coral rubble, soft coral, sponges and bare rock. It is recommended to perform multiple (~ 5) transects to get a good overview of the area.

Materials needed:

- 20 m tape measure
- Snorkel equipment
- Slate and pencil

3.3 Physical characteristics



To acquire a general description of the area to be restored, the following physical characteristics are described: depth, wave intensity, tidal currents, turbidity, salinity, nutrients and amount of sediments.

Figure 5: Measurement of environmental variables e.g. tidal currents and turbidity (Source: REEFolution Foundation, 2017)

3.4 Socio-economic status

In order to get an impression of the daily catches of fish before any restoration activities have been performed, a socio-economic survey is necessary. Local fishermen can be asked for a week about the amount and type of fish of their daily catches. Such surveys can be repeated several times before the restoration activities start to get an idea of the (seasonal) variation in catches. Besides, information should be gathered on other sources of income from the community conserved area, such as tourism. Lastly, the type and magnitude of threats to the coral reefs should be noted down.

Step 3 Output - Baseline report on fish abundance, benthic cover and socio-economic status

Step 4: Identification of coral species and the donor site(s)

The goal in this step is to minimize impact to the donor and maximize survivorship of coral fragments. Selection of coral species to transplant is critical because it is one of the major determinants of a successful restoration exercise. In order to maintain high diversity and prevent inbreeding, a diverse group of coral species with different growth forms should be collected. Donor sites are coral reef places where donor colonies or coral fragments, of the selected coral species for transplanting, can be obtained.

4.1 Selection of coral species

The decision on coral species should be based on logical process that considers the following:

- Coral species that are naturally occurring at the site proposed.
- Coral species that are known to have naturally occurred at the proposed site in the recent past.
- Coral species/genotypes that are tolerant to bleaching (reassembling novel coral communities that are resistant to bleaching)
- Coral species that exhibit phenotypic plasticity (reassembling novel coral communities that are robust to global change conditions)
- Coral species that are fast-growing and with branching growth forms- these may offer a speedy increase in coral cover and topographic complexity (caution: these tend to be more susceptible to bleaching, disease and coral predators).
- Coral species functioning as primary reef ecosystem engineers.
- Size of the area: the geographic areas from which coral fragments are chopped or collected should be large enough to ensure collection from a variety of different donor colonies or diverse species.

Figure 6: A possible expansive donor coral reef (Source: KMFRI and REEFolution Foundation, 2017)

4.2 Selection of donor sites

The decision on donor sites should be based on logical process that considers the following:

- Neighboring coral reefs that have a sufficient population size of the chosen species. This information can be obtained from literature review on coral communities assemblage patterns or by doing a manta tow survey
- A combination of species from neighboring reefs and distant reefs. This is a good strategy to mimic or to simulate a rare long-distance dispersal event.
- Donor sites should have similar physical characteristics to the proposed transplantation site.
- Important physical characteristics to be considered include: wave intensity, tidal currents, turbidity, depth, light intensity, salinity, nutrients and amount of sediments.

Step 4 Output - Coral species and donor sites identified

Step 5: Hands-on training for local community and other relevant stakeholders to participate in reef restoration

This stage involves training local community members and other key stakeholders such as resource managers on the importance of protecting coral reef and restoration of degraded reefs. The main objective of this stage is to build the capacity of key stakeholders and generate a pool of skilled personnel for effective and sustained coral reef restoration. Whilst environmental education and awareness on the threats facing coral reefs is important, proactive reef restoration is more inspiring particularly when it is undertaken in collaboration among fishers, government agencies, conservationists and researchers. A coral reef restoration project is a strong reminder that the future of our coral reefs is literally in the hands of the communities relying on reefs.

5.1 Restoration technique

Reef restoration is based on the coral gardening technique, which involves fundamentally two-steps:

- Firstly, coral fragments (nubbins) from donor colonies and broken/loose fragments are grown in nurseries until they attain sufficient large sizes.
- Secondly, the nursery grown corals are transplanted onto damaged reef areas or artificial reefs.

Coral gardening nurseries are used for growing corals in areas with high water quality conditions, so as to allow good survival and growth of propagated corals before they are placed onto degraded reef rock or artificial reef. Corals growing on these nursery conditions tend to grow 3-5 times faster than their natural counterparts and will survive in an extended range of physical conditions.

