REEF RESTORATION PROGRAMME

JOALI

WHY ARE CORAL REEFS IMPORTANT?

Coral reefs are large, living calcium carbonate structures located between 20° north and south of the equator. They cover less than 0.1% of the ocean floor and are home to approximately 25% of all marine life. Coral reefs are highly valuable tropical marine ecosystems and are known as the rainforests of the sea for their high diversity of marine flora and fauna (Xin et al, 2016). Coral reefs are exceptionally important to tropical island nations and provide a number of ecosystem services, including, but not limited to, coastal protection, sand production, fisheries and food security, and tourism (Hoegh-Guldberg, et al., 2007). Coral reefs have become a main attraction for eco-tourists, with eco-tourism operators gaining revenue from tourists participating in scuba diving, snorkeling, reef restoration sponsorship and activities, as well as from hotels and businesses and their offered activities close to these reefs (Lee et al., 2017).

Globally, approximately 850 million people live within 100km of the coast, over 275 million live in the direct vicinity of coral reefs (within 30km of the reef and 10km of the coast), with over 200 million living along coastlines less than 5m above sea level (http://www.reefresilience.org/coral-reefs/reefs-and-resilience/value-of-reefs/). It is estimated that at least 500 million people rely on coral reefs for food, coastal protection and livelihoods. According to a 2008 Conservation International report the total net benefit of the World's coral reefs is $29.8 billion; between $5.7 billion and $6.8 billion for fisheries, $9 billion for coastal protection; $5 billion for biodiversity and $9.6 billion for tourism and recreation. Over 350 million people visit coral reef coasts each year as tourists (http://oceanwealth.org/ecosystem-services/recreation-tourism/). In the Maldives the tourism industry directly benefits from the coral reefs that make up the islands and their surroundings. Many people visit the Maldives to dive and snorkel, to see marine megafauna such as whale sharks and mantas.

JRRP
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Reef Restoration Programme

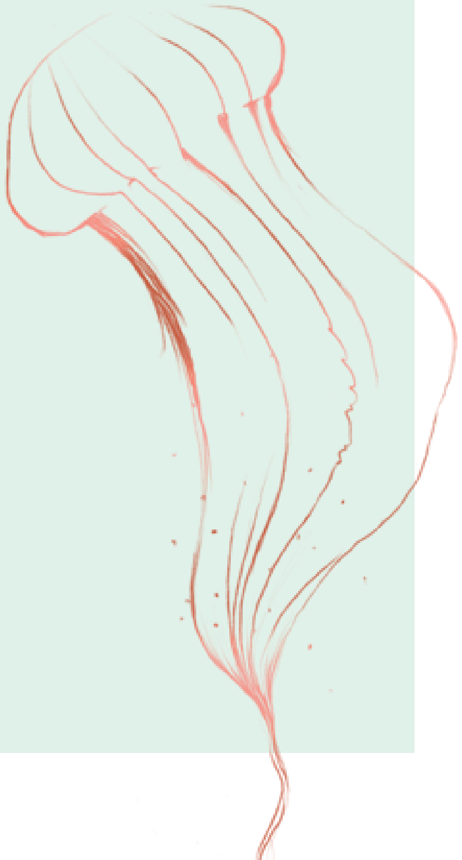
JOALI
— MALDIVES —

MALDIVES GEOGRAPHIC LOCATION

The Maldives archipelago is located south-southwest of India in the Western Indian Ocean. The country is made up of approximately 1190 coral islands grouped in a double chain of 26 atolls, stretching ~1000km long and ~100km wide. The Maldives is part of submerged mountain range that extends from the Lacaadives (Lakshadweep) in the north to the Chagos Islands in the south. The average size of the islands are only one or two square kilometers and sit, on average, at 1.5m above sea level. The low-lying islands make the Maldives the flattest country on earth and particularly vulnerable to rising sea levels. The coral reefs of the Maldives are incredibly important to the nation as a form of coastal protection, for food security as well as providing a source of income, directly and indirectly, through tourism activities.

PREVIOUS BLEACHING EVENTS IN MALDIVES

Between 2014 and 2017 coral reefs around the globe suffered the worst coral bleaching event in history. This was due to the year-to-year changes associated with the El Niño Southern Oscillation, combined with unprecedented increases in sea surface temperature caused by anthropogenic-induced climate change (Guardian, 2018; Change 2016; Cai, et al., 2014). This global bleaching event had a huge impact on the reefs across the Maldives archipelago. After the 1998 mass bleaching event, the coral reefs experienced high levels of mortality, with live coral cover decreasing from 42% to just 2% (Edwards, et al., 2001). It took a total of 12 years for the reefs to recover to pre-bleaching levels after the 1998 event. After the 2016 mass bleaching event coral cover in the Maldives was 6.9% directly after the bleaching and declined to 2.1% by March 2017 likely due to disease and predation by Drupella sp., Acanthaster planci and Culcita schmideliana (Pisapia, et al., 2016). It is expected that we will experience similar timings after the 2016 event. However, reefs will only be able recover if given enough time to do so before another mass bleaching event. Time seems unlikely given recent models suggesting El Niño events are becoming increasingly more severe and occurring more frequently due to global climate change (van Hooidonk et al, 2016; Santoso et al., 2017). It is possible that recovery on a local scale could be aided by reef restoration, if carried out effectively and with genetic diversity in mind.



