# Scaling Coral Reef Restoration in Climate-Stressed Island Systems:

# Optimizing Nursery Time for *Acropora* Species

# in Coral Restoration in Mafia Island, Tanzania

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**Abstract:**

Coral restoration typically involves growing coral fragments in underwater nurseries before transferring them to damaged reefs. This research examined whether Acropora corals need this nursery period, and whether shortening it could provide a more efficient approach to reef restoration. This question is important because coral nurseries require considerable time, labor, materials, and funding, which can limit the scale of restoration programs, particularly those led by local communities with limited resources. Although previous research has examined factors affecting coral survival and growth, less is known about how long corals need to remain in a nursery before being transplanted. Working with the Ropes of Hope coral restoration program in Mafia Island Marine Park, Tanzania, a field experiment was designed comparing freshly fragmented corals with corals assigned to separate one-month and two-month nursery treatments. The experiment included four *Acropora* species, with approximately 30 fragments per treatment, and a photographic method was developed to consistently monitor the plots over time. The fieldwork showed that translating an experimental design into a working community restoration program presents important practical challenges. Coral availability made it difficult to create equal treatment groups, while differences in the starting size and condition of freshly fragmented and nursery-grown corals could affect later comparisons. The next stage of research is to continue monitoring the established plots to determine whether shorter nursery periods can achieve comparable restoration outcomes and potentially reduce the resources required for community-based coral restoration.

## Central Question

Does limiting or omitting the nursery phase affect coral survival and growth compared with the traditional two-step nursery-based coral gardening approach?

## Introduction

This experiment investigates whether the amount of time coral fragments spend in a nursery after fragmentation affects their survival and growth after being outplanted. The study focuses on four species of *Acropora*, with one *Pocillopora* species included as a comparison group within the Ropes of Hope restoration site. Specifically, the experiment compares freshly fragmented corals with fragments that have spent different amounts of time recovering in a nursery before being outplanted. By looking at different nursery periods, the goal is to determine whether the nursery phase can be shortened or skipped without significantly affecting coral survival and growth.

This question is important because coral gardening normally follows a two-step process: corals are first grown in a nursery and then moved to a restoration site. While this approach has been widely used, there is much less research specifically looking at how much nursery time is actually necessary. Most existing research focuses on improving nursery conditions rather than asking whether the nursery stage itself can be shortened or removed. There is also limited research addressing this question within community-led restoration programs in the Western Indian Ocean (WIO). The study compares *Acropora* fragments with different nursery histories, while also recording differences in fragment size and condition that could influence restoration outcomes. Freshly fragmented corals are compared with fragments that have had time to recover in the nursery before being outplanted. Survival, attachment success, and early growth are used to compare the different treatments and look for differences among species. It is hypothesized that *Acropora* fragments given time to recover in a nursery before transplantation will have higher survival, attachment success, and growth than fragments that are directly outplanted after fragmentation. The null hypothesis is that there will be no significant difference in survival, attachment success, or growth between nursery-reared and directly transplanted fragments.

## Significance

Coral restoration is becoming increasingly important as reefs experience more frequent bleaching, warming oceans, and other human-driven pressures. However, successful restoration is not just about keeping corals alive. The amount of time, labor, and resources required to grow and maintain those corals also affects how much restoration a community-based program can realistically carry out. Traditional coral gardening requires coral fragments to be maintained in a nursery before they are outplanted onto degraded reefs. This gives fragments time to recover and grow, but also requires additional space, materials, maintenance, and monitoring. If some *Acropora* species can survive and grow after a shorter recovery period, there may be an opportunity to reduce some of these demands. On the other hand, if nursery time improves survival, then the additional effort may be worthwhile.

Coral reefs are closely linked to the livelihoods and wellbeing of many island communities. Successful restoration can help support reef fisheries and food security, protect biodiversity and healthy reef ecosystems, maintain tourism and other reef-based livelihoods, reduce coastal exposure by supporting reef structure, and create local skills, employment and stewardship through community-led restoration. This issue is especially relevant in the WIO, where community-based restoration is becoming more common but resources for long-term monitoring and maintenance can be limited. By looking specifically at nursery residence time, this project addresses a practical gap in coral restoration research. More broadly, it asks how restoration methods can be adjusted so that they are not only biologically effective, but also realistic for communities to maintain and expand.