Figure 7: Coral gardening practices at Wasini Village. Left: preparing nursery disks in which coral fragments will be planted. Middle: Preparation for placement of coral nurseries. Right: Placement of coral nursery under water (Source: KMFRI 2014)

5.2 Capacity building

The workshop lectures and hands-on training will provide participating local communities with knowledge on all aspects involved in coral reef restoration including:

- Collecting coral of opportunity
- Transplanting them on nursery beds
- Maintain healthy nursery beds
- Transplanting them to degraded or artificial reefs
- Maintenance and monitoring operations after they have been outplanted

Figure 8: Restoration steps. Left: Coral fragment collection. Middle: coral fragment storage. Right: Coral fragment transportation to the storage site (Source: KMFRI 2014)

Figure 9: community participation in the nursery preparation and out planting of coral fragments on the degraded coral reef. (Source: KMFRI 2014)

Step 5 Output – Key stakeholders and the local community trained on all aspects of the restoration works

Step 6: Construction of nursery structures

A prerequisite for reef restoration is the construction of coral nurseries that will host large numbers of coral fragments, which can later be grown at the site to be restored. There are many different types of nursery designs that have been used. Here we describe two nursery methods that have been used successfully in Kenya.

6.1 Selection of nursery method

Active coral reef restoration is a time and energy consuming project and requires financial resources. The major question is what restoration technique results in the highest productivity and survival rates at low cost? There are many techniques of growing corals, many of which are cheap and easy to construct and maintain. Techniques for nursery raising of corals have advanced, but the basic principle is still the same: "secure broken corals so they will survive". The objective of a nursery is to secure corals safely into conditions that minimize the risk of damage from waves, shifting sediments and the possibility of being buried by sand. Today, we use a variety of stronger and more long-lasting materials to secure the corals. In this protocol we describe two types of nursery structures that have been successfully used in pilot coral reef restoration projects in Kenya: (1) nursery beds and (2) the Coral Tree. The nursery beds are more stable and therefore more suitable to use in more rough conditions. However, the lifespan of the nursery beds is short due to the corrosion of the steel. The nursery beds enable coral to be grown on cement discs, which greatly facilitates outplanting of the coral onto degraded reefs. The Coral Tree is much cheaper to construct and has a long life span but might be less suitable to using in rough conditions due to its many moveable parts. Coral fragments in the Coral Tree are grown in nylon loops, thus additional material is needed to outplant and secure these fragments onto degraded reefs.

Table 2: Construction Cost of Nursery Structures

Nursery type:	*Material costs*	*Construction time*	*Durability*
Coral Tree	~1500 KES (15 USD)	~5 man hours	~10 years
Nursery beds	~6000 KES (60 USD)	~5 man hours	~1 year

6.2 Construction of nursery structures

Depending on which nursery design has been chosen, follow the guidelines below for either option 1 or option 2 on how to construct the nursery structure. It is advised to construct your nursery structures nearby the nursery location, as this will reduce transportation costs and effort.

6.2. 1 Option 1: Nursery Bed

Figure 10: Trained community members assembling different parts to construct nursery cages. (Source: KMFRI 2014)

Constructing a nursery bed typically involves different types of metals/rods and mesh frames structures that are attached to form a frame nursery shown above. While the actual shape and size of the frames can vary, the basic design consists of a rigid or semi-rigid structure that keeps coral fragments away from the substrate.

- Unit construction: frames can be built in a variety of shapes, including a frame or domes.
- Anchoring device: the frame can be attached to the substrate using a variety of anchoring methods, including rebar or iron rods.
- Disc base attachment: disc base prepared can be attached to the frames using cable wires.