a few of my favourite things

JOALI MALDIVES LOCATION

Muravandhoo island is located in the middle of Raa Atoll (Northern Maalhosmadulu), Maldives, (5°36'29.6"N 72°57'09.5"E). Raa Atoll is 56km in length and 24km across at its widest point and the deepest atoll in the Maldives archipelago. Muravandhoo, a previously uninhabited island, is the home of Joali Maldives, ultra-luxury resort. Construction for the resort started in 2015/2016 and now, in November 2018, is near completion and we welcome the arrival of our first guests. The island itself is tear-shaped with the longest part being ~500m long and the widest point is ~300m across, the point of the tear is to the west and the wider, rounder end to the west. The arrival of Joali resort saw the construction of a 1.3km jetty with 49 over-the-water villas along with 35 beach villas. The construction of Joali Maldives has will have increased the stress experience by the coral through boat traffic, large machinery moving across the reef, the building of structures over the water/reef, construction debris (both large and small) and increased sedimentation. Sedimentation is also increased during the raining season with increased run-off onto the reef. Ongoing sedimentation from construction activities will not last indefinitely and once construction is completed, we should see things start to settle down and the water to clear.

INITIAL ASSESSMENT OF THE REEF

As per the Environmental Impact Assessment conducted by LaMer Pvt Ltd in October 2015 and the Addendum to the EIA conducted in October 2016, the average coral cover prior to the 2016 bleaching event was 69.1%, with 85.28% as the highest and 45% as the lowest. This compares with an average live coral cover of 3.2% (highest is 6.73% and lowest is 0.8%). It was concluded that the dramatic decrease in live coral cover was mostly as a result of the b-+leaching event that occurred in March/April 2016 along with added stress from resort construction activities.

From my own observations there is very little algal growth on the reef, helped by the large number of herbivorous fishes on the reef. It can be quite common, after devastating environmental events, for a phase shift to occur in an ecosystem. In the case of coral bleaching the reef can go from being dominated by hard branching corals before the bleaching to being dominated by turf algae after the bleaching. The fact that there is very little turf algae growth is particularly good news for coral recruits as there will be little competition for settlement and reduced chance of smothering once settled. **There is a plan in place to carry out reef health surveys in the near future, amongst others, surveys will include turf algae height and fish diversity/abundance.** From observing the reef during regular snorkel activities, visual observations conclude prior to the 2016 bleaching event the reef was mostly dominated by branching and tabulate Acropora colonies, the remaining live coral cover seen today is mostly boulder corals and some digitate Pocilloporids.

WHAT IS REEF RESTORATION?

Ecosystem **restoration** is the act of returning an ecosystem from its degraded condition to its original condition. Ecosystem **rehabilitation** involves partially or fully replacing the structural or functional characteristics that may have been diminished or lost. Alternatively, it can involve substituting qualities or characteristics, different from those originally present. They should have more social, ecological or economical value than those that existed before the disturbed or degraded state. (Chavanich et al. 2015).

Due to the rapidly changing environment, extreme El Niño events becoming more severe and frequent, and increasing anthropogenic pressures it may not be possible to ever restore reefs back to their pre-2016 condition. However, it is possible to have a positive impact and contribute to their recovery.

There are an increasing number of methods that have and can be employed across the tropics to assist reef recovery through restoration and regeneration. Broadly speaking they can be split into four groups. For the purpose of this proposal I will only be including in-situ methodology.

1. direct transplantation, whereby corals of opportunity (fragments of coral that have been dislodged or unattached from the parent colony by natural or anthropogenic related disturbances) are collected and out-planted directly onto the reef using one of several methods (these will be discussed later under the "Out-planting" section)
2. fixed nurseries/Artificial Reef Structures (ARS) are attached to the substrate and cannot be easily moved or are so large and heavy that they cannot be moved to a different location. Many of these fixed structures can also be classified as artificial reef structures.
3. Artificial Reef Structures (ARS) - manmade structures deployed in the ocean at various depths. Sometimes they are left for corals to recruit to naturally, but more often, coral fragments are transplanted directly on to them. Structures usually cover a fairly large area on sandy or rubble-based substrate and provide a habitat for marine life.
4. Mid-water nursery - corals are grown in the water column on ropes/lines, trays or PVC trees. Predation and disease are reduced due to little or no benthic contact.