## Background

Coral restoration efforts have utilized coral gardening as a technique to propagate coral fragments in nursery systems before they are transplanted onto degraded reefs. However, practitioners are increasingly finding that for some species the nursery phase can be shortened or even skipped, while others may still benefit from nursery conditioning. The approach developed from Rinkevich's "gardening concept" and has been particularly useful for propagating fast-growing branching corals such as *Acropora* (Rinkevich 2005; Shafir, Van Rijn, and Rinkevich 2006). More recent research has focused on making restoration more efficient and

scalable as the need for active reef restoration continues to increase (Levy, Ripple, and Winters 2018).

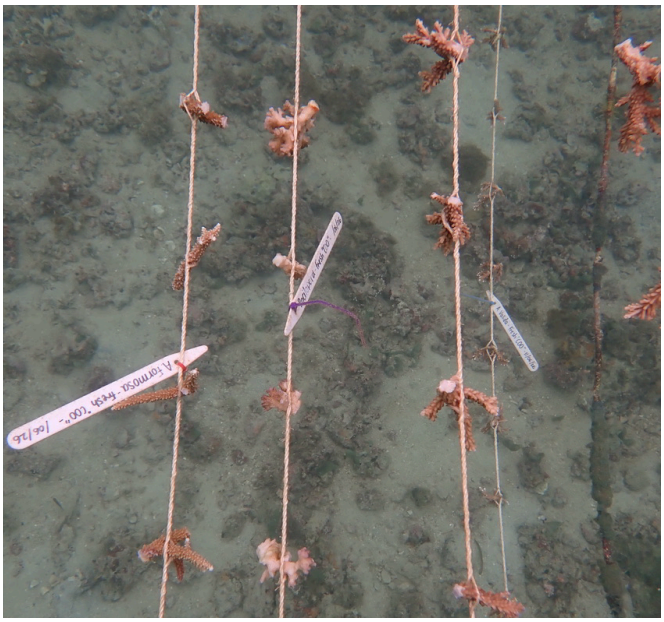

***Figure 1. Acropora fragments growing on nursery ropes at the Ropes of Hope coral nursery in Mafia Island Marine Park, Tanzania.***

Previous studies have shown that coral survival and growth can be affected by several factors, including species, genotype, fragment size, attachment method, nursery structure, and outplanting technique (Goergen, Ostroff, and Gilliam 2017; Ware *et al.* 2020). However, much less attention has been given to nursery residence time itself. Although nursery recovery is commonly incorporated into coral gardening, it is not clear whether every coral species requires the same amount of time in a nursery before being outplanted. This is particularly important for community-led restoration programs, where nursery maintenance requires time, labor, and materials.

The 2025 Ropes of Hope trials provided the starting point for the present study. Those experiments looked at whether fragment size and time spent in the nursery affected coral survival and growth on Diamond Mesh Fencing (DMF) substrate. Freshly fragmented and nursery-reared corals were compared across different size classes and genera, including *Acropora* and *Pocillopora*. The results suggested that smaller, freshly fragmented *Acropora* fragments had

lower survival, while larger fragments and several non-*Acropora* corals showed more consistent survival. A second trial expanded the comparison to additional coral genera and again examined freshly fragmented and nursery-reared corals across different size classes and replicated diamond mesh fencing plots. These observations suggested that *Acropora*, particularly staghorn forms, may be more sensitive to direct outplanting and fragment size than some of the other corals tested. They also indicated that responses to fragmentation and nursery recovery were not the same across all coral groups.

This current 2026 study builds on those observations by focusing specifically on selected *Acropora* species and treating nursery residence time as the main variable being tested. Rather than simply comparing freshly fragmented and nursery-reared corals, the study compares freshly fragmented corals with separate one-month and two-month nursery treatments to better understand whether a shorter nursery period can provide similar early survival, attachment, and growth after outplanting.