6.2.2 Option 2: Coral Tree

Step-by-step construction:

1. Gather the materials you need for the construction of the Coral Tree:
    - 1 x 1.2 m PVC pipe with a diameter of 5.1 cm/ 2 inch (the main trunk)
    - 6 x 1 m PVC pipe with a diameter of 1.3 cm/ 0.5 inch (the side branches)
    - Drill with a diameter of 1.3 cm
    - Drill with a diameter of 1 mm
    - Monofilament
    - Nylon rope
    - 80 cm Rubber hose
    - Scissors
2. In the main trunk, drill a hole of 1.3 cm at 10 cm below the top. Drill completely through the PVC pipe, so that you get a hole at both sides of the trunk.
3. Drill another two holes (1.3 cm diameter) 40 cm and 80 cm below the hole you drilled in step 2. Now you have drilled the holes for the first three branches.
4. Turn the main trunk 90° and drill another 1.3 cm hole 30 cm below the top.
5. Drill another two holes (1.3 cm diameter) 40 cm and 80 cm below the hole you drilled in step 4.

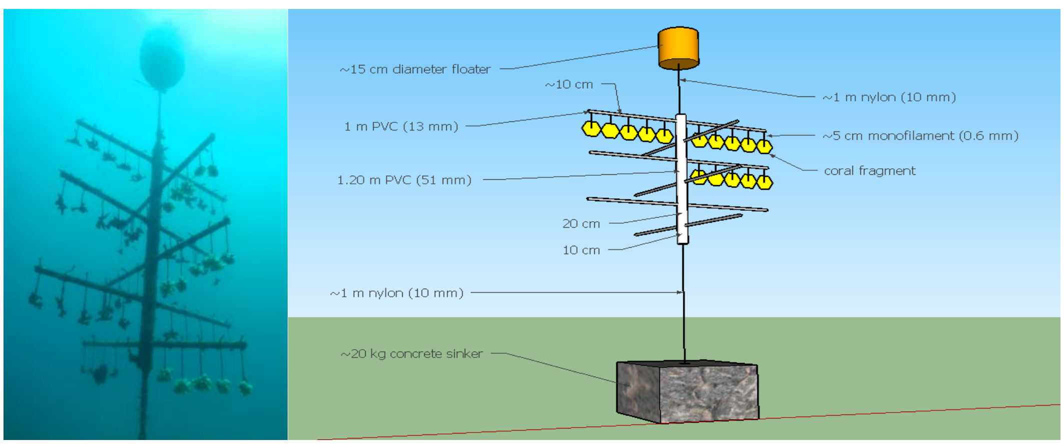


Figure 11: Depiction of a coral tree nursery (Source: REEFolution Foundation, 2017)

6. In the main trunk, drill a hole of 1.3 cm at 5 cm below the top and one at 5 cm from the bottom. These are the holes to attach the anchor and buoy to the Coral Tree.
7. In the side branch, drill a hole of 1 mm at the very end of the branch.
8. Drill a hole of 1 mm 10 cm further from the hole you drilled in step 7. Repeat this three times, until you have drilled 5 holes in total in the side branch.
9. Turn the side branch around and repeat steps 7 and 8 so that you end up with a total of 10 holes in the side branch.
10. Repeat step 7 till 9 until you have 6 side branches each with 10 holes.
11. Insert the six branches in the holes you drilled in the main trunk. Now the main frame is finished.
12. Cut 60 pieces of monofilament of ~30 cm.

13. From the 60 pieces of monofilament, create loops (the size of your finger) by knotting slip knots.
14. Put the long end of the loops through the 1 mm holes of the side branch and secure by knotting.

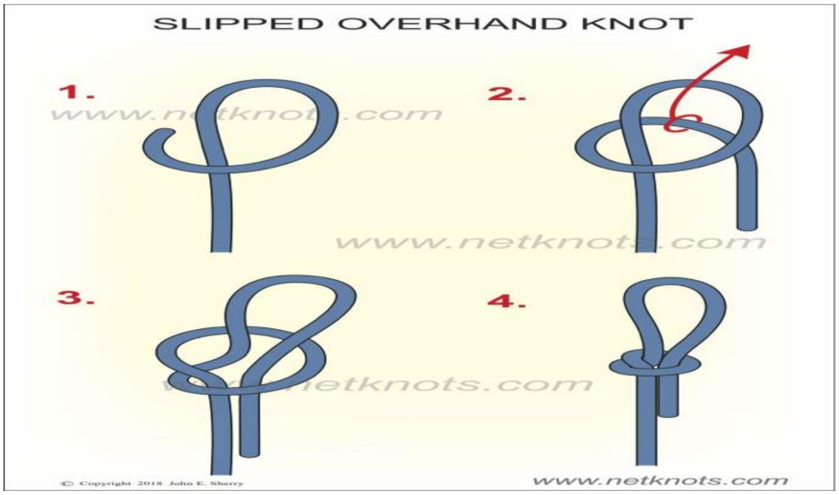


Figure 12: Illustration on how to tie a slipknot that is used to secure coral fragments to the tree nurseries (Source: www.netknots.com)

