

REEFOLUTION KENYA

- A CORAL RESTORATION PROJECT IN SOUTHEAST KENYA

Annual report Jan 2023 – Jan 2024



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Summary

The project aimed to set up a reef restoration model project following the coral gardening concept. In this concept small fragments of coral were cultured in the field on specific culture frames. Once sufficient in size, the young corals were outplaced on degraded reef areas, for example parts of coral reefs that have been damaged due to blast fishing. In this way, the recovery of such damaged sites can be jump-started. Additionally, we aimed to build additional reef areas, by outplacing cultured coral fragments onto artificial substrates that are positioned in areas with no natural reef development. By creating new reef areas, we aimed to enhance local fish stocks. This will increase opportunities for local fishermen as well as opportunities for dive tourism. In this way, the project aimed to stimulate local development.

BACKGROUND OF THE PROJECT

The East African coast has the second longest fringing reef in the world, stretching from the coast of Somalia along Kenya to southern Tanzania. A large part of these coastal reefs is situated in Kenyan waters where they support artisanal fishing and tourism industries. As most African countries, Kenya faces a fast-growing population. Limited awareness of coastal ecology and low commitment to sustainable practices has had an increasingly detrimental impact on coastal ecosystems such as mangrove forests and coral reefs. Blast fishing using dynamite or fertilizer bombs and unsustainable tourism have caused serious damage to coral reefs in Kenya [1]. Although Kenyan authorities have effectively banned blast fishing, the consequences of blast fishing activities in the recent past are still visible on many of the Kenyan coral reefs (Fig 1). In addition, increased pressure on the coral reef fish stocks due to increased fisheries following human population growth is an ongoing threat to the coral reef ecosystem. These negative aspects can be counter balanced by initiatives that stimulate more sustainable use of the coral reefs. To improve coral reef quality in Kenya, active coral reef restoration can be considered. Active coral reef restoration has been implemented successfully in several countries such as the Seychelles [2], the Philippines [3] and the US [4]. In 2016, a local entrepreneur in Shimoni (Pilli Pipa Dhow Safaris Ltd) commenced an initiative to actively restore damaged coral reefs and to create new coral reef areas in the coastal zone in Southeast Kenya (Fig. 2). This initiative, that has been supported from the start by Eric Stokman (founder of the REEFolution Foundation), aims to improve the quality of natural reefs, thus preserving natural heritage and stimulating possibilities for dive tourism, and to develop new fish enhancement zones around the coastal villages, thus establishing more opportunities for fisheries. The purpose of the current document is to provide an overview of the scientific support to this local initiative for the year 2023.

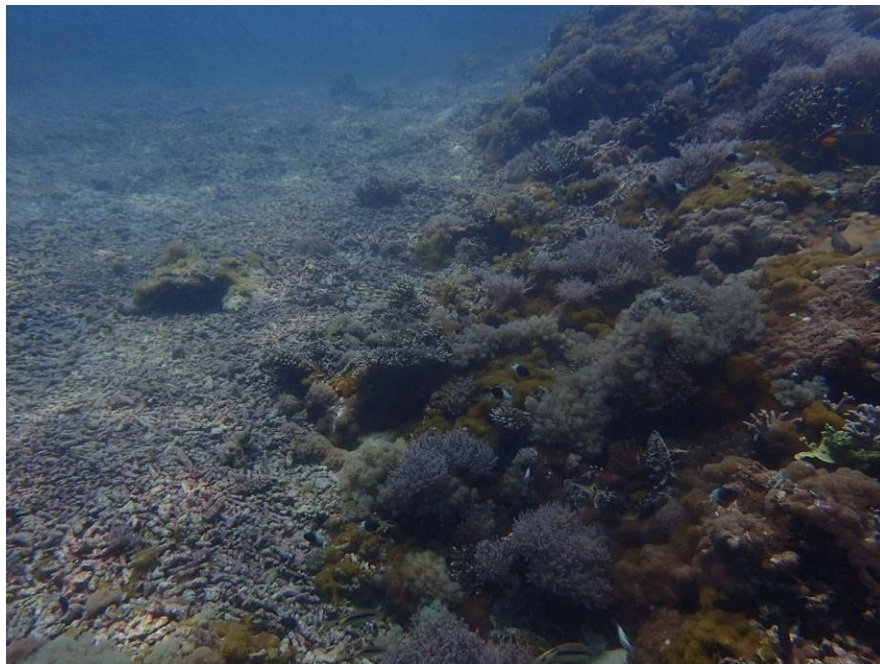


Figure 1. Degraded reef in Kenya. The part of the reef on the left-hand side of the picture is severely damaged by blast fishing.