## My Role and Approach

My role in this project was to work alongside Teddy Lugeye, a Tanzanian masters student at the University of Dar es Salaam, under the direction of Dr. Jean de Villiers, to develop a feasible and replicable field experiment testing whether the nursery phase could be shortened or omitted for *Acropora* corals. I contributed to the experimental design, establishment of the treatment plots, coral outplanting, and development of the photographic monitoring method. As part of this, I independently researched and designed a custom camera rig for standardized underwater photography, sourced the materials, found and worked with a welder in a local village on Mafia Island to fabricate it, and personally funded its construction. Working within an active community restoration program also meant adapting both the experimental design and monitoring system to the coral fragments, nursery stock, materials, and field conditions available at the time.

## Methodology

The fieldwork was conducted as part of the Ropes of Hope coral restoration program in Mafia Island Marine Park, Tanzania. Coral preparation and nursery work took place at the Ropes of

Hope nursery off Chole Island, while the experimental plots were established at the Kitutia (KT) site. The study examined how nursery residence time affects coral restoration outcomes, while also recording differences in fragment size and condition that could influence comparisons between treatments.

A consistent method for monitoring the experimental plots was also developed. Four *Acropora* species were included: *A. humilis*, *A. austera*, *A. valida*, and *A. muricata*. *Pocillopora* was included as an additional comparison group. Coral fragments were sourced from existing nursery stock and naturally occurring donor colonies and grouped according to nursery history, including freshly fragmented, one-month, and two-month treatments. Approximately 30 fragments per species and treatment were targeted, although the number available varied between treatments. Experimental plots were established as 1 m x 1 m areas at the KT site and labeled according to species and treatment.