15. Cut a piece of 3 m nylon rope and burn the ends to prevent fraying.
16. Tie the nylon rope to the 20 L barrel and tie the other end to the top of the main trunk. Cover the nylon rope with a rubber hose (~20 cm) at the places were the loop is in contact with the main trunk to protect the rope from wearing.
17. Cut a piece of 4 m nylon rope and burn the ends.
18. Fill a 20 L barrel with cement together with a metal loop in the middle.
19. Tie the nylon rope to the anchor and tie the other end to the bottom of the main trunk. Use a slip knot to tie the rope. Cover the nylon rope with a rubber hose (~20 cm) at the places were the loop is in contact with either the metal loop of the anchor or the main trunk to protect the rope from wearing.
20. Now your Coral Tree is finished and can be placed and filled with coral fragments!

6.3 Site selection for nursery deployment

If you have ever been involved in securing coral fragments or coral gardening, then you know that it is not quite so simple as just attaching the corals, but the site where nursery is deployed has to be conducive for growth and survival. Generally, this means that the site must have good sunlight exposure levels (depth) and area with low or absent sedimentation, pollution and human activities such as boat anchorage. The nursery location should also be located close to the area to be restored, as this guarantees that the coral grown in the nurseries is already adjusted to the local conditions. Lastly, nursery structures should be placed in such a way that they will not damage the natural reef if detached or moved during rough weather.

6.4 Deployment of nursery structures

Nursery structures are placed in shallow waters to expose them to plenty of light for good growth, but not too shallow as this would result in bleaching. Advised depths range between 2 and 6 meters during low tide.

6.4.1 Option 1: Nursery Bed

Deployment of nursery beds is very simple: the structures are transported by boat to the right location and then lowered into the water.

- Facilitates anchoring, which is recommended if the nursery will be needed for more than four weeks.
- Attach wire mesh using the zip tie method with plastic electrical ties or low-grade steel wire.
- Screw anchors or steel rods are often used as temporary anchors because they are inexpensive, readily available, and screw into the seafloor easily. The anchoring of nurseries depends on the bottom type and the strength of waves and currents in the area. If the site is sand bottom, the cage nursery can be deployed and the legs secured on concrete blocks to enhance stability.

6.4.2 Option 2: Coral Tree

A concrete sinker is lowered from the boat onto the right spot. Then the Coral Tree is brought into the water, lowered (buoy filled with water) and attached to the sinker with nylon rope. Once attached, the buoy can be filled with air.

Step 6 Output – Functional nursery structures in place

Step 7: Translocation of coral fragments from donor to nursery beds

Translocation protocols need to be designed to reduce stress on the coral fragments and to increase the success (i.e., coral survivorship) of the relation efforts. The method of translocation should depend on the weather conditions, but in general coral fragments should be transported in large plastic bins.

Figure 13: Coral of opportunity collected by snorkelers or scuba divers (Source: REEFolution Foundation, 2017)

7.1 Collection of coral fragments

Based on the manta tow performed during stage 4, a site is selected for the collection of coral. Ideally loose and detached fragments (corals of opportunity) are collected, as these would otherwise die soon. If such fragments are scarce, it can be chosen to collect coral pieces from natural colonies. It is highly recommended that not more than 10% of natural colonies should be pruned to reduce the chances of negative impacts on the parent coral. Wear surgical gloves during the collection of coral to reduce damage to the coral fragments. If the donor site is close to the nursery site, coral can be transported submerged in seawater. Otherwise, coral fragments should be placed in shaded, water-filled buckets on the deck as they should not be exposed to air or sunlight.