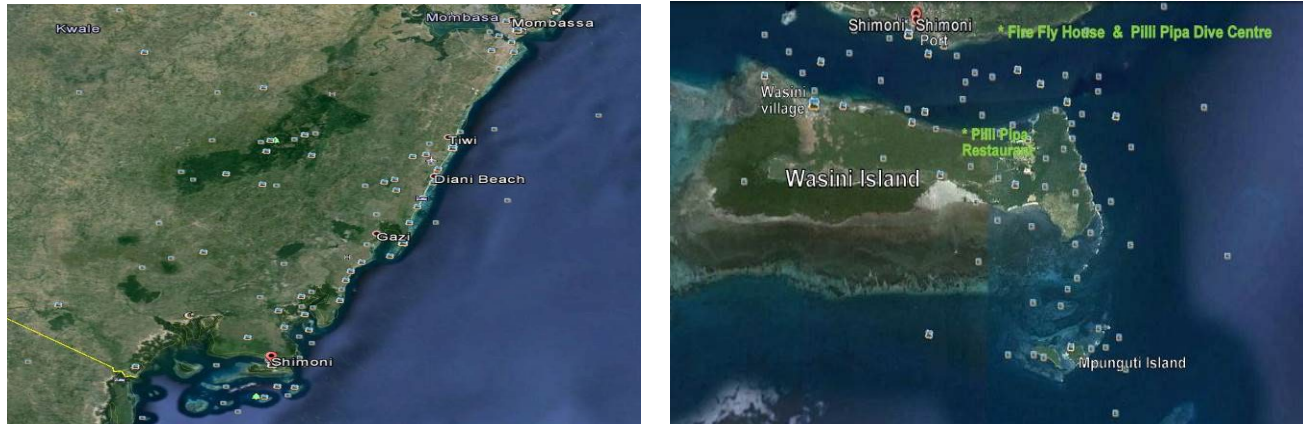


Figure 2. Targeted study area. Left: Southeast coast of Kenya. Right: Wasini Channel between Wasini Island and Shimoni

OUTLINE AND OBJECTIVES OF THE PROJECT

Stony corals (Phylum: Cnidaria; Order: Scleractinia) form the fundament of coral reef ecosystems. Many of these corals host symbiotic microalgae and are the main primary producers (i.e. the engines) on the reef. Because stony corals build a hard, stony skeleton, they create large three-dimensional structures that are home to thousands of species of fish and invertebrates. As such, corals reefs are among the most biodiverse and productive marine ecosystems on the planet. This makes corals reefs an interesting target for both tourism and fisheries. Since stony corals are the main building blocks of coral reefs, methods to produce stony corals form the backbone of active coral reef restoration projects. Currently, the most commonly applied concept for active coral reef restoration is the so-called “coral gardening” concept [5]. Coral gardening refers to a two-step procedure: first, corals are being aquacultured in nurseries; second, the cultured corals are being outplanted onto natural substrates in the field. In this way, degraded reef areas are jump-started to enhance their recovery.

The current project in Shimoni is based upon this “coral gardening” concept. With the help of volunteers, Pili Pipa Dhow Safaris has placed the first coral nurseries in the field in autumn 2015 to test different nursery types and different nursery locations. These studies revealed that a location just opposite the Pili Pipa restaurant on northern Wasini Island (Fig. 2B) was the most suitable compromise between culture success and logistic accessibility. Two out of three culture methods tested proved suitable for further experimenting and upscaling: the coral tree methods that was adopted from the Coral Reef Foundation in the Caribbean (Fig. 3) and the table method (Fig. 3). Also, a series of artificial substrates termed “bottle reefs” (Fig. 4) was positioned in the Wasini Channel in spring 2016, in order to create the first artificial coral reef in this area.



Figure 3. Culture methods successfully applied in Shimoni. Left: Coral tree. Right: Coral table.



Figure 4. Bottle reef: a concrete structure holding 16 glass bottles that are used to hold corals.

Wageningen University and Pwani University intend to provide scientific support to this initiative. Supervised by tenured staff, master students from the two universities executed thesis projects that has contributed to the following objectives:

1. Increase our understanding of the ecology of the area
2. Optimisation of methods to aquaculture different species of coral
3. Optimisation of methods to outplant the cultured corals
4. Creation of artificial coral reefs in the Wasini Channel
5. Upscaling of the methods for aquaculture and outplacement
6. Monitoring of the activities
7. Outreach and education
8. Our understanding of public perception of projects such as this
9. Training and knowledge transfer to local communities

In the year 2023, a series of four subprojects were performed within this set of objectives. These subprojects are described below.