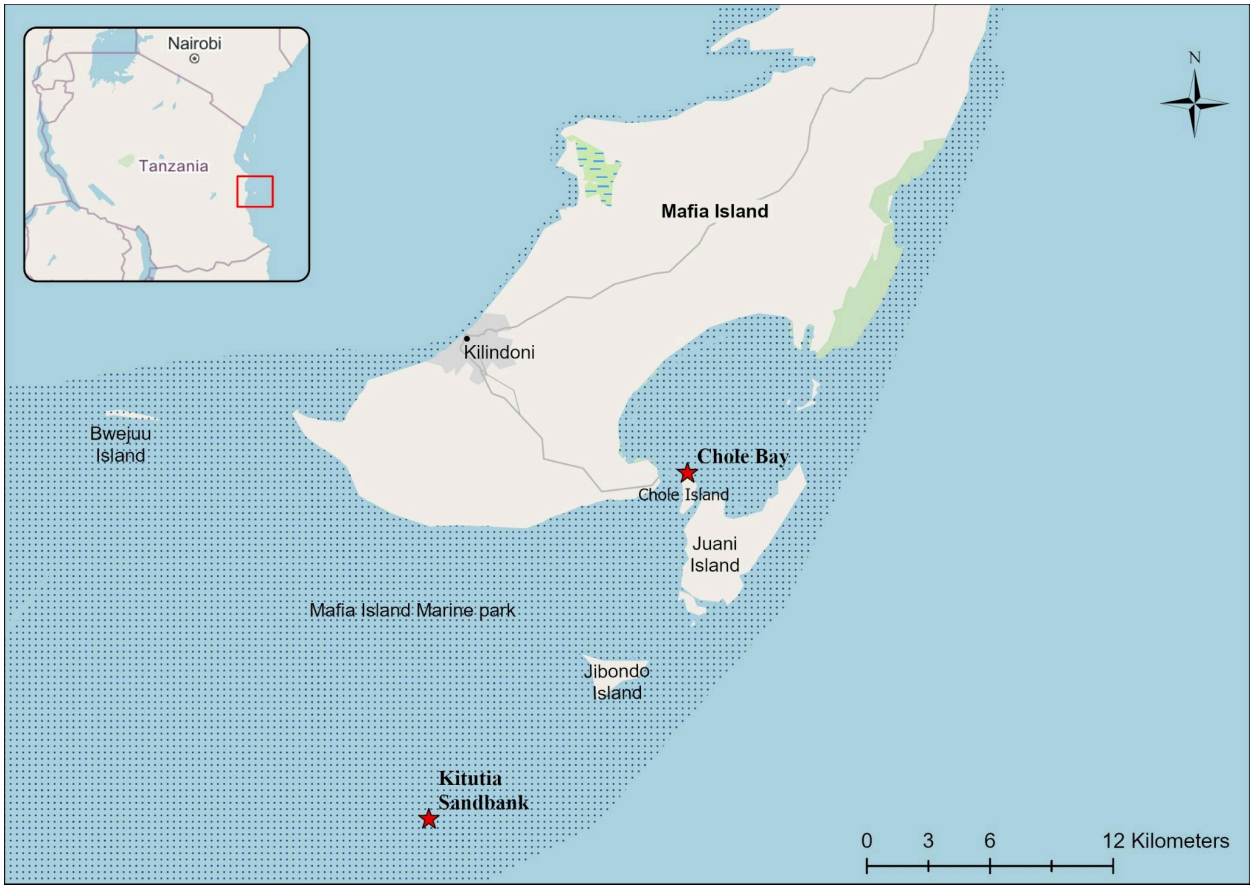


***Figure 2. Study area in Mafia Island Marine Park, Tanzania, showing the Kitutia experimental site and Chole control site***

*Figure 3. Sorting and preparing coral fragments for the nursery-time experiment with the Ropes of Hope team.*

ORIENTATION:

1m

shallow side

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1m | O2 | M3 | Q2 | M1 | n1 | O1 | S2 |
| 2 | C2 | d2 | A3 | h1 | E2 | f2 | A1 |
| ORIENTATI 3 | Q1 | j2 | S1 | b3 | n3 | d3 | Q3 |
| 4 | K2 | l2 | f3 | d1 | A2 | b2 | t3 |
| 5 | r3 | S3 | t2 | l1 | f1 | K1 | C1 |
| 6 | E1 | j1 | G1 | l1 | p3 | r1 | b1 |
| 7 | t1 | p2 | r2 | G2 | h2 | E3 | l3 |
| 8 | C3 | O3 | l2 | p1 | M2 | n2 | G3 |
| 9 | empty | empty | empty | j3 | K3 | l3 | h3 |

June 2026

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Control *Pocilopora* Planted: | A | Pocilopora 2 months nursery | *Acropora muricata* Planted: | I | Muricata 2 months nursery | *Acropora austeria* Planted: | Q | Austeria 2 months nursery |
| | b | Pocilopora 1 month nursery | | j | Muricata 1 month nursery | | r | Austeria 1 month nursery |
| | C | Pocilopora large fresh | | K | Muricata large fresh | | S | Austeria large fresh |
| | d | Pocilopora small fresh | | l | Muricata small fresh | | t | Austeria small fresh |
| *Acropora humilis* Planted: | E | Humilis 2 months nursery | *Acropora valida* Planted: | M | Valida 2 months nursery | | | |
| | f | Humilis 1 month nursery | | n | Valida 1 month nursery | | | |
| | G | Humilis large fresh | | O | Valida big fresh | | | |
| | h | Humilis small fresh | | p | Valida small fresh | | | |

*Figure 4. Experimental plot layout showing the distribution of coral fragments by species, nursery treatment, and fragment size.*

Fragments were attached to the restoration structures using cable ties. Following outplanting, survival, condition, and growth were monitored. Underwater photography was also tested as a way to create a consistent record of the experimental plots. An Olympus underwater camera was mounted on a custom-built stand so that images could be taken from the same position during monitoring. Initial testing showed that photographing an entire 1 m x 1 m plot from one position caused parts of the plot to appear blurry because the autofocus focused on the closest coral tips. Different camera positions and multiple images per plot were therefore tested to improve image quality. Other challenges, including uneven plot surfaces, differences in fragment availability, and difficulty positioning the camera stand without disturbing the corals, were recorded throughout the fieldwork. These observations were used to improve the monitoring approach and develop a method that could be continued by the Ropes of Hope team.