Figure 14: Engaging communities in collection of thousands of opportunistic fragments and handling of the coral species collected (Source: KMFRI 2014)

7.3 Filling nursery structures

Now that a diverse collection of fragments has been gathered, the coral can be placed in the nursery structures. Only use completely healthy fragments to fill your nursery structures. Large fragments can be cut into smaller (2 - 5 cm) fragments to increase the number of nursery structures that can be filled from the collected coral. When you are spacing the coral fragments, ensure that no colonies are touching and allow for the growth or shifting of colonies, depending upon the length of expected nursery stay. Secured coral fragments are grown out for 6 - 12 months. Once larger and more likely to survive, nursery grown corals are outplanted to degraded reef or concrete blocks.

<u>7.3.1 Option 1: Nursery Beds</u>

This stage involves the planting or placing of coral fragments onto table structure, which serves as a coral nursery. Attach the coral fragment to base disc prepared to ensure permanent attachment. The base discs are small palm-sized balls prepared by mixing one part of Portland cement, four parts of sand and water and poring the mixture into PVC moulds. The PVC moulds are made by cutting plastic bottles. A 200 mm cable tie is incorporated into each concrete base while still wet. The cable tie will allow convenient attachment of the bases to the substrate after transplantation.

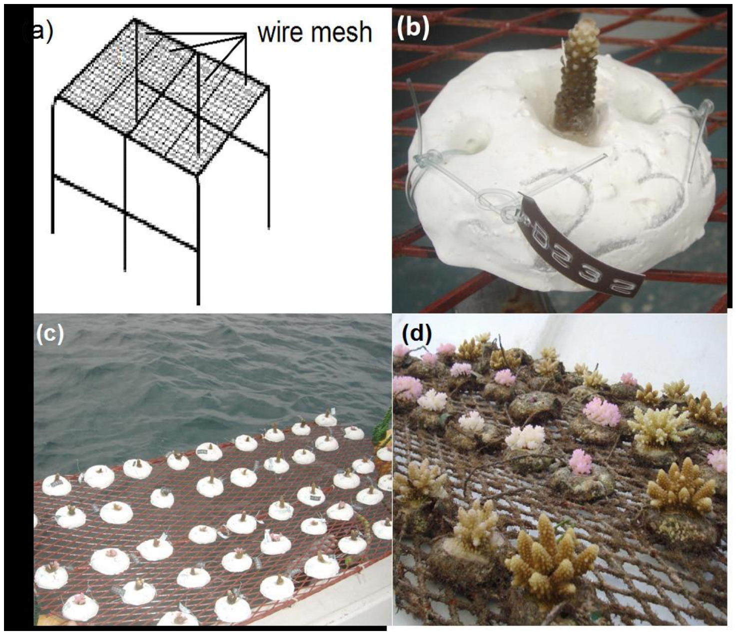


Figure 15: a) diagram of a nursery cage, b) coral fragment attached to a labeled cement disk and secured to the wire mesh grid with cable wires, c) fragments prior to deployment and d) coral fragments at the end of the experiment (Source: KMFRI 2014)

7.3.2 Option 2: Coral Tree

To fill a Coral Tree nursery structure, coral fragments can simply be hung in the loops: place the fragment inside the loop and slip the knot tight.

7.4 Storage of species collected

In case too many coral fragments have been collected and cannot be transplanted into the nursery on the same day, the coral fragments have to be stored. The coral fragments should be stored in the sea, raised from the sediment, or otherwise in land-based tanks with good recirculation.

Step 7 Output - Healthy coral fragment translocated to nursery structures

Step 8: Regular monitoring of nursery-grown coral fragments

Generally, reef restoration is an expensive exercise and requires a high amount of regular checks and maintenance.

8.1 Measuring growth, survival and health of coral fragments

It is important to regularly (~monthly) check your nursery structures to see if the corals are still performing well. Survival of coral fragments can be scored and their general health status (such as diseased, bleached) can be recorded. Dead coral fragments should be removed and replaced.

If available, an underwater camera can be used to take photographs at regular intervals to track coral growth. Alternatively, coral growth can be monitored by estimating the length of fragments on a monthly basis.