PROJECT EXECUTION

SUBPROJECT 1: Effects of grazers and predators on coral culture success

Ecological work within this project primarily focused on grazing. Grazing animals are essential for the health of a coral reef ecosystem [6]. In the absence of herbivores, corals are often overgrown by macroalgae, in particular under conditions with relatively high availability of inorganic nutrients. Two main categories of herbivores on coral reefs are fish and bottom-dwelling organisms such as sea urchins. Opposite to herbivorous grazing, corallivory (i.e. predation on corals) can affect corals negatively. Corallivorous fish such as parrotfish, butterflyfish and triggerfish take bites out of living corals and are believed to have a net beneficial effect on reefs, because their bite marks create empty substrate for new coral recruits to settle and develop. However, their predation on corals in culture may decrease culture success by slowing down growth. Other predators, such as the snail *Drupella* sp. and the sea star *Acanthaster planci* can have devastating effects on coral reefs, since massive outbreaks of these predators sometimes occur. Whereas effects of herbivory and corallivory have been extensively studied for natural reefs, effects of these processes on corals in aquaculture remain virtually unknown. In Subproject 1, four aspects of grazing have been studied within the following results:

Identifying the main grazers and predators in the nursery area. By positioning underwater cameras in the vicinity of the experimental coral trees, we obtained footage of herbivory that allowed us to identify the main grazing fish species in the area and quantify their grazing activities (i.e. count bites). These video observations were complemented with direct visual observations on grazing and on distribution of reef fish in general and by quantifying the amount of algae growing on the structures representing the different treatments. Also, bites marks of corallivorous fish were quantified. A scientific paper titled “**Fisheries restrictions and their cascading effects on herbivore abundance and macroalgae removal at Kenyan coral reefs**” has been published in the [Journal of Experimental Marine Biology and Ecology](#). The main findings were that macroalgae consumption was significantly higher in protected areas and dominated by a few species from diverse functional groups. These results indicate that fishing restrictions are likely to support reef resilience by increasing herbivorous fish biomass of key species and thereby promote macroalgae removal. We also published a paper titled “**Coral predation and implications for restoration of Kenyan reefs: The effects of site selection, coral species and fisheries management**” in the [same journal](#). The main findings were that most coral predation was experienced by corals with a branching growth form, especially when just outplanted for restoration purposes, reducing their survival.

SUBPROJECT 2: First upscaling of nurseries

The coral trees have been identified as the best technique for early upscaling of the nursery capacity. Since 2019, we aimed to install at least a hundred culture trees in the Wasini Channel, each hosting 60 coral fragments. Activities in 2023 included preparation and positioning of the trees, collection of coral broodstock, positioning of fragments in the trees and regular (i.e. monthly) cleaning of the structures. This work also included the training of local communities and students in order to ensure future embedding of the

restoration project within the local constraints. Important in Subproject 2 is that a proper administration system is set up in order to separate different genotypes of the different species in culture. Having different genotypes is essential to prevent that later outplacement will result in a monoclonal culture, thus diminishing the potential for sexual reproduction on the restored reefs. Up to 2023, we managed to upscale the nursery and have now nearly 300 nursery structures holding over 17,000 coral fragments of around 30 different branching species. For the coming year, we plan to confirm the species identities using genetic work as well as identify the different genotypes present in the nursery through the collaboration with Pwani University.

SUBPROJECT 3: Monitoring of growth in relation to environmental variables and time

In order to rapidly obtain large amounts of coral materials for replantation on degraded reef areas, it is essential to strive for optimal growth of the corals in the aquacultures. Growth of coral fragments on experimental structures were analysed by determining the size of the corals as Ecological Volume (EV) [7]. This non-invasive method can be applied repeatedly to monitor coral size over time. EV has already been measured regularly since the start of the project on series of the four initially selected coral species (*A. formosa*, *P. cylindrica*, *P. meandrina* and *M. tenera*). New, experimental culture trees were placed at different depths to find the best light regime for coral growth. The Wasini Channel is characterized by a relatively high turbidity. On the growth kinetics a student report has been written titled: **“The impact of thermal stress on coral nurseries placed across a depth gradient”** in which it was shown that the optimal depth was species specific. For example, the species *Acropora verweyi* attained optimal growing conditions at shallow depth, even during a marine heatwave. In contrast, *Pocillopora verrucosa* preferred deeper depths, likely due to this thermal anomaly. These findings highlight the importance of nursery placement for coral growth and survival and show that depth preference is species-specific. Advice provided in this study could be used for future restoration projects.