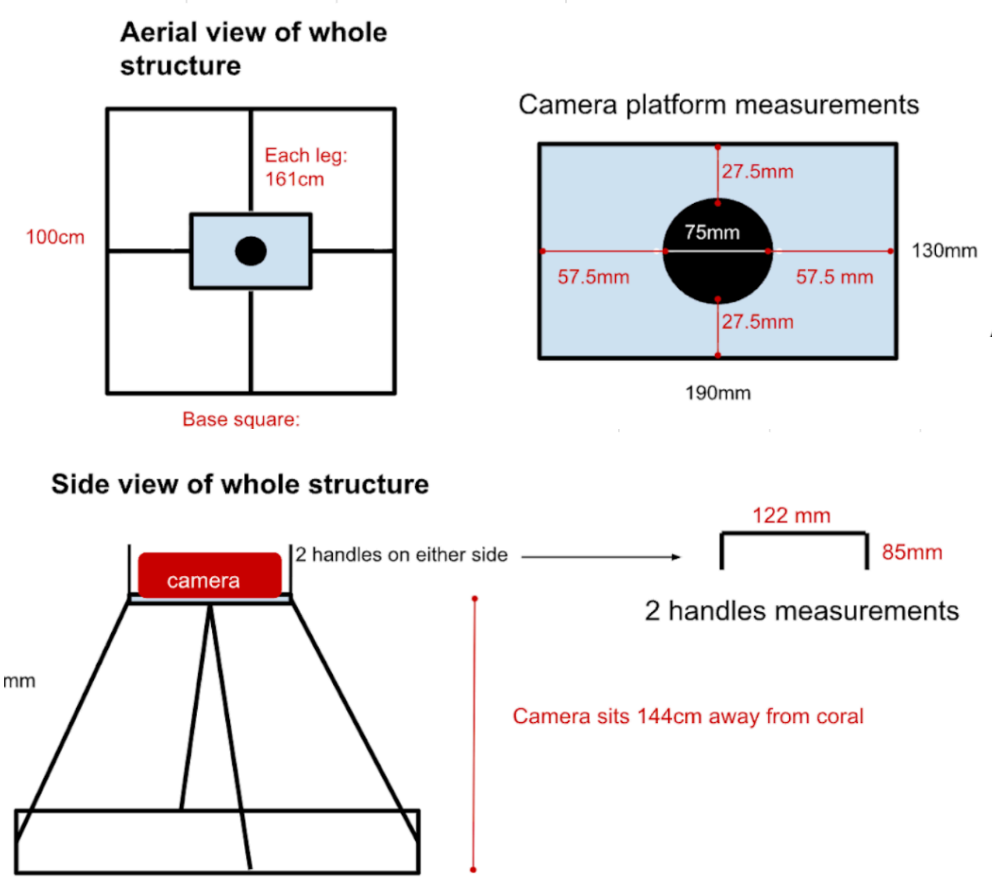


***Figure 5. Diagram of custom-designed camera stand.***

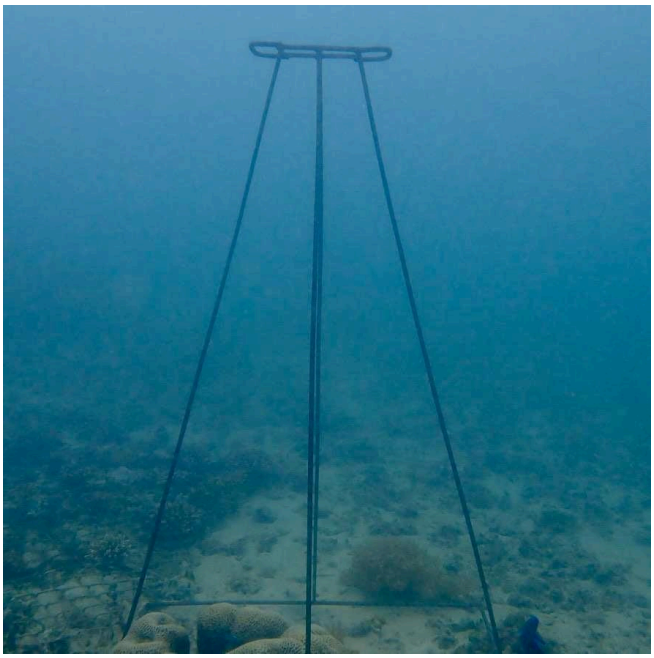

*Figure 6. Custom-designed camera stand for standardized underwater photography of experimental plots.*

*Figure 7. Outplanting coral fragments onto Diamond Mesh Fencing at the Kitutia experimental site, Mafia Island Marine Park.*

## Findings and Field Insights

The fieldwork showed that nursery time cannot be considered in isolation, because fragment size, condition, and species may also influence restoration outcomes. One of the biggest challenges was getting the same number of fragments for every species and nursery treatment. This showed one of the differences between designing an experiment on paper and carrying it out within an active restoration program, where the availability of corals cannot always be controlled.