Figure 16: Underwater measurements of coral growth (Source: REEFolution Foundation, 2017)

8.2 Cleaning of coral fragments

Cleaning of the nursery structures will improve coral growth and survival. When first stocked, the corals in the nursery require cleaning once a week for the first 3 months and later in the coral growth cycle, cleaning of algal overgrowth is reduced fortnightly or monthly. Using a soft brush, algae should be removed around the coral fragments. This should be done very carefully to avoid stressing the coral fragments

Also, removal of coral predators such as gastropods and echinoderms within the nursery should be done to ensure survival of coral fragments. There is also need to remove fowling algae, sediments and other debris that could interfere with the growth of coral fragments.

Figure 17: Algal removal from coral tree nursery to ensure optimal coral growth and survival (Source: REEFolution Foundation, 2018)

Step 8 Output – Healthy coral fragments ready for transplanting and a growth and survival database.

Step 9: Transplanting of nursery-grown corals to degraded or artificial reefs

After about 3-12 months, depending on health of the fragments, survival and growth rate, the healthier corals are securely fixed on the bare substrate of degraded reefs or onto artificial reefs. It is important to time outplanting during a benign time of the year in order to reduce stress for the outplanted fragments. Indigenous knowledge on the best season should be used, but as a general rule outplanting can best be done between June and October, as to avoid bleaching during the hot months (January - March) and excessive runoff during the long rains (April – May and November - December). Depending on the exposure of the area to be restored, it can be less rough weather during either *Kaskazi* or *Kusi* and it will be best to plan outplanting during the calm period to reduce detachment of fragments. The size of coral fragments that are ready for outplanting depends on the coral genera used, but as a rule of thumb massive corals of 5 – 10 cm are ready for outplanting and branching coral fragments of 10 – 15 are sufficiently large for outplanting. Self-attachment of the corals onto underlying substrate typically takes 1-2 months; this process can be aided by ensuring sufficient contact between live coral tissue and reef substrate.

Option 1: marine cement
The transplanted corals are pressed against marine cement-mould placed on bare substrate and after few minutes they will be able to be firmly attached on bare substrate. Alternatively, coral can be placed using the cement on artificial reefs made of concrete blocks.

Option 2: nails and cable wire
Coral can be attached to bare degraded reef using large (6 inch) nails and cable wires. Nails are hammered into stable calcium carbonate rock in areas denuded of hard corals (about 6 m depth) with little algal cover. The nursery-grown coral is then attached to the nails using cable wires. Alternatively, coral can be placed using the cable wires on artificial reefs made of steel.

Figure 18: Transplanted corals on natural hard substrate and concrete blocks, attached using marine cement (Source: KMFRI 2014)

Step 9 Output- Restored coral reefs established

Step 10: Monitoring and maintenance of transplanted corals

Monitoring and evaluation will form an important tool for both success and failure of rehabilitation process so as to allow adaptive management if things do not go according to plan. The frequency should be higher in the initial months and should reduce after positive results have been achieved over time.

The monitoring should be made simple so that it can be easily adapted by the community. The monitoring team established for the baseline survey in step 3 is also responsible for successive monitoring, as to reduce the variability in data collection. Frequency of more detailed scientific monitoring such as measurement of individual coral colony growth and nutrients levels, although highly recommended, can be have a lower frequency since it does not contribute directly to restoration success although it may ultimately contribute to a better understanding of reef restoration activity and thus better adaptive management of future restoration projects

10.1 Measuring growth and survival of out-planted corals

To see whether transplanted corals are performing well, monitoring continues after transplantation. Out-planted corals can be scored on their survival and health status (alive, bleached, diseased or dead).

If available, an underwater camera can be used to take photographs at regular intervals to record the recovery of the reef. Alternatively, coral growth can be monitored by estimating the length of fragments on a regular basis.

10.2 Cleaning of coral fragments

Cleaning the areas around the out-planted corals should be done at the initial stages (fortnightly ~2 times) until when coral colonies have successfully affixed on the substrate and can be left to grow on their own without further assistance. Small paint brushes are used to remove algae and other organisms settling around the coral disc base

Figure 19: Trained community member removing algae around the coral disc base (Source: KMFRI 2014)

10.3 Ecological monitoring (corals, invertebrates, fish, sea grass etc)

To assess whether the goals of your restoration activities have been achieved, ecological monitoring is continued. The protocols used for the baseline survey (stage 3) are repeated. To track changes in fish abundance and composition, the belt transect is repeated 6, 12 and 24 months after the first corals have been transplanted. Similarly, the point intercept transect is repeated after 6, 12 and 24 months.