REEF RESTORATION AT JOALI MALDIVES

At Joali Maldives we will be focusing our efforts on ecological restoration, whereby we will be assisting the natural recovery of the reef ecosystem surrounding the island that suffered severe losses at the hands of coral bleaching, and that which was exacerbated by the construction of the resort.

The reef restoration program to be implemented at Joali Maldives aims to:

- assist the natural recovery of the reef to ecologically relevant density levels
- promote biodiversity
- increase biomass and productivity
- maintain as much genetic diversity as possible
- establish a reproductive population
- establish an area of living coral reef that guests can enjoy snorkeling over
- ensure that the impact of restoration activities on nearby/donor reefs is limited
- Contribute to the literature and best practices for coral reef restoration projects in the Maldives

Coral restoration is a long-term (decadal) activity and it should be noted that it is not a quick fix for reef recovery. It is also important to note that coral restoration is still in its infancy and we still have a long way to go before being able to recreate a fully functional reef ecosystem. As a general rule of thumb, if coral did not originally exist at a site there is probably a good ecological reason for that. The reef surrounding Muravandhoo provides ample natural reef substrate for reef restoration as such, restoration efforts should be focused at these sites rather than trying to create new reefs where there previously were not.

To be able to restore even just a few hectares of reef, we will need several tens of thousands of coral fragments, in order to meet these demands, the reef restoration the program will take a two-step approach. First, a coral nursery will be established to 1) supply the large numbers needed for out-planting, 2) special attention will be given to collecting fragments within the same species but of different genotypes in order to maintain genetic diversity 3) raising some colonies to a size where they are reproductively mature and will spawn within the nursery seeding nearby reefs and 4) maintaining a genetic bank of resilient genotypes.

CORAL PROPAGATION PROTOCOL

COLLECTION

Coral fragments should be collected from donor reefs with similar environmental conditions to the nursery or eventual transplantation site as this can contribute to reducing the risk of losing coral material due to environmentally stressful events. “Matching donor and transplanted sites increases survivorship of transplanted fragments by at least 25% yearly. Performance in nurseries is not the same as performance in transplanted sites.” – Carlos Prada.

Donor reefs should be no more than 30-60 minutes away by boat from the nursery site

To capture as much genetic diversity as possible, nursery material should be collected from multiple donor colony sites over a large geographic range (within 30-60 minutes by boat of the nursery site), these should be treated as different genotypes in the nursery

For each species we should aim to collect fragments from at least 15 different genotypes. Having a coral nursery should mean that after initial collections, stress on donor colonies and reefs will be largely reduced, as we will continue to fragment corals of each genotype exclusively from the nursery stock.

Tools should be thoroughly cleaned after each use and WD40 applied to reduce rusting.

When collecting coral fragments from donor reefs it should be made a priority to collect to corals of opportunity, i.e. corals that would otherwise not survive without our intervention. This includes corals found on the sand at risk of being further smothered, corals displaying partial mortality, and fragments from donor colonies that are out-competing neighboring slower-growing coral species (No more than 10% of the donor colony should be removed)

If there are no corals of opportunity available, coral fragments can be taken from the perimeter of coral colonies that are larger than 25cm in diameter.

Coral fragments should be at least 5cm in length and should not be showing any signs of tissue necrosis.

Wire cutters, or a hammer and chisel can be used to carefully break off coral fragments from the donor colony. As much as possible, the branch should be cut cleanly and evenly to help ensure optimal survival of the fragment as well as healing and recovery for the donor colony. Injured colonies can be more susceptible to disease, boring organisms and algal growth.
If collecting from colonies, the donor colony should be healthy, displaying healthy colouration and high tissue coverage.

To reduce stress to the donor colonies it is wise to collect fragments during the cooler months of the year when temperature stress is reduced.

It can be beneficial to monitor the donor colonies after
It is very important that corals of differing genotypes should be kept separate.
Colonies should not be used if there is any evidence of bleaching.

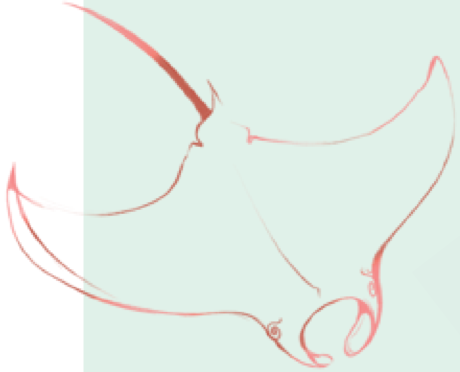
Portions of a colony suffering from coral disease should not be used. Fragments with some distance from the diseased section may be used, but disease presence on donor colony should be noted.