It also became clear that freshly fragmented and nursery-grown corals are not necessarily directly comparable. Nursery-grown fragments have had additional time to grow and recover, so they may differ in both size and condition when they are eventually outplanted. This made it important to keep track of fragment size and nursery history rather than assuming that all fragments began the experiment in the same condition.

The photography process also highlighted some challenges with the monitoring method. The original plan was to photograph the entire 1 m x 1 m plot from a single position, but the first images showed that the camera's autofocus focused on the closest coral tips while other parts of the plot were blurry. Testing different positions and taking multiple images of each plot produced a more useful approach for documenting the corals and could eventually support photogrammetry-based measurements.

Overall, the fieldwork showed that a good restoration experiment needs to be practical as well as scientifically controlled. The short field period did not allow for conclusions about long-term differences in coral survival or growth, but it did provide a starting point for continued monitoring. It also helped identify changes that could make future data collection more consistent and useful for the Ropes of Hope team.

## Limitations

This study had several limitations that affected how the results can be interpreted. The biggest limitation was the length of the field period. Because the study only covered the early stages of the experiment, long-term survival and growth could not be evaluated. The availability of coral fragments also made it difficult to keep the treatments equal. Not enough fragments were

available for every species and nursery period, which meant that some groups had fewer individuals than others. Unequal sample sizes make direct comparisons between some treatments more difficult. Fragment size and condition were another limitation. Corals that had spent time in the nursery had additional time to grow and recover compared with freshly fragmented corals. As a result, any differences between the groups could not necessarily be attributed only to nursery residence time. Differences between plots, including uneven substrate and positioning, may have also affected individual corals.

The underwater photography method was still being developed during the study. The first images were affected by autofocus, which caused the closest coral tips to be in focus while other areas were blurry. The camera stand was also difficult to position consistently over uneven surfaces. Multiple images and different camera positions were tested to improve the quality of the photographs, but the method will need further refinement before it can be used as a fully standardized long-term monitoring system. Finally, the experiment was carried out at one restoration site and over a relatively short period. Because of this, the findings should not be assumed to apply to all *Acropora* species, coral restoration programs, or environmental conditions. Instead, the study provides a starting point for longer-term monitoring and future experiments.

### Implications and Next Steps

This project suggests that nursery time is worth looking at more closely rather than automatically treating it as a fixed part of coral gardening. The differences seen in fragment availability, size, and condition showed how many factors can affect a restoration experiment before the corals are even outplanted. Understanding how long different *Acropora* species actually need to recover could help make nursery practices more targeted instead of using the same timeline for every coral. The most important next step is to continue monitoring the experimental plots. Since the fieldwork only captured the early stages of the experiment, longer-term data will be needed to see whether differences between the treatments continue or disappear over time. Continued monitoring by Ropes of Hope would also allow the photographic methods developed during the project to be tested and improved.

Future experiments could test additional nursery periods to identify more precisely how much recovery time different *Acropora* species require before outplanting. For example, several shorter recovery periods could be tested to find out when additional time in the nursery stops making a noticeable difference. These experiments could also be separated by species and fragment size since different *Acropora* species may respond differently to fragmentation and outplanting.

In the long term, the results could help Ropes of Hope develop a restoration approach that considers species, fragment size, and nursery duration together. If shorter nursery periods result in similar survival and growth, reducing nursery time could lower the labor, space, and resources required to restore larger reef areas. If longer nursery periods lead to better survival, then the additional time and effort may be justified. Either outcome would provide useful information for deciding how nursery resources can be used most effectively and how community-based coral restoration can be expanded in a way that is both practical and sustainable.

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