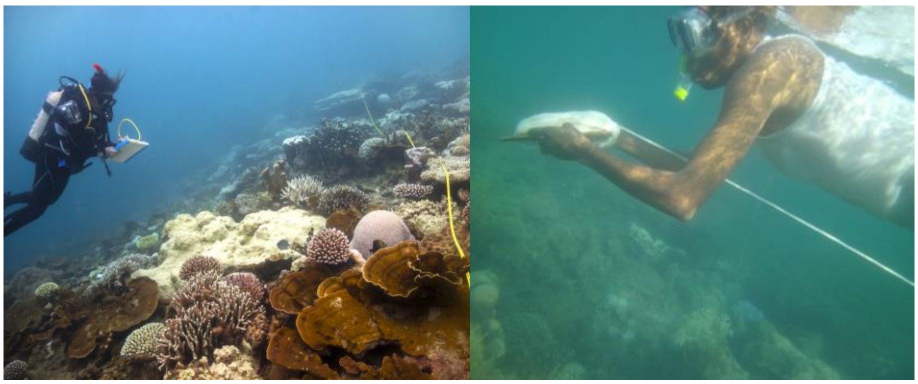


Figure 20: Monitoring of ecological variables of the restored sites (Source: REEFolution Foundation and KMFRI, 2017)

10.4 Socio-economic monitoring

To see whether the local community is benefitting from the restoration activities, also the socio-economic monitoring is continued. As during the baseline survey, local fishermen can be asked for a week about the amount and type of fish of their daily catches. Such surveys can be repeated in time to monitor long-term changes. In addition, improved livelihood conditions due to the restoration efforts (such as increased tourism or environmental awareness) are recorded.

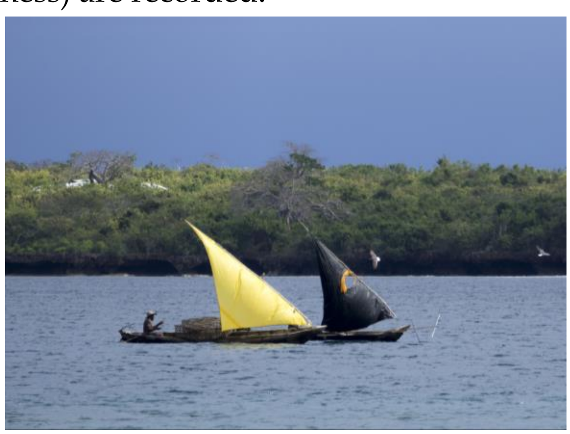


Figure 21: Monitoring socio-economics of the local communities depending on the coral reefs (Source: KMFRI 2014)

Step 10 Output – M & E report

- National coral reef restoration protocol
- Commencement of coral restoration in several sites
- Key stakeholders trained in reef restoration activities
- Increased coral coverage, fish abundance, fishing activity and tourism in the CCAs

Activity matrix and resources required for coral reef restoration

Table 3: Activity matrix and resources required for coral reefs restoration

Steps	Activity	Output	Indicator	Participants	Resources Required
Step 1: Education and Awareness Creation	1.1 Community mobilization and sensitization	• Local Community and key stakeholders reach to a consensus on the need to participate in restoration	• No. of meetings • Minutes of the meetings • No. of reports • Pictorials/video	• CBOs e.g. BMUs • General public • Govt institutions e.g. Fisheries dept., KWS, KMFRI, CDA • NGOs e.g. REEFolution Foundation, CORDIO EA, WCS • Local Adm. at both national and county level	• Technical personnel • • Stationeries • Refreshments • Transport
	1.2 Capacity building and Information Dissemination	• Restoration goals and objectives agreed upon.	• No. of meetings • Minutes of the meetings • Pictorials/video • No. of reports	• CBOs • Govt institution • NGOs • Local Adm.	• Technical personnel • Stationeries • Refreshments • Transport
Step 2: Identification of degraded reefs or area	2.1 Participatory mapping	• Specific degraded area mapped	• A report and • GPS map of degraded area	• • CBOs • Govt institution • NGOs • Local Adm.	• Technical personnel • Stationeries • Refreshments • Transport • Boat • GPS • Diving equipment • Underwater survey equipment (Camera, slates, tape measures etc)
	2.2 Identify and stop causes of degradation	• Causes of degradation identified			
	2.3 Zonation	• Restoration area zoned			
	2.4 Prioritization	• Area for intervention prioritized	• No. of areas to be restored		
Step 3: Baseline survey of the targeted area for restoration	3.1 Fish abundance data 3.2 Benthic cover data 3.3 Physical characteristics data	• Baseline data on fish abundance, benthic cover and socio-economic determined	• Baseline survey report	• CBOs reps • Govt institution • NGOs	• Technical personnel • Stationeries • Refreshments