Take number tags, monofilament and crimps with you, tie together frags from the same colony and attach a number tag to the bundle, keep all frags from one genotype together in a separate section of the basket from other genotypes. Use the number on the tag to make any necessary notes about the health of the donor colony, i.e. predation scars, evidence of tissue loss, disease, algae growth.

When transporting corals back to the resort they should be shaded from the sun and if it is a long-distance water should be changed at regular intervals.

PREPARATION

You should aim to collect corals and put them into the nursery on the same day. If possible, corals should always be kept in water, even when preparing them to be put into the nursery. To do this, cut of any areas of bare skeleton as this can encourage algae growth or the introduction of coral boring organisms into the nursery. Attach monofilament to the cut end of the coral 1-2cm from the base and use a crimp to secure the monofilament.



NURSERY

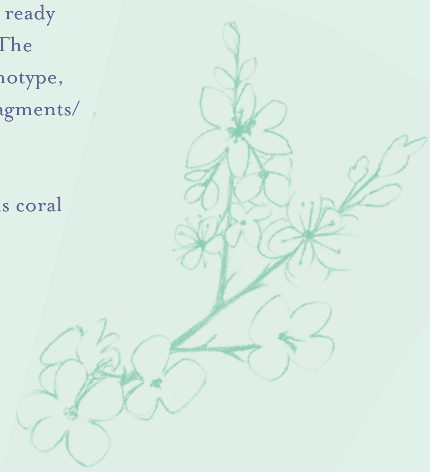
The initial coral trees in the nursery will be the genetic bank, each arm of a tree will represent a different genotype. After the first 9-12 months, the corals in the genetic bank will be propagated to both populate additional trees in the nursery and to start transplanting the corals onto the denuded house reef. When the corals in the genetic bank require subsequent propagation, the majority of the material will be transplanted to the reef along with coral material from the rest of the nursery. Only individual fragments within the genetic bank will have an individual tag. Tags will be fitted as needed in the main nursery in order to accurately identify the origin of coral fragments, each tree will be numbered, each arm will have a letter, and this will all be accurately mapped. Coral fragments will be attached to the trees using monofilament and filament crimps.

After the initial 1-2 years of collection, if enough genetic material has been collected (and survived) in the nursery, the nursery will be self-sufficient in providing enough coral fragments for transplantation, whilst honouring our aims to maintain/improve genetic diversity on the denuded house reef.

TRANSPLANTATION

After 9-12 months of growth in the mid-water nursery, farmed corals will be ready for transplantation to the selected sites on the House Reef at Joali Maldives. The corals will be clipped from the nursery trees, put into boxes, separated by genotype, and transported by boat to the transplant site. At the transplant site, coral fragments/ colonies will be attached to the reef using cement in piping bags.

Piping bags and other tools used will need to be thoroughly cleaned as soon as coral transplanting activities are complete.



NURSERY MAINTENANCE

Corals in the nursery will be closely monitored at a minimum of once every two weeks, to ensure that they are healthy and not suffering from accelerated algae growth, disease, tissue loss or bleaching. One of the reasons for choosing the coral trees nursery method has been the encouraging results from reef restoration practitioners around the globe who have observed reduced algae growth, disease and coral predation. With regards to elevated water temperature induced coral bleaching, as the coral trees are a mid-water nursery, by anchoring them at 10m this will allow us to adjust the height of the tree in the water at different times of year. Raising the tree up closer to the surface during the cooler months of the southwest monsoon and lowering them during the warmer months of the northeast monsoon.

It is natural for algae to grow on the nursery structures, however too much algae will smother the coral polyps and stunt growth or could cause tissue loss. Routine maintenance will be carried out to remove the algae. A toothbrush can be used to gently remove excess algae on the corals themselves. To remove algae build up on the structure, a larger wire brush or scourer can be used. Other fouling organisms such as hydroids, tunicates and sponges will also need to be removed either by hand or with small wire brushes.

The nursery structures will be monitored for damage sustained during stormy weather so if necessary, they can be repaired, parts can be replaced or, in a worst-case scenario the structure can be switched for a new one.

MONITORING

Growth monitoring – photos of all the fragments in the genetic bank will be taken, initially on a weekly basis for one month and thereafter on a monthly basis to monitor and measure total linear extension (TLE). This will be achieved by taking photos of each fragment with a ruled reference in shot. ImageJ software will be used to measure accurate TLE.

During any diving-based activities in the nursery we should be prepared to rescue fragments or repair broken nursery structures. That means ensuring equipment for carrying out these tasks is always available. Carry extra, pre-cut monofilament, crimps, pliers etc.

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