SUBPROJECT 4: Outplacement of corals on artificial reefs

Monitoring of reef restoration efforts and artificial reefs (ARs) has typically been limited to coral fragment survival, hampering evaluation of broader objectives such as ecosystem recovery. This subproject aimed to determine to what extent AR design influences the ecological recovery of restored reefs by monitoring outplanted coral fragments, benthic cover, coral recruitment and fish and invertebrate communities for two years. Four AR designs (16 m²), unrestored controls and natural reef patches as reference (n = 10) were established in Mkwiro Community Managed Area. ARs consisted either of concrete disks with bottles, layered concrete disks, metal cages or a combination thereof. A mixture of 18 branching coral species (mainly *Acropora* spp.) was outplanted on ARs at a density of 7 corals m⁻². The results of this study titled **“Community-managed coral reef restoration in southern Kenya initiates reef recovery using various artificial reef designs”** was published in the journal [Frontiers in Marine Science](#). We found that after two years, 60% of all outplanted fragments had survived, already resulting in coral cover on most ARs comparable (though *Acropora*-dominated) to reference patches. Coral survival differed between ARs, with highest survival on cages due to the absence of crown-of-thorns sea star predation on this design. In total, 32 coral genera recruited on ARs and recruit densities were highest on reference patches, moderate on concrete ARs and low on cages. ARs and reference patches featured nearly twice the fish species richness and around an order of magnitude higher fish abundance and biomass compared to control patches. Fish abundance and

biomass strongly correlated with coral cover on ARs. AR, reference and control patches all had distinct fish species compositions, but AR and reference patches were similar in terms of trophic structure of their fish communities. Motile invertebrates including gastropods, sea urchins, sea cucumbers and sea stars were present at ARs, but generally more abundant and diverse at natural reference patches. Taken together, all studied ecological parameters progressed towards reef ecosystem recovery, with varying influences of AR design and material. We recommend a combination of metal cages and layered concrete ARs to promote high fragment survival as well as natural coral recruitment. Ultimately, a longer period of monitoring is needed to fully determine the effectiveness reef restoration as conservation tool to support coral reef ecosystem recovery.

RESEACHERS INVOLVED AND THEIR ROLES IN THE PROJECT

Students from both Wageningen University and Pwani University were involved in the activities.

On behalf of Wageningen University, the following people were involved:

Dr Ronald Osinga, assistant professor, PI of the project (available for the entire project duration)

Ewout Knoester, external PhD candidate, local supervisor

On behalf of Pwani University the following people were involved:

Dr Sammy Wambua, researcher and lecturer

On behalf of Pilli Pipa Dhow Safaris Ltd the following people were involved:

Harm Lutjeboer, dive instructor (available for the entire project duration)

Yatin Patel, dive instructor

In Table 1, the assignment of the different master students to the different subprojects is outlined.

Table 1. Overview of tasks and researchers assigned to the tasks.

Subproject	Responsible researcher
1. Grazing – Task 1: identification of grazers	Veerle Plug, Ewout Knoester
1. Grazing – Task 2: identification of predators	Nienke Klerks, Sofia Kolkman, Ewout Knoester
2. Upscaling	Ewout Knoester
3. Growth monitoring	Kristina Hrelja, Ewout Knoester
4. Restoration monitoring	Jelle Rienstra, Quirijn Schurmann, Anne Wolma, Ewout Knoester

PROJECT BUDGET AND FUNDING

The project was funded through the following sources:

Wageningen University:	5.000 US\$
REEFolution Foundation:	10.000 US\$
Total:	<u>15.000</u> US\$

Costs:

Diving and boating:	11.000 US\$
Restoration materials:	900 US\$
Aquaculture materials:	1.300 US\$
Experimental structures:	1.700 US\$
Total:	<u>15.000</u> US\$

References

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- [3] Edwards & Gomez (2007). Reef Restoration Concepts and Guidelines: making sensible management choices in the face of uncertainty. Coral Reef Targeted Research & Capacity Building for Management Programme: St Lucia, Australia. 38 pp.
- [4] <https://coralrestoration.org> (official site of the Coral Reef Foundation).
- [5] Epstein et al. (2001). Strategies for gardening denuded reef areas: the applicability of using different types of coral material for reef restoration. Restoration Ecology 9: 432–442.
- [6] Mumby et al. (2006). Fishing, Trophic Cascades, and the Process of Grazing on Coral Reefs. Science 311 (5757): 98-101.
- [7] Shafir et al. (2006). Steps in the construction of underwater coral nursery, an essential component in reef restoration acts. Marine Biology 149: 679–687.