	3.4 Socio-economic data			• Local Adm.	• Transport • Boat • Diving equipment • GPS • Underwater survey equipment
Step 4: Identification of coral species and the donor site(s)	4.1 Selection of coral species	• Coral species identified	• No. of coral species identified	• CBOs reps • Govt institution • NGOs • Local Adm.	• Technical personnel • Stationeries • Refreshments • Transport • Boat • Diving equipment • Underwater survey equipment • Identification sheets
	4.2 Selection of donor sites	• Coral donor sites identified	• No. of donor sites identified		
Step 5: Hands-on training for community to participate in reef restoration	5.1 Restoration technique	• Community trained on all aspects of the restoration works	• Restoration technique for the area identified	• CBOs reps • Govt institution • NGOs • Local Adm.	• Technical personnel • Stationeries • Refreshments • Transport • Demonstration materials • Boat
	5.2 Capacity building		• No. of reports on training		
Step 6: Construction of nursery beds and concrete blocks	6.1 Selection of nursery method	• Functional nursery structures in place	• Type of nurseries in place	• CBOs reps • Govt institution • NGOs • Local Adm.	• Technical personnel • Stationeries • Refreshments • Transport • Construction material • Boat • Diving equipment
	6.2 Construction of nursery structures	• Option 1: Nursery Bed • Option 2: Coral Tree	• No. of nurseries in place		
	6.3 Site selection for nursery deployment	• Nursery site selected			
	6.4 Deployment of nursery structures	• Option 1: Nursery Bed • Option 2: Coral Tree			
Step 7: Translocation of coral fragments from donor to nursery beds	7.1 Collection of coral fragments	• Healthy coral fragment translocated to nursery structures	• No. of coral fragments collected and translocated to the nurseries	• CBOs reps • Govt institution • NGOs • Local Adm.	• Technical personnel • Stationeries • Refreshments • Transport • Construction materials • Boat
	7.2 Filling nursery structures	• Option 1: Nursery Beds • Option 2: Coral Tree			
	7.3 Storage of species	• Storage method			

	collected	adopted/used			• Diving equipment • Underwater survey equipment
Step 8: Regular monitoring of nursery-grown coral fragments	8.1 Measuring growth, survival and health of coral fragments 8.2 Cleaning of coral fragments	• Healthy coral fragments ready for transplanting and a growth and survival database.	• Survival data • Growth data • Coral condition data	• CBOs reps • Technical personnel	• Technical personnel • Stationeries • Refreshments • Boat • Diving equipment • • Underwater survey equipment
Step 9: Transplanting of nursery-grown corals to degraded or artificial reefs	9.1 Option 1: marine cement 9.2 Option 2: nails and cable wire	• Restored coral reefs established	• No. of coral fragment transplanted • Acreage of the transplanted area	• CBOs reps • Technical personnel	• Technical personnel • Stationeries • Refreshments • Transport • Construction materials • Boat • Diving equipment • Underwater survey equipment
Step 10: Monitoring and maintenance of transplanted corals	10.1 Measuring growth and survival of out-planted corals 10.2 Cleaning of coral fragments 10.3 Ecological monitoring (corals, invertebrates, fish, sea grass etc) 10.4 Socio-economic monitoring	• Community-based reef restoration protocol • Commencement of coral restoration in several CCAs • Community members trained in reef restoration activities • Increased coral coverage in the CCAs, biodiversity and fisheries	• Maintenance schedule/plan • M&E report	• Technical personnel • CBOs reps	• Technical personnel • Stationeries • Refreshments • Boat • Diving equipment • Underwater survey equipment

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